



Energy Transition and Environmental Sustainability in Nigeria: Assessing the Effects of Renewable Energy Consumption and Fossil Fuel Dependence on Carbon Emissions

Abdulkareem Samuel^{1*}, Dolapo Abraham Olude², Muhammed Muktar³

Department of Mechanical Engineering, Faculty of Engineering, University of Lagos, Lagos State Nigeria

ORCID ID: 0009-0005-9300-7387

Department of Mechanical Engineering, Faculty of Engineering, University of Lagos, Lagos State Nigeria

ORCID ID: 0009-0002-1712-7924

Department of Economics, Faculty of Social Science, Prince Abubakar Audu University Anyigba

DOI : <https://doi.org/10.55248/gengpi.07.0926.3043>

ABSTRACT :

Nigeria's economic development has historically been driven by fossil fuel resources, particularly crude oil and natural gas, which have contributed significantly to national revenue generation and industrial growth. However, continued dependence on fossil fuels has intensified environmental challenges, including rising carbon dioxide (CO₂) emissions, ecosystem degradation, and vulnerability to climate change impacts. In response to global climate commitments and the growing need for sustainable development, Nigeria has initiated an energy transition pathway that emphasises renewable energy deployment, energy efficiency, and low-carbon development. This paper examines the relationship between energy transition, renewable energy consumption, fossil fuel dependence, and environmental sustainability in Nigeria through a comprehensive review of theoretical perspectives and empirical literature. The study adopts a conceptual review approach by synthesising recent scholarly evidence and reports from international energy institutions. The findings indicate that increased renewable energy consumption contributes to environmental sustainability by reducing reliance on carbon-intensive energy sources, improving energy security, and supporting climate mitigation efforts. Conversely, excessive dependence on fossil fuels remains a major driver of carbon emissions due to Nigeria's petroleum-based economy and limited diversification of its energy system. However, the transition towards renewable energy faces significant barriers, including inadequate infrastructure, financial constraints, technological limitations, weak institutional capacity, and policy implementation challenges. The study concludes that achieving sustainable energy transition in Nigeria requires coordinated policy reforms, increased renewable energy investment, technological innovation, and stronger institutional frameworks. The paper recommends accelerating renewable energy development, improving energy governance, expanding private-sector participation, and integrating climate considerations into national development strategies.

Keywords: Energy transition; Renewable energy; Fossil fuel dependence; Carbon emissions; Environmental sustainability; Nigeria; Climate change.

1. Introduction

The energy system worldwide is in the midst of a fundamental transition as a result of growing concerns over climate change, environmental degradation, energy security, and sustainable economic growth. For over 100 years fossil fuels, including coal, oil and natural gas, have been the leading sources of energy provision on earth, underpinning the process of industrialisation and economic growth. The widespread use of fossil fuels, however, has led to notable environmental impacts such as greenhouse gas emissions that contribute to global warming and climatic instability (Intergovernmental Panel on Climate Change [IPCC], 2023). As a result, countries around the world are seeking energy transition models to shift carbon-heavy energy systems to cleaner, more sustainable, alternatives.

Energy transition is a process of structural change of energy production, distribution and energy use from traditional fossil fuel-based energy systems to low-carbon, renewable and more energy-efficient energy systems (Smil, 2022). Such a shift is not only a technological one, but also an economic, institutional, social, and energy governance restructuring. In recent years, renewable energy sources such as solar, wind, hydropower, and biomass have also become key elements of global climate strategies for their ability to decrease carbon emissions and enhance energy accessibility and resilience (International Renewable Energy Agency [IRENA] 2023).

Table 1: Overview of Nigeria's Energy Transition Characteristics

Dimension	Current Situation	Sustainability Implication
Energy structure	Dominated by oil and natural gas	High carbon exposure
Renewable resources	High solar, hydropower and biomass potential	Opportunity for low-carbon transition

Fossil fuel dependence	Petroleum remains important for revenue and energy supply	Creates environmental vulnerability
Electricity access	Persistent supply challenges	Limits economic development
Policy framework	Energy Transition Plan 2022 and Climate Change Act 2021	Provides transition direction
Major barriers	Finance, infrastructure, technology and governance	Slows renewable deployment

Source: Authors' compilation based on Energy Commission of Nigeria (2024), International Renewable Energy Agency (2023), and Federal Government of Nigeria (2022).

