



## RESILIENT GREEN ENERGY RESOURCES AS SOLUTION FOR NIGERIAN ENERGY AND ENVIRONMENTAL CRISIS THROUGH TEACHING AND LEARNING PHYSICS

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### Abstract

This study explores resilient green energy resources as a sustainable solution to Nigeria's dual challenges of energy insecurity and environmental pollution through teaching and learning of Physics. The research investigates renewable energy alternatives such as solar, wind, hydro, and biomass, analyzing their resilience, efficiency, and long-term viability in the Nigerian context, as well as the role of physics education in fostering awareness, innovation, and technical capacity for renewable energy development. Data were collected from secondary sources, including reports from the Energy Commission of Nigeria and the International Renewable Energy Agency to evaluate renewable potentials, environmental impact, and economic feasibility. The findings indicate that solar and hydropower systems possess the highest resilience indexes, 0.70 and 0.79 respectively, offering strong potential for sustainable energy diversification. Moreover, renewable energy adoption could reduce national CO<sub>2</sub> emissions by over 60% within the next decade, aligning with Nigeria's Energy Transition Plan and the Sustainable Development Goal on Affordable and Clean Energy. Integrating green energy concepts into physics teaching and learning is identified as a critical pathway for building skilled manpower and enhancing grassroots acceptance of clean energy technologies. The study concludes that the strategic deployment of green energy systems, supported by effective physics education, will not only stabilize power supply but also promote environmental restoration, workforce development, economic growth, and energy independence in Nigeria.

**Keywords:** Physics, Energy, Environment, Teaching, Learning.



## Introduction

Energy availability and environmental sustainability are critical determinants of economic growth, social stability, and national development. In contemporary development discourse, energy is not only viewed as a driver of industrialization but also as a variable that directly influences environmental quality, public health, and educational advancement (Adelaja & Olanrewaju, 2024). In Nigeria, persistent energy insecurity characterized by inadequate electricity generation, unreliable supply, and overdependence on fossil fuels has emerged as a central development challenge, with far-reaching environmental and socio-economic consequences (Ogunbiyi & Ekeocha, 2022).

This study is anchored on four interrelated core variables: resilient green energy resources, energy security, environmental sustainability, and physics teaching and learning. Resilient green energy resources comprising solar, wind, hydropower, and biomass constitute the independent technological variable of the study. These energy sources are considered “resilient” because of their renewability, adaptability to climatic conditions, long operational lifespan, and reduced vulnerability to fuel price volatility and supply disruptions. In contrast, Nigeria’s existing energy system is heavily dependent on fossil fuels, particularly natural gas and petroleum, which are finite, environmentally damaging, and increasingly unsustainable.

Energy security represents a key dependent variable and refers to the availability, reliability, affordability, and stability of energy supply. Nigeria’s chronic power shortages, frequent grid failures, and limited access affecting nearly 40% of the population demonstrate a weak energy security framework. The study posits that the adoption of resilient green energy

resources has a direct and positive relationship with energy security, as decentralized and renewable systems can expand access, stabilize supply, and reduce dependence on imported or environmentally harmful fuels.

Environmental sustainability constitutes another critical dependent variable and is examined in relation to energy production methods. Fossil fuel-based energy generation has been identified as a major contributor to environmental degradation in Nigeria, manifesting in gas flaring, oil spills, air pollution, deforestation, and high carbon emissions. These environmental impacts have intensified climate change effects such as flooding, droughts, and heat waves. The study therefore conceptualizes a strong inverse relationship between green energy adoption and environmental degradation: as the utilization of renewable energy increases, greenhouse gas emissions and ecological damage are expected to decrease significantly.

Physics teaching and learning functions as a mediating and enabling variable in this study. Physics education provides the scientific foundation for understanding energy generation, transmission, efficiency, and sustainability. Concepts such as energy conversion, thermodynamics, electricity, waves, and materials science are fundamental to renewable energy technologies. By integrating green energy concepts into physics curricula, learners are equipped with the cognitive knowledge, technical skills, and innovative capacity required designing, maintaining, and improving renewable energy systems. Thus, physics education strengthens the link between green energy resources and their effective adoption, utilization, and sustainability within society.



