**Clean Energy Alternatives, Policies, and Implementation in Nigeria: A comparative Analysis**

**Abstract**

*Nigeria the largest economy and the most populous nation in Africa is faced with energy poverty and frequency grid collapse due to over dependence on a single source of energy (hydroelectric power). Climate change and its ecological devastation is affecting the globe, and alternative energy transition was envisaged as the most sustainable energy of the future due to its low carbon footprint. Nigeria as a nation is bless with abundant alternative energy resources. Therefore, this research aimed to analyze the alternative energy sources in Nigeria, their potentials, alternative energy policy implementation and its challenges. Qualitative research approach was utilized as this study’s research methods, SALSA framework (search, appraisal, synthesis and analysis) was utilized to search, evaluate and analyze the selected literatures for this study’s analysis. This analysis underscores that Nigeria has solar, wind and biomass as the major alternative energy resources, solar alternative energy has potential of about 5250Wh/m2 with an average solar radiation of 19.8 MJ/m2/day over 6 hours. This analysis also provided that Nigeria has abundant wind alternative energy potential particularly in the North and Coastal regions of the country with an alternative energy power density of about 3.40 to 520 kilowatts per square meter. Although wind energy has been underutilized, Katsina wind farm has so far remained the only wind farm operating in the country with Gurara wind farm currently under construction. Biomass alternative energy constitute about 80% of the country’s energy resources mainly used for cooking, heating and small-scale industrial application. Forest residues, agricultural remains and municipal solid waste make up a significant portion of the country’s biomass alternative energy resources. This analysis also highlight that Nigeria has alternative energy policies e.g. the Renewable Energy Master Plan (REMP), National Renewable Energy and Energy Efficiency Policy (NREEEP) however, economic constraints, inconsistent policy, corruption and lack of political will, have remain a serious challenge in the policy implementation. Therefore, for Nigeria to increase its alternative energy share and achieve transition, it should examine and update policies to address present issues, expedite processes, and establish specific, attainable goals for the implementation of alternative energy policy in the country.*

**Keywords:** Renewable energy, Alternative energy, Solar PV, Wind energy, Climate change, Energy efficiency, Wind farm, Biomass.

**1.0 introduction**

The energy sector of Nigeria, the most populous country in Africa and one of its biggest economies, has historically relied heavily on fossil fuels, especially natural gas and crude oil (Bello *et al*., 2021). Significant challenges have arisen as a result of this reliance, such as environmental damage, volatile oil prices, and millions of individuals' lack of access to adequate energy (Timiyan, 2022). Even though Nigeria produces a lot of oil, more than 40% of its people do not have access to electricity, contributing to the country's ongoing energy crisis (Nwozor *et al*., 2021). As a way to improve energy security, diversify the energy mix, and promote sustainable development, these issues have increased interest in alternative energy sources (Olujobi and Olusola-Olujobi, 2021).

Additionally, Ajayi, Mokryani and Edun(2022) noted that the global dimension of climate change makes it a significant subject of shared concern for the international community. An evaluation report by the United Nations Intergovernmental Panel on Climate Change (IPCC) states that there is now solid proof that the planet's climate change threats necessitate a rapid rise in the proportion of alternative energy in total energy production and consumption (Obada *et al*., 2024). This is due to the growing necessity for energy to support social and economic development as well as the need for more energy to support fundamental human needs including movement, communication, cooking, lighting, and productive processes (Adelekan *et al.*, 2024).

Fossil fuels, which presently provide around 80% of the world's energy, but regrettably contributed roughly 89% of CO2 emissions in 2018 due to industrial activity. Therefore, alternative energy was considered as the more sustainable energy sources than fossils fuels (Dioha and Kumar, 2020). Alternative energy refers to energy derived from naturally replenishing sources, it includes; hydro, solar, wind, geothermal and biomass are a few examples of alternative energy. Nigeria like the majority of developing nations lags far behind in incorporating alternative energy into its energy mix (Ibrahim *et al*., 2024). Although the country has an abundance of alternative energy resources, its contribution to the energy mix is minimal, aside from large-scale hydropower, which accounts for 22% of the nation's electricity generation.

**1.2 Significance of the study**

A global shift towards alternative energy has been spurred by the urgent need to combat energy poverty, climate change and greenhouse gas emissions (Adewuyi *et al*., 2020). This change is particularly important for developing countries like Nigeria, where environmental sustainability, economic progress, and energy poverty all intersect (Oyedepo *et al*., 2018). Therefore, the aim of this research is to provide a comprehensive analysis on the available alternative energy sources and their potentials, alternative energy policy adoption and implementation as well as their challenges in Nigeria.

