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Techno-Economic Assessment of Renewable Energy Systems and Their Role in Achieving Sustainable Development Goals (SDGs)

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Abstract

The global shift toward sustainable energy highlights the critical role of renewable energy systems (RES) in addressing climate change, energy insecurity, and economic development. This study conducts a techno-economic assessment of solar photovoltaic (PV), wind, and biomass energy systems in Nigeria, examining their potential contributions to the United Nations Sustainable Development Goals (SDGs). Secondary data from international and national energy agencies, complemented by peer-reviewed literature, were analyzed to evaluate technical feasibility, economic viability, and developmental impact.

Findings reveal that solar PV holds the greatest promise due to Nigeria's high solar irradiance and rapidly declining costs, while wind and biomass provide complementary options in specific regions and rural areas. Levelized cost of electricity (LCOE) analysis indicates that renewable energy technologies are increasingly competitive with fossil fuels, with solar PV and wind now achieving cost parity. Beyond economic viability, renewable energy expansion contributes significantly to SDGs, particularly SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action).

The study concludes that renewable energy adoption is both a strategic and practical pathway to sustainable development in Nigeria. However, infrastructural limitations, inconsistent policies, and financing barriers continue to constrain progress. It recommends strengthening regulatory frameworks, promoting innovative financing models, investing in grid and off-grid infrastructure, and fostering public awareness and community participation. This research underscores the urgency of accelerating renewable energy deployment to enhance energy security, stimulate green growth, and position Nigeria to achieve its SDG commitments by 2030.

Keywords: Renewable Energy; Techno-Economic Assessment; Sustainable Development Goals; Solar PV; Wind Energy; Biomass; Nigeria

1. Introduction

Energy is still a vital force of economic development, social development and environmental sustainability. The historical energy sources that have predominantly relied on fossil fuels have led to the industrialization and global

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wealth but they have also caused the climate change, environmental degradation and energy insecurity (Stern, 2011). The need of the world to have clean, affordable, and sustainable sources of energy has thus put the renewable energy technologies in the centre of the development discussion.

The renewable energy systems include solar, wind, hydro, biomass, and geothermal which are very essential in resolving the environmental and developmental problems. These sources of energy are not only assisting to greatly cut the number of greenhouse gases in the atmosphere, but also provide avenues to sustainable and inclusive economic development. Unlike fossil fuels, which are limited, contaminate the environment, and in most places are mostly imported, renewable resources are naturally replenished, distributed on a wide scale and more sustainable to the environment (REN21, 2022). Its use increases security of energy, promotes domestic industries and decreases energy reliance in the fluctuating international markets. Moreover, renewable integration is at the core of what the United Nations Sustainable Development Goals (SDGs) suggest particularly SDG 7 that promotes universal access to affordable, reliable, sustainable, and modern energy. In addition to SDG 7, the use of renewable energy also encourages the achievement of other global objectives, including enhancing the health rates, educational opportunities, innovation, and combating global warming (United Nations, 2015).

The techno-economic evaluation of the renewable energy systems is one of the assessments that look at the technical feasibility and the economic viability of implementing such technologies. Technical feasibility will include efficiency of energy, reliability, and accommodability to local factors, whereas economic feasibility will concern cost-effectiveness, investment prospects, and viability over time (Kabir et al., 2018). This twofold discussion is essential since projects concerning renewable energy have usually experienced problems associated with high start-up capital, insufficiency of infrastructure, and policy unpredictability.

1.1. Problem Statement

Despite the fact that most people accept that renewable energy has a transformative potential, a significant number of the developing world especially in the Sub-Saharan Africa continues to face the challenge of poor access to modern energy services. According to International Energy Agency (2021), over 733 million people in the world stay without electricity, and the bulk of this group is located in rural areas of Africa and Asia. This is the continuing energy gap which obstructs social development, constrained the productivity of industries and also creates poverty cycles in such areas. Meanwhile, a high dependence on fossil fuel is not an easy task. On top of causing environmental degradation and climate change, the reliance on fossil fuels causes economies to be extremely sensitive to changes in global oil prices which most times translate into fiscal instability, trade imbalances and cost pressures on resources in oil-starved countries (Oyedepo, 2019). It is therefore only natural that the lack of credible and sustainable energy infrastructure would further divide the developing economies and the more industrialized ones, which makes the need of increasing the speed of the renewable energy acquisition highly pressing.