Energy transition is difficult for developing countries since the exploitation and consumption of fossil fuels have driven economic growth in many instances. Nigeria is a key case because of its status as one of the biggest oil producers in Africa and its reliance on oil resources for government revenue, foreign exchange and industrial activities. Despite the availability of renewable energy resources, notably solar energy which is the country's geographical advantage, Nigeria's energy sector is still dominated by fossil fuels, posing a serious environmental and socioeconomic challenge (Energy Commission of Nigeria [ECN], 2024).

Oil exploration, gas flaring, transport, power generation and industrial production have all led to rising carbon emissions in Nigeria, as a result of its reliance on fossil fuels. While natural gas is being viewed as a “transitional fuel,” due to its lower carbon footprint than coal and oil, this continued reliance on hydrocarbons could hinder the transition to cleaner energy sources and slow progress towards long-term climate goals (International Energy Agency [IEA], 2023). Fossil fuel reliance has negative environmental impacts such as air pollution, loss of biodiversity, degradation of ecosystems, and exposure to climate-related risks like floods, droughts and extreme weather events.

Meanwhile, Nigeria has huge renewable energy resources that can fuel sustainable development. The country has a huge solar energy potential along the year, a huge potential for hydropower and opportunities for biomass and wind power development (IRENA, 2023). The potential expansion of renewable energy can help in reducing carbon emissions, expanding electricity access, enhancing energy security and economic diversification. Nevertheless, owing to financial, institutional, and infrastructural bottlenecks, the adoption of renewable energy is still low despite policy measures like the Nigeria Energy Transition Plan initiated in 2022 and the Renewable Energy Master Plan put in place (Federal Government of Nigeria, 2022).

The Energy-use relationship with the environment has been studied earlier and it has been revealed that there is a negative relationship between energy use and carbon emissions with the use of renewable energy while the use of fossil fuel contributes to environmental degradation (Acheampong et al., 2021; Nathaniel & Iheonu, 2019). Much of the literature that exists, however, has been for the general developing country context with little attention to Nigeria's energy structure, energy policy context, and development issues. In addition, there is a lack of a holistic picture of the interconnections between renewable energy usage and fossil fuel reliance in Nigeria's transition towards environmental sustainability.

Hence, the study in this paper focuses on the contribution of energy transition towards environmental sustainability in Nigeria, emphasizing the environmental implication of fossil fuel consumption, renewable energy consumption and carbon emissions. It makes a significant contribution to knowledge by delivering a comprehensive overview of theory, evidence and policy dilemmas surrounding Nigeria's transition to a sustainable energy future.

1.2 The objectives of this study are to:

To explore the linkage between Renewable energy use and Carbon emission reduction in Nigeria.

2. Examine the implications of Nigeria's reliance on fossil fuels on the environment.
3. Assess Nigeria's energy transition pathway challenges and opportunities.
4. Propose policy options for sustainable and low carbon energy development.

Conceptual Understanding of Energy Transition and Environmental Sustainability

2.1 Energy Transition and Sustainable Development

Energy transition is a complete paradigm shift in the production, transmission and use of energy in societies. It involves a gradual shift from conventional energy systems dominated by fossil fuels towards cleaner, renewable, and more sustainable energy alternatives. Energy transition is not just a one-for-one swap of one energy source with another, but rather a complicated transformation of technology, infrastructure, economic structure, political institutions and social norms (Cherp et al., 2021). The current energy transition can be seen as being primarily motivated by the necessity to curb GHG emissions, enhance energy security, eradicate energy poverty and reach global energy and climate goals as set in international climate agreements like the Paris Agreement.