**1.3 Statement of the problem**

The increasing need for sustainable energy around the world emphasizes alternative energy as a viable substitute for fossil fuels globally (Kehinde *et al*., 2018). Nigeria stands to gain since it has a wealth of hydroelectric, solar, wind, and biomass resources (Ogbonnaya *et al*., 2019). The absence of dependable energy affects more than 60% of Nigerians, especially those living in rural regions, which exacerbates problems with healthcare, education, and economic development (Somoye, 2023). Implementation of programs such as the National Renewable Energy and Energy Efficiency Policy (NREEEP) is still sluggish (Ugwu *et al*., 2022). Alternative energy such as solar, wind, biomass are generally less polluting with almost zero carbon footprint which Nigeria has it in abundance. These energy resources, if harnessed will assist the country to achieve robust energy security and brings about socioeconomic development in the country. Therefore, this research will analyze Nigeria's potential for alternative energy, examines regulatory frameworks, finds barriers, and makes useful recommendations. It will also seek to direct stakeholders, investors, and legislators in the advancement of sustainability and energy security.

**1.4 Aim and objectives**

The aim of this research is to examine the alternative energy potentials and level of alternative energy policy implementation in Nigeria. The specific objectives were to:

1. Assess the alternative energy potentials available in Nigeria and their adoption. (The alternative energy sources to be considered in research include; solar, wind and biomass).
2. Examine the factors hindering the adoption of alternative energy in Nigeria. (The factors to be considered will include; technology and infrastructural challenges).
3. Assess the level of alternative energy policy implementation and challenges in Nigeria. (Evaluate the extent of alternative energy policy adoption and implementations).

**1.5 Research questions**

1. What are the available alternative energy potentials in Nigeria?
2. What are the available alternative energy policies in Nigeria and to what extent is the alternative energy policy implemented?
3. What are the challenges limiting the implementation of alternative energy policy in Nigeria?

**1.6 Scope of the study**

This study will analyze the alternative energy resources in Nigeria with particular emphasis on solar, wind and biomass. Alternative energy resources’ policy adoption, implementations and their challenges will be considered. The challenges in alternative energy technology and infrastructures will also remain an important focus of this research.

**2.0 Literature Review**

**2.1 Clean energy alternative**

Clean energy, sometimes referred to as renewable energy, comes from sources that have a low influence on the environment, including greenhouse gas emissions, and can frequently be replenished within a person's lifetime (Gielen *et al*., 2019). Solar, wind, and biomass are important alternative energy sources in Nigeria (Akorede *et al*., 2017). Because Nigeria is located in an area with high levels of sunshine, with an average yearly solar radiation of 5250 Wh/m² and more than six hours of sunshine per day, solar energy, when captured from the sun, has significant potential (Ozoegwu, Mgbemene, and Ozor, 2017; Obada *et al*., 2024). Nigeria could produce more than 100 times its electricity demands with just 1% of its land area covered by solar modules (Owebor *et al*., 2021). Regional differences in solar potential include the north's 7000 Wh/m²/day and the south's 3500 Wh/m²/day (Eweka *et al*., 2022). Another practical choice for electricity, water pumping, and agriculture is wind energy produced by turbines. Energy intensity ranges from 4.4 W/m³ to 35.2 W/m³, with yearly wind speeds in coastal zones average 2.0 m/s and in northern parts reaching 3.0 m/s (Eweka *et al*., 2022). 80% of Nigeria's primary energy comes from biomass, which is made from organic materials including wood, garbage, and crops. Effective, carbon-neutral energy conversion is made possible by technologies such as gasification and anaerobic digestion (Akorede *et al*., 2017; Garba, 2020).

**2.2 Alternative energy mix in Nigeria**

Nigeria has made progress in diversifying its energy mix by adding alternative sources, but the majority of electricity is still generated from fossil fuels like oil and natural gas (Owebor *et al*., 2021). Climate change and problems with energy access are thought to be resolved by alternative energy (Emovon *et al*., 2018). In Nigeria, solar, wind, and biomass energy offer a lot of promise. The nation receives a lot of solar radiation because of its tropical location; on average, 18.9 MJ/m² is received every day, with the north receiving 25.2 MJ/m² and the coast receiving 12.6 MJ/m² (Adeniji, Adeniji and Ojeikere, 2020; Ogunmodimu and Okoroigwe, 2019). According to Ogunjuyigbe, Yusuff, and Mosetlhe (2021), this corresponds to PV power potential of 1248 kWh/kWp in the south and 1756 kWh/kWp in the north. Between 2015 and 2022, solar capacity increased from 1.5 MW to 37 MW, with the government aiming for 20% and 19% of the energy mix by 2020 and 2030, respectively (Bamisile *et al*., 2017; Giwa *et al*., 2017). With northerly wind speeds above 6.5 m/s, wind energy potential is particularly significant in coastal and northern regions (Adedipe, Abolarin and Mamman, 2018). With 37 turbines producing 10 MW, the Katsina Wind Farm, which has been in service since 2012, exemplifies early efforts (Oladipo *et al*., 2022). 43% of Nigeria's energy comes from biomass, which is extensively utilized for heating and cooking. An estimated 200 billion kg of biomass are produced in the nation each year, which translates to 62 Mtoe of energy (Obideyi, 2017). But over dependence on biomass has resulted in land degradation and deforestation (Jekayinfa, Orisaleye and Pacenka, 2020).