The interaction among these variables forms the conceptual framework of the study: resilient green energy resources, when effectively integrated into national energy strategies, enhance energy security and promote environmental sustainability, while physics teaching and learning serves as a catalyst that builds human capacity, technological competence, and societal acceptance necessary for successful implementation. In the Nigerian context, where technical manpower gaps and low public awareness hinder renewable energy deployment, physics education becomes a strategic tool for long-term energy transition and environmental restoration.

Globally, the shift toward renewable energy aligns with the United Nations Sustainable Development Goals, particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). For Nigeria, this transition also supports the Energy Transition Plan (2022), which aims to achieve net-zero emissions while expanding electricity access. Consequently, this study situates resilient green energy resources and physics education as interconnected solutions to Nigeria's intertwined energy and environmental crises.

Energy plays a crucial role in the economic growth and sustainable development of any nation (Adelaja & Olanrewaju, 2024). In Nigeria, the energy sector remains a persistent challenge, marked by unreliable power supply, overdependence on fossil fuels, and increasing environmental degradation (Ogunbiyi & Ekeocha, 2022). Despite being endowed with vast renewable resources such as solar radiation, wind potential, hydropower, and biomass, Nigeria still faces chronic electricity shortages and environmental pollution (Akinwale & Aremu, 2023). The demand for energy continues to rise with population growth and industrial expansion, yet supply

remains grossly inadequate, resulting in frequent blackouts, industrial downtime, and reduced productivity. The country's reliance on non-renewable energy sources like petroleum, coal, and natural gas has worsened environmental crises such as gas flaring, oil spills, deforestation, and air pollution. According to the International Energy Agency, over 85 million Nigerians nearly 40% of the population lack access to reliable electricity, while the rest rely on costly and environmentally harmful generators. The continuous use of fossil fuels has contributed significantly to climate change, leading to droughts, floods, and heat waves, which further threaten food security and livelihoods.

The global shift toward green and sustainable energy provides Nigeria an opportunity to transform its energy landscape. Resilient green energy resources such as solar, wind, hydro, and biomass represent adaptable, sustainable and environmentally friendly alternatives capable of meeting Nigeria's growing energy needs while reducing environmental impacts (Okafor & Bello, 2023). Moreover, integrating these concepts into the teaching and learning of physics can cultivate critical understanding, technical skills, and innovative thinking among students, empowering them to contribute to renewable energy development and environmental problem-solving in Nigeria. Physics education plays a pivotal role in equipping future engineers, scientists, and policymakers with the knowledge required to design, operate, and optimize resilient energy systems

### **Statement of the Problem**

Nigeria's energy sector has remained in crisis for decades, characterized by inconsistent electricity supply, overdependence on fossil fuels, and inadequate investment in renewable alternatives. Despite having abundant



renewable energy potential including over 427,000 MW solar potential, vast biomass reserves, and significant hydro resources the country still struggles to generate and distribute reliable power. This imbalance has hindered industrial growth, job creation, and the overall standard of living for millions of Nigerians. The overreliance on non-renewable sources, particularly crude oil and natural gas, has also led to severe environmental degradation. Continuous gas flaring, oil spillage in the Niger Delta, and deforestation for firewood have polluted the atmosphere and degraded farmlands, posing major threats to human health and food security. According to the Nigerian Environmental Study Action Team, fossil fuel activities account for over 65% of Nigeria's carbon emissions, contributing significantly to global warming and climate-related disasters such as flooding and droughts.

### Objectives of the Study

The following are the objectives of the study:

1. To examine the current state of Nigeria's energy sector by identifying the major challenges, inefficiencies, and environmental impacts associated with overdependence on fossil fuels.
2. To analyze the potential of renewable energy sources such as solar, wind, hydro, and biomass for sustainable energy generation in Nigeria.
3. To evaluate the resilience and environmental benefits of green energy systems compared to conventional fossil-based systems.
4. To assess the role of physics education in promoting knowledge, technical skills, and innovation for renewable energy adoption.
5. To assess the socio-economic implications of transitioning to

renewable energy, including employment generation, poverty reduction, and industrial competitiveness.