The idea of energy transition has become more and more prominent as the current energy system is heavily reliant on carbon-intensive resources. Despite the rapid growth of renewable energy technologies, fossil fuels are still a significant share of the world's primary energy supply, according to the International Energy Agency (IEA, 2023). This reliance has posed major environmental issues, including the emissions of carbon dioxide (CO₂) and other greenhouse gases linked to the process of fossil fuel extraction, refining and use.

Energy transition is intrinsically linked to sustainable development in developing economies, as energy is a driver of economic growth, poverty alleviation, industrialisation and social welfare. But if sustainable development is to be achieved, then there must be a balance of economic development and the protection of the environment. The Sustainable Development Goals (SDGs), including SDG 7 on Affordable and Clean Energy and SDG 13 on Climate Action, underscore the critical need for shifting energy systems towards inclusive and environmentally responsible

development (United Nations, 2023).

Energy transition is both a challenge and an opportunity to Nigeria. Historically, fossil fuels have been a significant part of the country's development and economy has relied on this. Yet this reliance has made the country vulnerable to potential economic problems due to oil price fluctuations in the world market, and the environment problems due to petroleum production and consumption. This shift to renewables can thus be seen as an opportunity to diversify the energy sector, to increase energy security, and to decrease environmental degradation.

Expansion of renewable energy capacity is not enough to achieve a successful energy transition in Nigeria. It is dependent on electricity infrastructure, investment in clean technologies, building local technical capability, robust regulatory environments, and increased involvement of private sector stakeholders. So, energy transition should be seen as a multi-dimensional phenomenon, in terms of technological innovation, institutional change and socioeconomic adaptation.

2.2 Renewable Energy Consumption and Low-Carbon Development

Renewable energy use is the use of a naturally replenishable energy source like solar, wind, hydropower, geothermal energy and biomass to satisfy energy demand. Renewable energy sources (RES) have much lower greenhouse gas (GHG) emissions over their life cycles than fossil fuels, and play a critical role in global efforts to reach low-carbon development (IRENA, 2023).

Low-carbon development is about economic development under a low-carbon economy. It understands that energy expansion is necessary for developing countries to raise their living standards, while at the same time decreasing the environmental effects of conventional energy systems. Renewable energy technologies can play a key role in achieving this balance by helping to generate electricity, increasing access, and decreasing reliance on imported and/or environmentally damaging energy sources (Bhattacharyya, 2021).

The advantages of renewable energy for the environment are well known. Further uptake of renewables can lead to lower carbon emissions, with the potential to decarbonise electricity generation and lower the carbon intensity of energy systems. The research has revealed that the countries that have more renewable energy have less carbon emission because the renewable technologies do not directly burn fossil fuels to produce electricity (Danish et al., 2020; Khan et al., 2022).

Nigeria has a huge potential for developing renewable energy resources owing to its encouraging geographical and climatic conditions. Solar energy is one of the most promising renewable sources since in most parts of the country high solar radiation is received throughout the year. Besides, hydropower potentials of major river systems can be exploited to generate renewable electricity on large scale, biomass potentials of agricultural activities can be utilized to generate electricity on decentralized scale (Energy Commission of Nigeria, 2024).

While these opportunities exist, the use of renewable energy in Nigeria is still low. Renewable energy expansion is constrained by a number of factors such as lack of financing mechanisms, high initial investment costs, low grid capacity, limited technological capacity and lack of policy consistency. These challenges have slowed progress towards achieving a diversified and sustainable energy system.

There are also wider socio-economic implications of renewable energy development. Growth of renewable energy can generate jobs and jobs can support rural industries, contribute to rural electrification, and help alleviate energy poverty. So renewable energy must not only be considered as an environmental solution, but also as a tool for inclusive economic development and social transformation.

2.3 Fossil Fuel Dependence and Carbon Emissions in Nigeria

Fossil fuel dependence: continued dependence on coal, petroleum and natural gas as the main source of energy for economic activities, electricity generation, transport and industrial production. Fossil fuels historically have been the backbone of industrialisation and economic growth, and their significant use is the biggest source of global GHGs (IPCC, 2023).