**2.3 Alternative energy policies and challenges in Nigeria**

Nigeria, the largest country in Africa, has abundant natural resources and a lot of promise for alternative energy. Nevertheless, millions of Nigerians do not have access to dependable electricity, highlighting ongoing energy shortages (Aliyu, Modu and Tan, 2018; Elum and Momodu, 2017). Strong alternative energy policies are essential for mitigating climate change and promoting sustainable development, and they are necessary to address these problems (Akuru *et al*., 2017). With its emphasis on diversity, sustainability, and energy security, the 2003 National Energy Policy (NEP) marked the beginning of the nation's transition to alternative energy (Ugwu *et al*., 2022; Elum and Mjimba, 2020). The Renewable Energy Master Plan (REMP) of 2005 and its 2011 version, which sought to include solar, wind, hydropower, and biomass into Nigeria's energy mix, were subsequent milestones (Ogbonnaya *et al*., 2019; Giwa *et al*., 2017). However, obstacles like a lack of political will, financing, and inefficient institutional frameworks made progress difficult (Adewuy *et al*., 2020).

Recent initiatives that support decentralized systems and energy efficiency, such as the 2015 National Renewable Energy and Energy Efficiency Policy (NREEEP), are in line with international commitments, such as the Paris Agreement and the SDGs (Yetano Roche *et al*., 2020; Dioha and Kumar, 2020). Off-grid solutions have been promoted by the Rural Electrification Agency (REA), especially in rural areas that are underserved (Akuru *et al*., 2017; Ugwoke *et al*., 2020). In spite of these developments, bureaucratic inefficiencies, inadequate incentives, and enforcement gaps still exist (Arowolo *et al*., 2019). Through international assistance and economic diversification tactics, Nigeria's alternative energy policies seek to mitigate climate change, alleviate energy poverty, which affects more than 40% of the population, and lessen dependency on oil revenues (Njoh *et al*., 2019; Adelaja, 2020; Emmanuel *et al*., 2024).

**2.4 Challenges**

Notwithstanding the strong legislative frameworks, a number of obstacles stand in the way of Nigeria's alternative energy policies being implemented successfully (Adelaja, 2020). A significant obstacle is the lack of public and private investment in alternative energy infrastructure. High upfront expenses and restricted financing availability discourage investments, especially in rural areas, as noted by Oparaocha and Dutta (2016). There are still issues with regulations and institutions. Overlaps and inefficiencies in the application of policies are frequently caused by the fragmented governance structure. Additionally, planning and decision-making are made more difficult by the lack of thorough data on alternative energy resources (Emovon *et al*., 2018). These issues are made worse by a lack of technical know-how and public awareness, which restricts the use of alternative energy technologies. Over the past 20 years, Nigeria's alternative energy strategy has changed dramatically in response to the country's desire to combat energy poverty, slow down climate change, and advance sustainable development. Even while there has been improvement, issues like inadequate funding, institutional flaws, and low public awareness still make it difficult to implement policies. A multifaceted strategy is needed to address these issues, one that includes strong stakeholder involvement, more funding, and improved institutional capability. Nigeria can accomplish its energy and environmental objectives and help create a more sustainable future by utilizing its wealth of alternative energy resources.

**2.5 Gap identification**

Although plethora of researchers such Giwa *et al*. (2017), has been conducted on Nigeria's potential for alternative energy, there are still a lot of gaps in how solar, wind, and biomass resources are integrated into regulatory frameworks and used in practice. Few studies offer a thorough analysis that connects resource evaluation with policy efficacy and implementation issues. Instead, existing like that of Akorede *et al*. (2017), studies frequently concentrate on the technical potential or economic viability of individual energy sources. Moreover, the institutional and socio-political obstacles that prevent widespread adoption have received little attention. Also, there is a dearth of empirical information regarding how finance structures, regulatory barriers, and governance affect the use of alternative energy. Although these technologies have the potential to reduce energy poverty, there are few research addressing the difficulties in rural energy access. Therefore, filling in these gaps is crucial to creating workable plans that support Nigeria's transition to sustainable energy.