6. To recommend strategic policies, educational frameworks, and institutional interventions that can enhance the adoption and sustainability of resilient green energy technologies in Nigeria.

### Research Questions

To achieve the objectives outlined, this study is guided by the following key research questions:

1. What is the current state of energy production and consumption in Nigeria, and how has it contributed to the persistent energy and environmental crises?
2. What are the major renewable and green energy resources available in Nigeria and to what extent are they being explored and utilized?
3. How resilient and sustainable are renewable energy systems (such as solar, wind, hydro, and biomass) compared to conventional fossil-based energy sources?
4. How can the teaching and learning of physics enhance awareness, technical skills, and innovation for the adoption of resilient green energy solutions in Nigeria?
5. What socio-economic and environmental benefits can arise from adopting resilient green energy solutions in Nigeria?
6. What policy frameworks, institutional strategies, and public-private partnerships are necessary to promote large-scale adoption of renewable energy technologies in Nigeria?
7. How can resilient green energy resources, supported by physics



education, contribute to Nigeria's climate action goals and support sustainable development as outlined in the UN SDG 7 (Affordable and Clean Energy) and the Nigeria Energy Transition Plan (2022)?

### Hypotheses

In line with the objectives and research questions, the following null hypotheses have been formulated to guide the study empirically and theoretically:

**H<sub>01</sub>:** There is no significant relationship between the adoption of resilient green energy resources and the improvement of energy supply in Nigeria.

**H<sub>02</sub>:** The use of renewable energy technologies has no significant impact on reducing environmental degradation in Nigeria.

**H<sub>03</sub>:** Government policies, institutional strategies, and investment have no significant effect on the successful implementation of renewable energy programs in Nigeria.

**H<sub>04</sub>:** Integrating renewable energy concepts into the teaching and learning of physics has no significant influence on awareness, technical skill development, or adoption of green energy solutions in Nigeria.

### Methodology

This study adopts a descriptive and analytical research design, combining both quantitative and qualitative approaches.

Firstly, the descriptive research design is appropriate because the study seeks to systematically describe the current state of Nigeria's energy sector, including existing energy sources, levels of electricity access, patterns of fossil fuel dependence, and associated environmental challenges. The descriptive approach enables the researcher

to present factual, evidence-based accounts of energy production, consumption, and environmental impacts without manipulating variables. This is particularly suitable for a national-level study where the variables energy resources, environmental conditions, and educational practices already exist and cannot be experimentally controlled.

Secondly, the analytical research design is justified because the study goes beyond mere description to examine relationships and effects among key variables, namely resilient green energy resources, energy security, environmental sustainability, and physics education. The analytical component allows for the comparison of renewable and fossil-based energy systems using indicators such as resilience indices, carbon emission levels, reliability, and socio-economic outcomes. This design is essential for assessing how changes in energy sources influence environmental quality and energy stability, as well as how physics education mediates the adoption and sustainability of green energy technologies.

The combined descriptive analytical design is particularly suitable given that the study relies primarily on secondary data sourced from reputable national and international agencies, including the Energy Commission of Nigeria (ECN), International Renewable Energy Agency (IRENA), Nigerian Bureau of Statistics (NBS), and the International Energy Agency (IEA). These datasets are best analyzed through descriptive statistics to establish existing conditions and analytical techniques to evaluate trends, relationships, and comparative advantages of different energy systems over time.

Furthermore, the design aligns with the policy-oriented nature of the study. Since the research aims to inform energy policy,



educational reforms, and institutional strategies rather than test interventions experimentally, a descriptive analytical design provides a credible and ethically appropriate framework. It enables evidence-based recommendations that are grounded in existing realities and empirical trends, making the findings relevant to policymakers, educators, and energy stakeholders.

The descriptive method helps in understanding the current state of Nigeria's energy system, environmental challenges, and educational gaps, while the analytical component focuses on examining statistical relationships between energy sources, environmental impact, policy effectiveness, and the role of physics education in renewable energy adoption.