Nigeria's economy is a noteworthy case study of the environmental problems that come with fossil fuel reliance. Since the crude oil was discovered in commercial quantities, Petroleum resources have been playing a pivotal role in the economic activities of the country. The oil and gas industry is one of the major contributing industries to government revenue and foreign exchange but has caused environmental issues especially in the oil-producing areas where the exploration activities have led to pollution, damage to the ecosystem, and biodiversity loss (Adewuyi, 2020).

Nigeria has a variety of sources of carbon emissions such as petroleum production, gas flaring, fossil fuel power generation, transport and industry. Gas Flaring is a major environmental issue since Nigeria has flared large quantities of associated natural gas in oil production, resulting in the emission of carbon dioxide, methane and other pollutants into the atmosphere (World Bank, 2023).

Carbon emission and fossil fuel consumption relationship has received a significant amount of attention. The existing studies show that there is a general increase in carbon emission with the increase in the use of fossil fuels due to the huge amount of greenhouse gases (GHGs) released during the combustion process (Nathaniel & Iheonu, 2019; Usman et al., 2021). This relationship is especially significant in the economies of developing countries like Nigeria, where energy intensive activities, depending on fossil fuel, have been used to commence economic growth.

But getting off fossil fuels is tricky. The petroleum sector continues to have an important economic role in Nigeria, and a quick transition away from fossil fuels without other economic opportunities could bring about some major socio-economic challenges. To this end, the country needs a well-planned transition path that helps to take the economy down the carbon-road, in a gradual yet stable way, while keeping the system economically viable and energy secure.

For Nigeria, it is not just about phasing out fossil fuels, it is about diversifying the energy system. Natural gas, renewable energy, energy efficiency and new technologies can take a transition role as the country moves towards a more sustainable energy system. To get this balance right, one needs good governance, long-term planning and coherence between the energy and climate policies.

3. Theoretical Framework

The literature underpinning this study affords the conceptual underpinning of the relationship between energy transition, renewable energy adoption, fossil fuel dependency, and environment sustainability in Nigeria. Being considered as the technology, economic, environmental and institutional factors affects energy systems, this study employs three theoretical approaches alongside with each other: Energy Transition Theory, Sustainable Development Theory and Environmental Kuznets Curve Theory. These theories offer explanations for the shift towards cleaner energy systems from fossil fuel sources and the impact of energy choices on environmental outcomes.

3.1 Energy Transition Theory

Energy Transition Theory is used to describe the long-term shift from one main energy source to another as a result of technological developments, resource availability, economic change and environmental concerns. The theory proposes that energy transitions are multi-faceted processes, consisting of energy production – and consumption – change, infrastructure change, institutional change and behavioural change (Smil, 2022).

In the past, global energy transitions have taken place by gradually phasing out traditional biomass for coal in industrialisation, and then switching to oil and natural gas in modern economies. Unlike previous transitions, which were dominated by concerns of energy security and affordable prices, the current transition is mostly motivated by the need to achieve environmental sustainability and to reduce the greenhouse gas emissions linked to fossil fuel use (Cherp et al., 2021).

The theory focuses on the fact that energy transitions are not a one-for-one switch of energy sources, but rather a long-term process shaped by technology, economics, politics and social acceptance. Renewable energy technologies (RETs) are increasingly significant because they offer an alternative to carbon intensive energy systems and can help to mitigate climate change.

The Energy Transition Theory is relevant to Nigeria as it sheds light on the country's transition from fossil fuel-based energy system to multiple renewables-based energy system. Nigeria's historical dependence on oil and gas has influenced the country's economic structure, energy infrastructure and policy focus. But growing environmental pressures, climate pledges and energy security issues have led to the necessity of shifting to cleaner energy sources.

The theory points out that Nigeria's energy transition goes beyond a mere build-up in renewable energy. Needs structural transformation in energy governance, investments, infrastructure, technology and institutions. These are all interdependent and must be addressed to ensure the success of Nigeria's Energy Transition Plan.