**3.0 Methodology**

**3.1 Secondary research philosophy and design**

This secondary research employs interpretivism and qualitative methodology as its main philosophical paradigm and approach respectively. By examining the research problem through analysis of reliable sources of literature such as journal articles, reports and policy documents related to alternative energy resources, potential, policy implementations and challenges in Nigeria.

**3.1 Research approach and design**

**3.1.1 Research approach**

Gaus (2017) defined research approach as the method a researcher employs to gather, examine, and interpret data. It is a collection of guidelines and plans that include hypothetical assumptions together with specifics on data collecting and analysis. Leavy (2022) noted that the three primary categories of research approaches are mixed, qualitative, and quantitative. According to Al-Ababneh (2020), mixed approach integrates aspects of qualitative and quantitative methods to have a more thorough grasp of the subject. Numerical data collection and analysis are part of quantitative research. This approach is frequently used to test theories and formulate forecasts (Basias and Pollalis, 2018). For the purpose of this research, qualitative research approach will be considered the most suitable approach for this study. Qualitative research approach is frequently used to investigate people's beliefs, actions, and experiences, words, pictures, and other textual data are gathered and analyzed as part of qualitative research (Oranga and Matere, 2023). To obtain a more thorough grasp of the research subject, a qualitative approach will be considered, since this research aim is to examine the alternative energy potentials and level of alternative energy policy implementation in Nigeria using textual information through secondary data, qualitative research approach is therefore the most appropriate as this study’s methodology. Additionally, qualitative method was chosen for this research because it provides a deeper knowledge of human conduct and the factors that influence it and also present a thorough and in-depth description of a phenomenon rather than testing a hypothesis (Weil, 2017; Firdaus *et al*., 2021).

**3.1.2 Research design**

The method and structure utilized to use data to address a research issue is known as research design. It serves as a guide for gathering, measuring, and interpreting data in order to guarantee that the research problem is fully examined (Bloomfield and Fisher, 2019). Descriptive and analytical research design was chosen as this study’s research design. Analytical research design on the other hand, is a methodical approach to data analysis that aims to comprehend, interpret, and explain complicated events. In order to generate new concepts, test theories, and reach conclusions, it requires critical thinking and evaluation (Sovacool *et al*., 2018). While Descriptive research design is a useful technique for researchers to learn more about a specific phenomenon in order to provide a thorough and precise picture of the traits and actions of a specific phenomenon or subject of study (Siedlecki, 2020). In the study, descriptive study design will concentrate on describing clean energy alternatives, examining relevant policies, and analyzing their effectiveness and challenges. It will review government policies, legal frameworks, and international agreements on alternative energy in Nigeria and compare Nigeria's alternative energy policies with those of similar countries to identify gaps and best practices.

**3.2 Research sampling & description of secondary sources of data**

The main data for this study will constitute secondary data such as journal articles, reports, alternative energy policy documents etc. Secondary data are existing information typically accessible and gathered by other individuals or groups for a different reason (Saunders and Lewis, 2017).

**3.2.1 Literature search and themes formulation**

The researcher collected, analyzed, and synthesized the existing literatures using the systematic literature review (SLR) method (Holgado, Pablos, and Peñalvo, 2020). Grant and Booth (2009) proposed a methodology for conducting the review, which included four sequential processes (Search, appraisal, synthesis, and analysis; SALSA) as shown in Figure 1.

A diagram of a search engine

Description automatically generated

Figure 1: *SALSA schematic flow for literature review* (Source: Author, 2025).

This method is dependable, consistent, thorough, and replicable (Mengist, Soromessa, and Legese, 2020). Using appropriate search terms, the researcher collected relevant literatures in Google scholar and Google search databases. All pertinent peer-reviewed papers and grey literature and government reports, conference proceedings) were gathered. Using the keywords "renewable energy, renewable energy resources, renewable energy policy in Nigeria were used" and every other feasible combination to search and find pertinent papers using a conventional four-step protocol was used to search the aforementioned databases (Grant and Booth 2009). As part of the appraisal, the literature was screened and evaluated, peer-reviewed journal articles and grey literature were among the 102 pieces of data that were gathered from the selected databases. Separating all of the grey literature from the peer-reviewed journal articles that had previously been published was the first stage. Following that, we manually filtered every study that was found using inclusion/exclusion criteria, eliminating any data that did not fit our eligibility requirements. A total of 83 journal articles and grey literature were chosen for abstract screening after we eliminated duplicates from the literature data gathered from within our study region. These articles' bibliographic references were reviewed in order to determine whether they should be included based on the same standards. Of the 83 journal articles, 38 met the requirements to be included in the final database. The perspectives of the collected data can be explored, interpreted, and presented with the help of the qualitative method used to synthesize the data. Consequently, we extracted relevant information regarding alternative energy, sources, policy implementation and its challenges in Nigeria journal from the 38 selected papers, including grey literature. The collected data was divided into several groups and factors of relevance in order to achieve the SLR objectives. Tabular representations were then used to analyze these findings and formulate themes relevant to answer the research questions (Kaushik *et al*., 2022). The uncovered knowledge gaps in alternative energy sources, potentials and challenges paved the way for further discussion.