Although renewable energy systems offer opportunities of cleaner energy transitions, there is also no thorough research that combines both technical and economic aspects and connects them directly to the SDGs. Most of the already available literature have been inclined to focus on either technical performance or cost analysis separately, thus giving incomplete information to policymakers and investors (Al-Garni and Awasthi, 2017). This study fills in this gap through a comprehensive techno-economic evaluation of renewable energy systems in the context of sustainable development.

1.2. Research Objectives

The overall goal of the project is to discuss the techno-economic viability of renewable energy systems and its role in the achievement of the Sustainable Development Goals. The targeted purposes are to:

- Determine the technical performance of the chosen renewable energy systems.
- Evaluate the economic viability of the implementation of renewable energy technologies.
- Discuss the contribution of the renewable energy adoption of SDG 7 and other goals.
- Give policy suggestions regarding sustainable energy changes in emerging economies.

1.3. Research Questions

- This research paper will aim to respond to the following questions:
- What are the technical pros and cons of renewable energy systems?
- How cost effective are the renewable energy technologies in comparison to the traditional energy sources?
- What are some of the ways through which renewable energy systems can help to achieve the SDGs?

- Which policy frameworks are applicable in improving the incorporation of renewable energy systems into national development agendas?

2. Literature Review

2.1. Conceptual Review

2.1.1. Renewable Energy Systems

Renewable energy systems refer to a variety of technologies that use and harness the power of naturally occurring replenishing sources, which include the solar radiation, wind currents, biomass, geothermal heat, and hydropower, among others. These sources of energy are clean and sustainable as opposed to fossil fuels, which are limited and harmful to the environment and are widespread in most parts of the world. Renewable systems are becoming more commonly advocated as useful alternatives to traditional energy sources because they have a dual opportunity to improve on the negative effects of climate change as well as trigger the long-term economic transformation (REN21, 2022). Of all the other renewable sources, solar photovoltaics (PV) and wind energy technologies have become the fastest growing areas, with both sectors experiencing an exponential increase in capacity and deployment in developed countries and developing economies. The International Renewable Energy Agency (IRENA, 2022) observes that the cost reduction of solar panels and wind turbine is currently being adopted faster due to the favorable policies in place and due to its pre-eminence in the global shift to a low-carbon energy future. The assessment of the expense of the power source will rely on the cost-benefit analysis method.

2.1.2. Techno-Economic Assessment (TEA)

The cost-benefit analysis approach will be used to assess the cost of the power source. Techno-economic assessment (TEA) is a multidisciplinary method which involves integrating the technical evaluation with economic analysis to evaluate the viability and sustainability of energy projects (Short et al., 1995). Technically, efficiency of the system, its reliability, adaptability as well as capacity factor are considered. Meanwhile, the economic aspect considers such indicators as Net Present Value (NPV), Levelized Cost of Energy (LCOE), and Payback Period (Kabir et al., 2018). With a combination of these attitudes, TEA offers useful insights to the policymakers and investors to enable them to allocate their resources effectively.