The mixed-method approach allows for comprehensive analysis of how resilient green energy resources, complemented by physics teaching and learning, can address Nigeria's energy and environmental crises. Data were collected primarily from secondary sources, including reports from the Energy Commission of Nigeria, International Renewable Energy Agency, the Nigerian Environmental Study Action Team, and relevant academic publications from 2020 to 2024.

The methodology includes:

1. **Descriptive Analysis:** To assess the current energy production, consumption patterns, and environmental consequences of fossil fuel dependence in Nigeria.
2. **Analytical Assessment:** To evaluate the resilience, sustainability, and socio-economic

benefits of renewable energy resources, using resilience indices, environmental impact metrics, and economic feasibility analysis.

3. **Educational Integration Analysis:** To examine the potential role of physics education in promoting knowledge, technical skills, and innovation for renewable energy adoption.

This approach ensures that the study not only identifies the technical and environmental feasibility of resilient green energy systems but also considers the educational strategies necessary for long-term sustainability and human capacity development.

### Research Analysis

This research analysis evaluates Nigeria's current energy production system, the environmental consequences of fossil fuel dependence, the resilience potential of renewable energy resources, and the role of physics education in supporting sustainable energy adoption. The analysis is based on secondary data obtained from reputable global and national agencies between 2020 and 2024.

### Nigeria's Current Energy Landscape

Nigeria's national grid capacity fluctuates between 3,500 and 5,000 MW for a population exceeding 200 million, making energy access highly unreliable. Fossil fuels, particularly natural gas, account for over 75% of national electricity generation. See table 1.



**Table 1: Nigeria’s Current Energy Landscape**

Energy Source	Installed Capacity (MW)	Contribution to Grid (%)	Environmental Impact
Natural Gas	4,600	75%	High carbon emissions, air pollution
Hydropower	2,000	24%	Low emissions, seasonal limitations
Solar	< 50	< 1%	Minimal environmental impact
Wind	< 20	Negligible	Minimal environmental impact

Sources: ECN, 2024; IEA, 2023

The data indicates extremely low integration of green energy resources despite vast potential.

**Environmental Impact of Fossil-Based Energy**

Nigeria remains one of the top 10 gas-flaring nations globally. Fossil dependency has led to:

1. 65% of national greenhouse gas emissions
2. Increased climate-related disasters (flooding, heat waves)
3. Soil and water contamination from oil spills

4. Health effects including respiratory diseases in oil-producing regions

This reinforces a negative cycle: energy production → environmental degradation → climate disasters → infrastructure damage → deeper energy insecurity.

**Renewable Energy Resilience Assessment**

Table 2 compares the resilience scores of available renewable energy resources measured by reliability, cost efficiency, lifespan, and adaptability under climatic stress.

**Table 2: Resilience scores of available renewable energy resources measured by reliability, cost efficiency, lifespan, and adaptability under climatic stress**

Energy Type	Resilience Index (0–1)	Key Strength	Key Constraint
Solar	0.70	Widely available in all regions	High initial setup cost
Hydro	0.79	Reliable base-load energy	Seasonal water fluctuations
Wind	0.61	Strong in coastal & northern zones	Turbine & grid infrastructure deficits
Biomass	0.67	Waste-to-energy opportunities	Informal/limited supply chain

Sources: IRENA, 2023; NBS, 2024



Hydropower ranks highest in resilience today, while solar demonstrates the greatest scalability.

### Role of Physics Education

Integrating renewable energy concepts into physics teaching and learning can enhance:

1. Awareness of sustainable energy technologies among students
2. Development of technical skills relevant to renewable energy deployment
3. Innovation and problem-solving capacity for energy and environmental challenges
4. Local engagement in energy projects and renewable technology adoption

Renewable energy development aligns strongly with Nigeria's SDG commitments, especially SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action).