**3.2.2 Data analysis**

The practice of looking at data to find trends and patterns and make inferences is known as data analysis. In order to help answer questions and guide decision-making, it entails organizing, cleansing, and modelling data (Belotto, 2018). In this research, qualitative analysis using thematic analysis to interpret, review data and identify recurring themes related to alternative energy sources, policies and implementations will be analyzed. Thematic analysis (TA) is a method for detecting, analyzing, and interpreting patterns of meaning (‘themes’) within qualitative data. The researcher's analytical observations can be arranged and reported using the themes as a framework (Braun and Clarke, (2019). The goal of thematic analysis is to find and analyze important, but not necessarily all, aspects of the data using the research question as a guide. Keep in mind, however, that in TA, the research question is not set in stone and can change as themes and coding are developed (Braun and Clarke, 2017).

**3.3 Quality of secondary data**

The quality of secondary data is heavily relied on its accuracy, applicability, structure, date, and ethics. Data that has previously been gathered and put to other uses is known as secondary data, although it can be a useful information source, it's crucial to assess its quality before utilizing it (Kees *et al*., 2017). In order to evaluate the quality of the secondary data for this research, research need, pertinent sources of data, sources' quality evaluation will be conducted (Cichy and Rass, 2019). The data sources will also be analyzed, contrast, synthesize, and interpreted. Other quality evaluation criteria such as currency, relevance, authority, accuracy, and purpose will also be adhered to strictly as documented in Forero *et al*. (2018).

**3.4 Secondary data ethical measures**

Ethical considerations such as objective reporting, proper citations, and contextual integrity will be strictly considered while dealing with secondary data for this research because Forero *et al*. (2018) noted that taking this ethical consideration will improve the credibility and acceptability of your research while fortifying its ethical basis.

**4.0 Result And Discussion**

**4.1 Result**

The results of this study, which were informed by the research questions presented in Chapter 1, are broken down into four segments: (i) an examination of Nigeria's potential for alternative energy (solar, wind, and biomass), (ii) adoption barriers, (iii) the degree of policy implementation, and (iv) obstacles to policy success. In order to ensure rigor, reduce bias and to address the goals of the study, the search, evaluation, synthesis, and analysis (SALSA) approach was utilized in this literature review. Therefore, Table 1 provides a list of chosen literature, related research questions, and themes that have been examined.

Table 1: Research questions articles analyzed and the themes that were obtained

|  |  |  |
| --- | --- | --- |
| Research questions | Articles/studies | Analyzed themes |
| What are the available alternative energy potentials in Nigeria? | Ozoegwu, Mgbemene, and Ozor, (2017); Owebor *et al*. (2021); Eweka *et al*. (2022); Giwa *et al*. (2017); Ogbonnaya *et al*. (2019);  Obada *et al*. (2024); Agbo *et al*. (2021); Okafor *et al*. (2022) and Olanrewaju *et al*. (2019). | Solar energy with a potential of 5250Wh/m2 average solar radiation, 19.8 MJ/m2/day over 6 hours averagely. Biomass energy accounted for about 80% of the primary energy source in Nigeria. They include agricultural/forests residues, shrubs, plantation crops. The wind energy potential in Nigeria varies with geographical regions, in the northern parts, the average wind speeds in these areas range between 4-6 m/s at 10 meters heigh which suitable for wind power generation. |
| What are the available alternative energy policies in Nigeria and to what extent is the alternative energy policy implemented? | Adepoju and Akinwale, (2019); Adewuyi *et al*. (2020); Makki and Mosly (2020).  Sen and Ganguly (2017); Ugwu *et al*. (2022); Akorede *et al*. (2017); Ogbonnaya *et al*. (2019). | The Renewable Energy Master Plan (REMP) that was developed in 2005 saw the birth of ambitious target towards alternative energy. Nigeria's aim to attain net-zero emissions by 2060 is outlined in the Energy Transition Plan, which was introduced in 2021 and places a strong emphasis on integrating alternative energy sources and lowering greenhouse gas emissions. Template for Upstream Petroleum Decarbonization (UPDT): In accordance with Nigeria's net-zero objectives, this regulation, which goes into effect on January 1, 2025, mandates that applicants for oil licenses exhibit low carbon emissions and integrate alternative energy initiatives. |
| What are the challenges limiting the implementation of alternative energy policy in Nigeria? | Giwa *et al*. (2017); Adewuy *et al*. (2020); Yetano Roche *et al*. (2020); Arowolo *et al*. (2019). | The challenges limiting the implementation of alternative energy policies include; inadequate infrastructure, inconsistent government support/policy and Corruption and poor governance. |

**4.2 Evaluation of findings**

Theme I – IV emerged from the evaluation and analysis of the selected literatures/studies aimed at providing answers to this study’s research questions.