2.1.3. The sustainable development goals (SDGs) and renewable energy

The UN Sustainable Development Goals (SDGs) are an extensive outline to the way the world can work towards inclusive and sustainable development. The renewable energy assumes a central position in this agenda, namely in the attainment of SDG 7, which emphasizes on universal access to affordable, reliable, sustainable, and modern energy. However, under renewable energy, the role is much more than this objective. Renewable energy assists in meeting SDG 3 (Good Health and Well-being) as it reduces air pollution and improves air quality inside the house. The fact that it is used to power schools and digital learning centers compounds SDG 4 (Quality Education), whereas its incorporation into industrial activities and infrastructure improvements propels development on SDG 9 (Industry, Innovation, and Infrastructure). In addition, renewable energy should be adopted to attain SDG 13 (Climate Action) because it will lower the emission of greenhouse gases and improve climate resilience (United Nations, 2015). This multidimensional effect is supported by practical examples: the implementation of decentralized solar systems in rural populations does not only help to improve electrification but also improves access to education opportunities, as they can study in the evenings and have access to digital resources, but also help to improve healthcare delivery, since a decentralized solar system can ensure the availability of electricity for medical devices and storage of vaccines (Bazilian et al., 2012).

2.2. Theoretical Review

2.2.1. Energy Transition Theory

The Energy Transition Theory assumes that societies pass through successive changes of their main energy base, which is usually characterized by a transition of traditional energy base (biomass, wood, crop residues, animal waste) into fossil fuels (coal, oil, and natural gas) and further into renewable and low-carbon energy sources (Smil, 2010). These transitions are not only influenced by the changes in the technology but also by the structure socio-economic changes, the policy intervention and the resource limitation (Geels, 2014). The theory underlines a fact that energy changes are hardly linear but are characterized by disruption, resistance, and technological replacement periods (Kern and Markard, 2016).

Within the framework of developing countries, this model points to the possibility of leapfrogging, i.e. not going through the long period of reliance on fossil fuels and immediately switching to renewable energy technologies (Sovacool, 2016). Leapfrogging is possible because solar and wind energy costs are declining, their storage methods are becoming better, and climate agreements exist on the global level. Therefore, the Energy Transition Theory provides a theoretical basis upon which the acceleration of a process towards the Sustainable Development Goals (SDGs) can be understood through renewable energy systems in areas where energy poverty is present, as well as, where environmental degradation is being experienced.

The theory of sustainable development is a viewpoint that examines the viewpoints regarding sustainable development, its characteristics, and its effects on development and the environment.<|human|>2.2.2 Sustainable Development Theory The theory of sustainable development is a perspective that explores the perspectives on sustainable development, its nature and the impacts on development and the environment.

The theory of Sustainable Development that has become known due to Brundtland Report (WCED, 1987) has its basis in the idea of the intergenerational equity: development should not harm the capacity of future generations to fulfill their needs. The theory is based on three key dimensions economic growth, social inclusion, and environmental protection, put into a comprehensive policymaking and technological adoption framework (Sachs, 2015).

Renewable energy technologies are very consistent with this theory as they will reduce and lessen the ecological footprints as well as enhance inclusive growth. Renewables will also help in environmental sustainability and socioeconomic resilience by lowering the amount of greenhouse gas emissions, diversifying the energy supply, and generating new jobs (Stern, 2011). In addition, the theory asserts the significance of institutional change and international collaboration so that the energy systems become not just economically efficient, but also socially just, e.g., by helping marginalized groups to gain access to energy.

Weighing the financial and non-financial gains and losses of an action is referred to as a cost-benefit analysis or life-cycle analysis model.

The Cost-Benefit Analysis (CBA) and the Life-Cycle Assessment (LCA) models are analytical models that can be used in evaluating the techno-economic and environmental feasibility of renewable energy systems. CBA analyzes the projects in terms of long-term economic gains, such as the cost of fuel imports, employment, health costs avoided due to pollution, with the initial capital costs of projects and their operational costs (Boardman et al., 2018). This framework facilitates an evidence-based policy because it quantifies the economic rationality of the investment in renewable energy infrastructure.

Meanwhile, LCA evaluates the environmental impact of energy systems on their whole life cycle of extraction and manufacturing of raw materials to operation, maintenance, and decommissioning (Al-Garni and Awasthi, 2017). The use of LCA is especially applicable when it comes to identifying clean and green technologies as even renewable energy has concealed environmental costs (e.g., resource extraction and land use to build a solar panel and a battery). Combining CBA and LCA, both monetary and ecological aspects are incorporated, which supports the two objectives of sustainability and profitability.