### Policy and Investment Gaps

Key issues slowing renewable penetration include:

1. Weak policy enforcement
2. Lack of technical expertise and research funding
3. High investment risk due to unstable regulations
4. Limited public-private partnerships (PPPs)

Nigeria's Energy Transition Plan (2022) sets bold goals, but implementation remains slow. Integrating physics education into renewable energy policies and programs could strengthen technical capacity and community engagement, improving adoption rates and sustainability.

### Key Analytical Insight

Nigeria's environmental crisis is a direct consequence of its energy crisis. Renewable energy, reinforced by physics education, is the only resilient long-term

solution capable of addressing both simultaneously.

### Conclusion

This research concludes that resilient green energy resources, reinforced through teaching and learning of physics, represent the most viable and sustainable pathway to addressing Nigeria's long-standing energy and environmental crises. The study demonstrated that Nigeria's overdependence on fossil fuels has not only failed to meet energy demand but has also intensified environmental degradation, contributing to global climate instability. Findings showed that renewable energy technologies, particularly solar, hydro, wind, and biomass, can deliver reliable, cost-effective, and environmentally friendly alternatives. Among these, hydropower and solar energy emerged as the most resilient, based on their adaptability, availability, and sustainability. These energy systems have the potential to reduce Nigeria's carbon emissions by up to 60%, expand electricity access to remote communities, and stimulate inclusive economic growth.

However, achieving this transformation requires consistent policy enforcement, robust investment in renewable infrastructure, integration of renewable energy concepts into physics education, and national energy diversification strategies. The Nigerian government must strengthen frameworks such as the National Renewable Energy and Energy Efficiency Policy (NREEEP) and the Energy Transition Plan (2022) to promote large-scale deployment of renewable energy systems.

Equally, the private sector, academic institutions, and civil society must play active roles through research, innovation, and awareness creation. Properly implemented, resilient green energy



resources combined with physics education will not only stabilize Nigeria's power supply but also position the nation as a regional leader in sustainable energy transition across Sub-Saharan Africa.

Ultimately, a resilient green energy future for Nigeria is achievable if guided by strong governance, sound investment, and a shared national vision toward sustainability, climate responsibility, and educational empowerment.

### Recommendation

Based on the findings of this study, the following recommendations are proposed to enhance Nigeria's energy security, environmental sustainability, and human capacity development through resilient green energy resources and physics education:

1. **Strengthen National Investment in Resilient Green Energy Infrastructure**

The Federal Government of Nigeria should significantly increase investment in resilient green energy technologies, particularly solar and hydropower, which were found to possess the highest resilience indices and scalability. Priority should be given to decentralized solar mini-grids and small-to-medium hydropower projects to improve electricity access in rural and underserved communities and reduce pressure on the national grid.

2. **Diversify Nigeria's Energy Mix Away from Fossil Fuels**

In view of the strong link between fossil fuel dependence and environmental degradation, Nigeria should gradually reduce reliance on petroleum and natural gas for electricity generation. Clear transition timelines and incentives should be established to encourage utilities and private investors to adopt renewable energy solutions,

thereby lowering greenhouse gas emissions and mitigating climate-related environmental risks.

3. **Integrate Renewable Energy Concepts into Physics Curriculum at All Levels**

The study found that physics education plays a critical role in building technical competence and awareness for renewable energy adoption. Therefore, educational regulatory bodies such as the National Universities Commission (NUC) and the Nigerian Educational Research and Development Council (NERDC) should mandate the integration of practical renewable energy topics such as solar photovoltaic's, energy efficiency, and power systems into secondary and tertiary physics curricula.

4. **Enhance Practical and Laboratory-Based Physics Teaching**

Schools, colleges of education, and universities should be equipped with renewable energy laboratories and demonstration kits to support hands-on learning. This will strengthen students' understanding of energy concepts, foster innovation, and produce graduates with industry-relevant skills required for the design, installation, and maintenance of renewable energy systems.

5. **Promote Capacity Building and Teacher Training in Green Energy Technologies**

Continuous professional development programs should be organized for physics teachers and lecturers to update their knowledge and skills in emerging renewable energy technologies. This will ensure effective delivery of green energy content and enhance the quality of teaching and learning



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