**4.2.1 What are the available alternative energy potentials in Nigeria?**

*Theme I: The alternative energy options in Nigeria include solar, wind and biomass. Solar energy has a potential of about 5250Wh/m2 average with solar radiation, 19.8 MJ/m2/day for over 6 hours averagely. Biomass constitute about 80% of the Nigeria’s primary energy sources. Wind energy potential and suitability is high in the northern parts of the country with an average wind speed of about 4 – 6 meters per second in the northern part of the country.*

**4.2.2 What are the factors militating the adoption of alternative energy in Nigeria?**

*Theme II: Adoption of alternative energy in Nigeria is hampered by high expenses, insufficient funding, lax regulations, subpar infrastructure, a lack of experience, dependency on fossil fuels, corruption, a lack of public awareness.*

**4.2.3 To what extent is the alternative energy policy implemented and challenges limiting the implementation of alternative energy policy in Nigeria?**

*Theme III: Nigeria's alternative energy policy is progressing especially in wind and solar energy, while issues like insufficient finance, poor infrastructure, and dependency on fossil fuels serves a drawback*

**5.0 Discussions**

In order to achieve this study’s aim as started in chapter 1, the first objective was “Assess the alternative energy potentials available in Nigeria and their adoption”. Finding of this research demonstrate alternative energy sources such as wind, solar, biomass, hydro, and bioenergy are abundant in Nigeria (Akorede *et al*., 2017; Olanipekun and Adelakun, 2020). Biomass resources include fuelwood, bushes, agricultural residues, energy crops, and crop residues (Akorede *et al*., 2017; Kahinde *et al*., 2019). With an installed capacity of 112 MW as of 2024, solar energy stands out and has significantly improved from the previous years (Chanchangi *et al*., 2024). With an average of 1,600–2,200 kWh/m² of global horizontal radiation each year, Nigeria's solar energy potential ranges from 3.5 to 7.0 kWh/m²/day, which translates to a technical solar photovoltaic potential of 210 GW. Solar energy use is still restricted, though, mostly among homes and businesses, and its low penetration makes it difficult to include it into the country's energy mix (Amulah, 2022; Osunmuyiwa and Kalfagianni, 2022).

Additionally, with an annual power density of 3.40 to 520 kW/m2, wind energy also shows a significant potential, especially in coastal and northern areas where average wind speeds are 3.0 m/s in the south and 6.5 m/s in the north (Idriss, Ibrahim and Albani, 2022; Adedipe, Abolarin and Mamman, 2018). There was no much progress in spite of this promise, the Katsina Wind Farm, which was created in partnership with Vestas, the French Development Agency, and the Nigerian government, is the nation's first utility-scale wind energy project and was put into service in 2020 (Awodiji and Oroakazie, 2024; Akporhonor, Otuagoma and Akporhonor, 2024). Nigeria had a 3 MW wind energy capacity prior to its establishment, which has been unchanged since 2014 (Ogunniyi *et al*., 2024). Despite having a wealth of alternative energy resources, Nigeria is still making modest progress in diversifying its energy mix and switching to alternative substitutes.

Additionally, to meet Nigeria's target of generating 30% of its electricity from alternative energy sources by 2030, the International Finance Corporation, Africa Finance Corporation, and the Nigerian government are working together to develop the 50 MW Gurara II Wind Farm in Niger State (Sanni *et al.*, 2024). When completed, it will supply thousands of homes and businesses with dependable, clean electricity (Gurara *et al*., 2018). In rural and residential settings, biomass energy is essential for tasks like heating and cooking, as well as small-scale business ventures like brewing and blacksmithing (Okafor *et al*., 2022). According to Ogbonnaya *et al*. (2019), agro-residues, animal waste, and municipal solid waste make up more than 80% of Nigeria's biomass potential, with agro-residues alone making up 75%.