These models combined together form the basis of techno-economic analysis, providing a multidimensional approach to it: CBA secures financial sustainability, and LCA secures environmental accountability. This two-fold strategy is necessary to policymakers, investors, and engineers when developing renewable energy systems that will not only be cost-effective but also in accordance with long-term sustainability goals.

2.3. Empirical Review

2.3.1. Technical Evaluations of Renewable energy systems.

Kabir et al. (2018) researched solar energy and discovered that it is very efficient in the tropical climate where the amount of solar rays is high. On the same note, Ayodele et al. (2019) studied hybrid systems that are a combination of solar PV, batteries, and diesel backup in Nigeria telecom base stations and emphasized better reliability over hurdles associated with intermittency.

Wind energy has received research as well, and Kumar and Sudhakar (2015) show that it has a great potential in the semi-arid areas of India. But the issues of weather variability and poor grid infrastructure can still be considered as an impediment to massive implementation. Hybrid Renewable Energy Systems (HRES) are suggested to solve the issue of intermittency by pairing or more energy sources (IRENA, 2022).

2.3.2. Economy of Renewable Energy Systems.

Economic analyses always indicate a decrease in the cost of renewable energy resources. According to the International Energy Agency (2021), between 2010 and 2020, the LCOE of solar PV dropped by almost 85 percent, and it became an economical option compared to fossil fuels. High initial costs according to Oyedepo (2019) continue to be a challenge in Nigeria, but long-term gains, in terms of less fuel imports and employment opportunities make the investment worthwhile.

Al-Garni and Awasthi (2017) concluded that the model of policy support, resource availability, and financing are vital to economic feasibility. Cost parity is achieved more rapidly in locations where there are favourable incentives (e.g. feed-in tariffs, subsidies).

2.3.3. Renewable Energy and the Sustainable Development Goals (SDGs).

Research associates the use of renewable energy with SDGs. Bazilian et al. (2012) stressed that electrification with the help of solar mini-grids can contribute to productivity, less poverty, and education in rural Africa. Sovacool et al. (2020) also proved that due to the implementation of renewables, the climate resilience, emissions, and sustainable industrialization are encouraged.

However there are challenges such as unavailability of funding, bad policies and inadequate infrastructure that hinder developments and in particular to the developing economies (Oyedepo, 2019). This leads to the relevance of the joint techno-economic study that also takes into account the SDG framework.

3. Methodology

3.1. Research Design

The proposed research will take the form of a mixed method research that is a combination of quantitative and qualitative research designs. The quantitative element involves the techno-economic modelling of the renewable energy systems in accordance with the second hand data on the energy capacity, costs and performance indicators. The qualitative component analyses the policy frameworks, stakeholder perceptions and how the use of renewable sources of energy can be reinforced with the Sustainable Development Goals (SDGs). Such a mixture of the two will ensure the complete picture of both technical-economic and developmental implications (Creswell and Plano Clark, 2017).

3.2. Sources of Data

The study will be founded on secondary information and the majority of materials will be gathered via reputable sources and they will include:

- International Databases: International Energy Agency (IEA), International Renewable Energy Agency (IRENA), REN21 and World Bank.
- National Sources: energy commission of Nigeria (ECN), rural electrification agency (REA) and national bureau of statistics (NBS).
- Academic Resources: Conference papers and policy statements on renewable energy and SDGs Peer-reviewed articles on the topic of renewable energy and SDGs.

3.3. Population and Scope of the Study

The focus of the study is on renewable energy systems with reference to solar PV and wind energy technologies, and this is due to the fact that they can be deployed very fast and are cost competitive across the world (IRENA, 2022). The geographical focus will be on the developing economies with Nigeria as a case study because of its huge renewable potential, energy poverty, and ongoing energy transition programs (Oyedepo, 2019).

3.4. Methods of Data Analysis

3.4.1. Technical Assessment

The technical analysis involves evaluating performance parameters such as:

- Capacity Factor (CF): Measures actual output relative to maximum possible output.
- Energy Yield (kWh/year): Estimated annual generation based on resource availability (solar irradiance, wind speed).
- Reliability Index: Examines consistency of power supply from renewable sources.

Simulation models such as HOMER Pro and RETScreen Expert may be used to estimate energy generation and system efficiency (Lambert et al., 2006).

3.4.2. Economic Assessment

Economic evaluation is carried out using standard financial metrics:

- Net Present Value (NPV):

$$NPV = \frac{\sum Rt - Ct}{(1 + r)t}$$

- Levelized Cost of Energy (LCOE):

$$NPV = \frac{\sum Ct\ (1 + r)-1}{\sum Et\ (1+ r)-t}$$

- Payback Period (PBP): Time required for cumulative net savings to equal initial investment.

These indicators provide insights into the long-term economic viability of renewable systems.

3.4.3. Contribution to SDGs

The study uses policy content analysis and impact mapping in order to measure its alignment with the SDGs. The analysis is done based on United Nations and World Bank data regarding key indicators, like the access to electricity (SDG 7.1), the share of renewable energy (SDG 7.2), carbon emissions reduction (SDG 13), and social benefits (education, health, jobs).

3.5. Model Specification

In order to conduct quantitative analysis, the regression model will be deployed to define the correlation between the deployment of renewable energy and the chosen development indicators:

$SDG_i = \beta_0 + \beta_1 RE_{tech} + \beta_2 RE_{econ} + \mu$

Where:
SDG = development results (electricity access, carbon reduction, poverty reduction).
REtech = technical (capacity factor, generation output).
REtech = economic measures (LCOE, NPV, PBP).
u = error term.

With this model, it is possible to test the hypothesis that renewable energy systems play an important role in the accomplishment of SDGs when they are both technically and economically feasible.

4. Results

4.1. Introduction

The chapter presents the findings of the techno-economic analysis of the renewable energy systems (RES) and critically assesses their implication in the attainment of Sustainable Development Goals (SDGs). The study is predominantly founded on the secondary data, which is retrieved in the form of the reputable international energy databases, including the International Renewable Energy Agency (IRENA), the International Energy Agency (IEA), and the World Bank as well as the reports of the national energy agencies and peer-reviewed academic publications. The discussion is particularly centered on three current renewable energy processes solar photovoltaic (PV), wind energy and biomass because of their propagation and widening of application in the global energy transformation. Such technologies are evaluated on the grounds of their technical feasibility, cost-effective, and the implications, in general, on the economy. Further, by comparing them, their potential contributions to the speed of the achievement process of the SDGs, in particular, in such areas as access to clean energy, climate action, industrial innovation, and poverty reduction, are raised. This chapter is a deep reflexion of how renewable energy may be applied as an alternative to fossil fuels and source of inclusive development taking into consideration both technical and economic perspectives.

4.2. Data Presentation

4.2.1. Installed Renewable Energy Capacity in Nigeria (2015–2024)

Table 1 Trends in Installed renewable Energy Capacity in Nigeria

Year	Solar PV (MW)	Wind (MW)	Biomass (MW)	Total RES Capacity (MW)	Share of National Geeneration(%)
2015	20	10	40	70	0.2%
2018	80	15	55	150	0.5%
2021	200	25	80	305	1.0%
2024	750	45	120	915	2.5%

Source: IRENA (2024), Nigerian Energy Commission (2023)

This table shows that renewable energy capacity in Nigeria has steadily increased over the past decade, with solar PV experiencing the fastest growth.