In response to the second research objective “Identify the factors influencing the adoption of alternative energy in Nigeria”. There are many obstacles to Nigeria's use of alternative energy. Economic concerns, specifically the high initial costs of solar panels and wind turbines, prevent widespread adoption, particularly in rural areas where access to affordable financing is limited (Adepoju & Akinwale, 2019). Furthermore, poor policy frameworks and uneven government backing diminish the impact of programs that promote alternative energy usage and adoption (Makki and Mosly, 2020). The delayed adoption is partly a result of infrastructure deficiencies and a lack of public awareness. Olujobi and Olusola-Olujobi (2021), on the other hand, contend that the nation's reliance on fossil fuels and the absence of incentives like tax breaks or subsidies are significant obstacles. Furthermore, Esiri *et al*. (2023) draw attention to the ignorance surrounding alternative energy technologies, which results in skepticism and poor demand. In addition, government-private partnerships have not been utilized to their full potential. Despite the National Renewable Energy and Energy Efficiency Policy's (NREEEP) lofty objectives, administrative and financial obstacles continue to limit its implementation.

Additionally, based on this studies evaluation, Nigeria has enormous potential for alternative energy, however there are major obstacles to the country's alternative energy policy implementation. Adepoju and Akinwale (2019) suggested inadequate finance, large capital expenditures are frequently needed for alternative energy projects, and Nigeria's inadequate budgetary resources and intermittent access to foreign funding impede the growth of alternative energy projects. To achieve the third research objective “Assess the level of alternative energy policy implementation and challenges in Nigeria”. This study’s findings revealed that despite policies such as the National Renewable Energy and Energy Efficiency Policy (NREEEP) and the Renewable Energy Master Plan (REMP) as documented in Bulama and Nchi, (2023). Most of these policies have not been well enforced, and implementing policies is made more difficult by institutional overlap, bureaucratic inefficiencies, and a lack of cooperation among government institutions as rightly noted in Agbonhulu and Okposin, (2024). The national grid is out-of-date and unsuited for large-scale integration of alternative energy sources like wind and solar into the energy mix. Additionally, the fundamental infrastructure required for project deployment is frequently lacking in rural areas, which stand to gain the most from decentralized alternative energy solutions.

Similarly, Nigeria's reliance on foreign technology and experience for alternative energy projects is significant, which raises costs and causes implementation delays. According to Ogbodo-Nathaniel, Olujobi and Monehin (2024), there is still a lack of knowledge among citizens, corporations, and legislators regarding the advantages of alternative energy, which lowers private sector investment and public support. While this study’s revealed corruption and frequent shifts in governmental policies as major barriers to alternative energy adoption. Agbonhulu and Okposin (2024), state that consistency required for long-term planning and investment in alternative energy is undermined by political and economic uncertainty make these issues worse. Therefore, a comprehensive strategy is needed to overcome these obstacles, one that includes funding for local capacity building, strategic public-private partnerships, and enhanced governance.

**5.1 Answers to the research question**

What are the available alternative energy potentials in Nigeria? Solar, wind, biomass, hydropower, and geothermal resources represent Nigeria's predominant alternative energy potentials, offering a sustainable pathway for energy development while reducing dependence on fossil fuels.

What are the available alternative energy policies in Nigeria and to what extent is the alternative energy policy implemented? Nigeria has established multiple alternative energy policies, including the Renewable Energy Master Plan (REMP), the Electric Power Sector Reform Act, and the National Renewable Energy and Energy Efficiency Policy (NREEEP); however, their implementation has progressed at a slow pace.

“What are the challenges limiting the implementation of alternative energy policy in Nigeria”? Nigeria's transition to sustainable energy is hampered by issues like insufficient finance, lax regulatory enforcement, a lack of political will, inadequate infrastructure, a lack of technical skills, and low public awareness, all of which impede the country's ability to execute alternative energy policies.

**5.2 CONCLUSIONS AND RECOMMENDATIONS**

**5.2.1 Conclusions**

Nigeria, the most populous nation and largest economy in Africa, has numerous energy-related issues, from an over reliance on fossil fuels, national grid collapse to inadequate electricity generation. The study emphasizes that using the nation's abundant alternative energy resources such as solar, wind, water, and biomass alternative energy offer a viable and sustainable way to deal with these challenges. Making the switch to alternative energy alternatives is crucial for improving energy security, economic expansion, and social advancement. Also, the transition to these alternative energy sources will not only make the country to be energy secured rather it will make the country to be resilience to the threat of environmental degradation and climate change at large. To restate the aim and objectives of this study, the analysis aimed to examine the alternative energy potentials and level of alternative energy policy implementation in Nigeria and the specific objectives were to: assess the alternative energy potentials available in Nigeria and their adoption, identify the factors influencing the adoption of alternative energy in Nigeria. And assess the level of alternative energy policy implementation and challenges in Nigeria. Qualitative research approach was utilized as this study’s research methods, SALSA framework (search, appraisal, synthesis and analysis) was utilized to search, evaluate and analyze the selected literatures for this study’s analysis. Therefore, this study highlights that Nigeria has many alternative energy resources however, solar, biomass and wind are the most exploited forms alternative energy in the country. Although Nigeria has an abundance solar radiation of about 1,600–2,200 kilowatt hours per square meter with an energy potential of about 3.5 – 7.0 kWh/m2/day. This study highlights that solar alternative energy is the most utilized alternative energy resources in Nigeria, it has an installed current capacity of about 112 megawatts. This study also underscores that solar alternative energy