4.2.2. Levelized Cost of Electricity (LCOE) for Renewable Energy Technologies

Table 2 Levelized Cost of Electricity (LCOE) for Selected Renewable Energy Technologies in Nigeria

Technology	LCOE (USD/kWh)	Global Benchmark (USD/kWh)	Payback Period (Years)
Solar PV	0.065	0.050-0.070	6-8
Wind	0.070	0.045-0.080	7-9
Biomass	0.090	0.070-0.100	8-12
Gas (Baseline)	0.110	0.065-0.050	10-12

Source: IEA (2024), World Bank (2023)

The LCOE analysis shows that solar energy and wind energy are currently at the same cost as natural gas. Simultaneously, biomass is a bit more costly and has some extra features, including the use of waste to energy.

4.3. Data Analysis

4.3.1. Technical Assessment

A high solar irradiance of 5.5-7.0 kWh/m2/day reduces the time required to deploy the solar PV in Nigeria, as it is one of the locations that are quite appropriate to both grid-connected and off-grid solutions (Ogunleye, 2022). The potential of wind is moderate, with a cluster in the coastal and northern areas and biomass potential provides consistent baseload potential in rural areas, where a significant amount of agricultural residues is present.

4.3.2. Economic Assessment

The analysis of the techno-economic indicates that solar pv and wind has reached the cost parity level with the fossil fuel. Specifically, the falling solar PV LCOE renders it appealing to large-scale utility facility projects and mini-grids distributed vastly (IRENA, 2024). Biomass projects are more expensive to establish, but are more sustainable in the long run in terms of waste-reduction and rural jobs.

4.3.3. Contribution to SDGs

- SDG 7 (Affordable and Clean Energy): The growth of solar mini-grids has enhanced the access to electricity in rural areas, minimizing the use of kerosene and diesel generators.
- SDG 8 (Decent Work and Economic Growth): Renewable energy use has also resulted in the generation of green jobs in the renewable energy installation and maintenance and manufacturing industries.
- SDG 13 (Climate Action): The switch to RES will help decrease carbon emissions, and solar and wind growth in Nigeria is projected to eliminate 3 million tons of CO2 per year by 2024 (World Bank, 2023).
- SDG 11 (Sustainable Cities and Communities): Urban renewable energy sources, including rooftop solar, enhance the resistance to the power outage and decrease environmental pollution.

5. Discussion of Findings

The results validate the fact that renewable energy systems are technically viable and cost effective to the sustainable development initiative in Nigeria. The PV solar provides the best technology owing to its scalability and reduced costs. Nonetheless, policy inconsistency, lack of good grid infrastructure, and lack of proper financing mechanisms are some of the challenges that make it difficult to adopt faster.

Nigeria has competitive values of LCOEs of renewables in comparison to those of other countries, which shows a possibility of increasing investments. Notably, the growth in renewable energies directly promotes several SDGs, which justify the necessity of planning energy and development.

5.1. Summary of Key Findings

The chapter provided and discussed the information on the techno-economic viability of renewable energy systems in Nigeria. The findings suggest that solar power, wind power, and biomass can be suitable, and the chances of development of SDGs are high. The discussion made it clear that despite the advancement being made, policy reform, monetary incentive, and infrastructure development is essential to the full realization of the renewable energy system benefits.

This paper set out to research on the techno-economic evaluation of renewable energy systems (RES) and their role towards supporting the Sustainable Development Goals (SDGs), in particular, in Nigeria. The first chapter emphasized the immediate necessity to stop the reliance on fossil fuels and increase the transition to the cleaner and more sustainable energy sources. It is on this basis that the research was structured to assess the technical, economical, and general developmental impacts of renewable energy technologies on the overall result of sustainable development.

The evaluation showed that renewable energy technology and especially solar photovoltaic (PV), wind energy, and biomass have a great potential to solve the never-ending energy problem in Nigeria. The chapter presents the findings of the techno-economic analysis of the renewable energy systems (RES) and critically assesses their implication in the attainment of Sustainable Development Goals (SDGs). The study is predominantly founded on the secondary data, which is retrieved in the form of the reputable international energy databases, including the International Renewable Energy Agency (IRENA), the International Energy Agency (IEA), and the World Bank as well as the reports of the national energy agencies and peer-reviewed academic publications. The discussion is particularly centered on three current renewable energy processes solar photovoltaic (PV), wind energy and biomass because of their propagation and widening of application in the global energy transformation. Such technologies are evaluated on the grounds of their technical feasibility, cost-effective, and the implications, in general, on the economy. Further, by comparing them, their potential contributions to the speed of the achievement process of the SDGs, in particular, in such areas as access to clean energy, climate action, industrial innovation, and poverty reduction, are raised. This chapter is a deep reflexion of how renewable energy may be applied as an alternative to fossil fuels and source of inclusive development taking into consideration both technical and economic perspectives.

Although these technologies were promising, there were still some challenges as revealed in the study that limit the mass implementation of these technologies. The challenges like the lack of proper infrastructure, inconsistency in regulations and policies, financial gaps, and a low level of awareness among people are also considered critical problems. To curb these challenges, governments, private investors, international organizations and the local communities need to work together. Nigeria can achieve the full potential of renewable energy systems to support its energy transition and achieve its SDG targets by promoting collaboration, institutional upgrading and enhancing access to funding and awareness.

5.2. Conclusion and Recommendations

The results of this paper adhere to the fact that renewable energy systems are technically viable and economically viable to support the development agenda of Nigeria. Solar photovoltaic (PV) technology is the most appealing technology whereby, its cost of installation is steadily reducing, it can be scaled up, and it can be used in both grid-connected and off-grid applications. Simultaneously, wind and biomass energy possess a high complementary value especially in terms of diversification of the energy portfolio and regional diversity of energy resources, which enhances the overall energy security of the country.

Renewable energy systems other than their technical and financial feasibility have a transformative role in assisting the achievement of Sustainable Development Goals (SDGs). Their implementation brings about inclusive economic development through the generation of job opportunities along the value lines, increased access to sound electricity to the underserved people, and reduced emissions of greenhouse gases that cause climatic change. Also, renewable energy projects encourage the development of urban and rural areas, as the cleaner and more sustainable energy sources can be offered to people, which helps to raise the living standards and increase productivity in such important fields as health, education, and agriculture.

However, to realize the full potential of renewable energy in Nigeria, it would be necessary to address the existing structural and institutional obstacles. The lack of good infrastructure, irregularity in policy execution, lack of access to financing, and lack of awareness by the population still limit the use of the strategy towards the big scale adoption. The solution to these barriers requires concerted efforts that would involve government agencies, private investors, foreign collaborators, and the local communities. It is against such co-operative processes that the deployment of renewable energy can be quickened in Nigeria, the energy transition goals attained and that considerable strides can be made towards its overall commitment of sustainable development.

Recommendations

Recommendations on the basis of the findings are as follows:

- Policy and Regulatory Framework.

Increasing the renewable energy policies and making it consistent should be reinforced by the government. Clear regulation systems and incentives like tax reliefs, feed-in tariffs, and subsidies are necessary to encourage the private investment.

- Financing Mechanisms

The capital barriers should be overcome by encouraging innovative financing schemes in the form of a public-private partnership (PPP), green bonds, and microfinancing rural energy projects. Other external climate funding should also be tapped into.

- Infrastructure Development

Modernization and expansion in the grid is essential to ensure that renewable energy sources are integrated effectively. The off-grid and mini-grid systems must be expanded to reach out to the remote communities.

- Capacity Building and Research.

It should focus on local capacity building in the installation of renewable energy, maintenance, and research. Universities and research institutions are expected to be assisted in creating indigenous technologies that correspond to the peculiarities of the situation in Nigeria.

- Community Dynamics and Publicity.

Awareness campaigns are important to inform households, industries as well as communities on the benefits of renewable energy. The participation of the community in the planning and implementation of the project will improve its adoption and sustainability.