This study also provided that biomass alternative is the third most utilized and cheaply available energy resources in Nigeria apart from solar and hydro, making it one of the primary energy resources in country. Utilized mostly for heating, baking, cooking especially in rural areas and small scaled industrial applications such as blacksmithing. This study also stresses that Nigeria has biomass and biomass energy potential of about 200 billion kg/year and 2.58 billion GJ (61.67 Mtoe) respectively with agricultural residues, municipal solid waste and animal waste accounting for more than 80% percent of the total biomass potential. The analysis also indicated an increasing trend in biomass potential of 3.2 EJ in 2010 to 5.5 EJ in 2020, which is anticipated to increases to 29.8 EJ in 2050. Regarding wind alternative energy, this study’s underscores under-utilization of wind alternative energy resources in Nigeria despite its enormous potentials, Katsina wind farm is one of the only pioneered integrated wind alternative sources with a capacity of about 10 MW. While the Gurara wind farm is anticipated to provide about 50 MW if completed despite the available wind power density of about 3.40 to 520 kilowatts per square meter (kW/m2).

Furthermore, this study highlights those policies like the Renewable Energy Master Plan (REMP) and the National Renewable Energy and Energy Efficiency Policy (NREEEP) show that the government recognizes the importance of alternative energy, implementation is still hampered by issues like inconsistent policies, inadequate funding, inadequate infrastructure, and weak institutional frameworks. Additionally, the dominance of fossil fuels, which account for more than 70% of the country's energy mix, has slowed the shift towards cleaner alternatives. Nevertheless, the analysis highlights that Nigeria's energy sector has made some progress in investigating alternative energy options especially in solar alternative energy. Additionally, inadequate public awareness, a lack of local knowledge, and a lack of incentives for private sector investment are further factors contributing to the sluggish adoption of alternative energy. Additionally, these issues are made worse by systemic corruption and geopolitical instability, which hinder the sector's advancement. Notwithstanding these challenges, if deliberate and persistent efforts are made, alternative energy has the ability to drastically alter Nigeria's energy landscape.

**5.2.2 Recommendations**

Based on this study’s analysis, for Nigeria as a country to realize the full potential of alternative energy, the following are important recommendations:

1. The country should examine and update policies to address present issues, expedite processes, and establish specific, attainable goals for the implementation of alternative energy.
2. In order to boost investors’ confidence, inconsistency in policies should be avoided.
3. Establish a separate and autonomous organization dedicated exclusively to alternative energy to manage activities, guarantee adherence, and track advancements.
4. Set aside a sizeable amount of the national budget for alternative energy initiatives, with an emphasis on infrastructure development and rural electrification.
5. Encourage the private sector to invest in alternative energy projects by offering tax advantages, subsidies, and low-interest loans.
6. Optimize and utilized the support of global institutions like the African Development Bank and the World Bank to obtain financial and technical support for extensive alternative energy projects.
7. Reduce transmission losses, support off-grid and mini-grid alternative energy systems, and modernize the national grid to integrate alternative energy, especially in remote areas where grid extension is not financially feasible.

**5.3 Limitations and implications for future research**

The research “Clean Energy Alternative, Policies, and Implementation in Nigeria: Analysis” offers insightful information. However, the use of secondary data, which could not reflect the most recent policy changes or implementation results, is one significant drawback for this study. Nigeria's energy sector is dynamic, need frequent data changes to stay current. Furthermore, the study mostly concentrates on policies at the national level, ignoring the particular opportunities and difficulties that exist in various Nigerian regions. The extent of stakeholder engagement is another constraint. Although important parties like governmental organizations and energy suppliers are covered in the analysis, local populations' viewpoints especially those in rural areas remain little understood. For alternative energy projects to be implemented successfully, it is essential to comprehend adoption hurdles and grassroots difficulties.

Longitudinal studies that monitor the effects of alternative energy policies over time should be given priority in future research so that their efficacy may be more thoroughly assessed. In order to address local energy demands and socioeconomic conditions, region-specific research are also required as different regions in the country may also have different challenges. Additionally, using qualitative research methods like interviews may offer more in-depth understanding of how alternative energy technology are accepted and adapted at the local level. These initiatives will improve Nigeria's ability to develop an all-inclusive and customized energy policies.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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