- Alignment with SDGs

The SDG implementation strategies of Nigeria should explicitly involve renewable energy project. The monitoring frameworks must monitor the contribution of renewable energy towards such targets like poverty reduction, creation of employment and climate action.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflict of interest regarding the publication of this research work.

Statement of informed consent

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References

[1] Akinyele, D. O., Olabode, E., & Amole, A. (2021). Techno-economic evaluation of renewable energy systems for sustainable rural electrification in Nigeria. Renewable Energy, 174, 927–939. https://doi.org/10.1016/j.renene.2021.04.056

[2] Aliyu, A. S., Dada, J. O., & Adam, I. K. (2018). Current status and future prospects of renewable energy in Nigeria. Renewable and Sustainable Energy Reviews, 81, 341–357. https://doi.org/10.1016/j.rser.2017.08.017

[3] Ayodele, T. R., Ogunjuyigbe, A. S. O., & Oladele, T. O. (2020). Techno-economic analysis of hybrid renewable energy system for sustainable energy supply in rural communities of Nigeria. Energy Reports, 6, 358–370. https://doi.org/10.1016/j.egyr.2020.11.027

[4] Ebhota, W. S., & Tabakov, P. Y. (2021). Renewable energy deployment in Nigeria: Opportunities and challenges. International Journal of Energy Economics and Policy, 11(3), 157–167. https://doi.org/10.32479/ijeep.10958

[5] Ejiogu, E. C. (2019). Achieving the sustainable development goals: The role of renewable energy in Nigeria's energy mix. African Journal of Economic Policy, 26(1), 45–63.

[6] International Energy Agency (IEA). (2023). World energy outlook 2023. Paris: IEA. https://www.iea.org

[7] International Renewable Energy Agency (IRENA). (2024). Renewable power generation costs in 2023. Abu Dhabi: IRENA. https://www.irena.org

[8] Mohammed, Y. S., Mustafa, M. W., Bashir, N., & Mokhtar, A. S. (2017). Renewable energy resources for distributed power generation in Nigeria: A review of the potential. Renewable and Sustainable Energy Reviews, 75, 734–743. https://doi.org/10.1016/j.rser.2016.11.078

[9] National Bureau of Statistics (NBS). (2023). Energy consumption and renewable energy statistics in Nigeria 2015–2022. Abuja: NBS.

[10] Ogunleye, E. K. (2022). Energy transitions in Nigeria: Policy, progress, and prospects. Energy Policy, 164, 112875. https://doi.org/10.1016/j.enpol.2022.112875

[11] Okedu, K. E., Uhunmwangho, R., & Ibrahim, O. (2020). A review of renewable energy potential in Nigeria and its contribution to sustainable development goals. International Journal of Renewable Energy Research, 10(2), 657–669.

[12] Oladeji, S. O., & Adegboyega, A. A. (2019). Renewable energy in Nigeria: Pathway to sustainable development. Journal of Sustainable Development Studies, 12(1), 45–60.

[13] World Bank. (2023). Tracking SDG 7: The energy progress report 2023. Washington, DC: World Bank. https://www.worldbank.org

[14] Yusuf, S. D., Mustapha, A. H., & Bala, G. (2021). Economic viability of solar PV systems in Nigeria: A case study approach. Heliyon, 7(5), e06984. https://doi.org/10.1016/j.heliyon.2021.e06984

[15] Zarma, I. H., & Ibrahim, I. (2022). Renewable energy systems and sustainable development goals: A review of Nigerian case studies. Environmental Management and Sustainable Development, 11(2), 121–139. https://doi.org/10.5296/emsd.v11i2.19547

[16] Ayodele, T. R., Ogunjuyigbe, A. S. O., Odigwe, I. A., & Oladele, O. O. (2019). Techno-economic analysis of hybrid solar PV/diesel/battery and solar PV/battery systems for GSM base station power supply in Nigeria. Renewable Energy, 135, 413–427.

[17] Oyedepo, S. O. (2019). Energy and sustainable development in Nigeria: The way forward. Energy, Sustainability and Society, 9(1), 1–16.