So, the Energy Transition Theory can validate the claim that a higher use of renewable energy sources can lead to a decrease in carbon emissions, and that fossil fuel dependence can hinder efforts towards environmental sustainability.

3.2 Sustainable Development Theory

Sustainable Development Theory is founded on the belief that development should meet the current economic and social needs without reducing the potential of future generations to do so (Brundtland Commission, 1987). The theory creates a link between the dimensions of economic development, environmental protection and social equity (the three dimensions of sustainability).

The theory states that economic growth should not be allowed to occur at the expense of the environment. Rather, development policies should encourage sustainable social, ecological and efficient use of resources. In the energy industry, sustainable development involves a shift from energy systems that are harmful to the environment, to energy options that are cleaner, more efficient, and readily available (Mensah, 2019).

Energy is at the core of sustainable development as access to reliable energy is essential for education, healthcare, industrialisation, job creation and poverty alleviation. But conventional fossil fuel based energy systems have environmental impacts in the form of carbon emissions, air pollution and destruction of ecosystems. Accordingly, Sustainable Development Theory would certainly aid the application of eco-friendly and renewable energy sources as a means to move forward in economic advancement while minimizing ecological impacts.

The theory is particularly relevant for Nigeria as it works towards economic development, while contending with environmental pressures. Oil and gas have also played a significant role as contributors of the country's income, but reliance on oil and gas has led to environmental issues and economic insecurity. In order to adopt a sustainable development approach, Nigeria needs to diversify its energy system by increasing the penetration of renewable energy and maintain the affordability and accessibility of energy.

Moreover, the theory emphasizes the need for social inclusion in the energy transition journey. Renewable energy development should not only aim at reducing emissions, but it should also be a tool for tackling energy poverty, by increasing electricity access, especially in rural areas and those where power is scarce. Thus, Sustainable Development Theory can be used in the understanding of how renewable energy can play a part in the protection of the environment, the development of the economy and the improvement of society.

3.3 Theory of Environmental Kuznets Curve Theory

The Environmental Kuznets Curve (EKC) Theory is a theory of the relationship between economic growth and environmental degradation. The theory, proposed by Grossman and Krueger (1995), implies that environmental degradation would initially rise in the initial phase of economic growth, but decline beyond a certain level of income. This relationship is sometimes expressed in the form of an inverted U-shaped curve between economic growth and environmental pollution.

Based on EKC theory, developing economy heavily relied on resource-based sector and fossil fuel consumption to gain economic growth. This phase is characterised by higher carbon emissions as a result of higher production levels, urbanisation and energy demand. But once an economy becomes richer,

it can implement cleaner technologies, stricter environmental policies, better energy efficiency and reindustrialization, which may lead to a decrease in environmental impact.

The relevance of the EKC framework for Nigeria is that Nigeria's economic growth has so far always been linked to petroleum production and fossil fuel consumption. The growing demand for energy and carbon emissions are due to greater exploration of oil, industrial activities, and urban developments. But according to the theory, technological progress, more stringent environmental policies, and more investment in less polluting energy sources, might help mitigate the environmental consequences of economic growth.

However, the relevance of EKC Theory in developing countries is still in question. Others suggest that economic growth is not necessarily related to environmental improvement as countries may keep using fossil fuels after reaching a higher level of income (Stern, 2017). Planning and policy actions, investment in renewables, and institutional changes are thus required to ensure that economic development will take a sustainable path.

As far as Nigeria is concerned, the EKC argument emphasizes the need for the dissociation of economic growth from energy utilization of a carbon-intensive nature. To attain sustainable development, the policies should promote the utilization of renewable energy, increase the use efficiency of energy, and limit the dependence on fossil fuels. In this way, EKC Theory is complementary to Energy Transition Theory as it demonstrates how a country's economic development trends affect its environment.

Table 2: Theoretical Perspectives Supporting Nigeria's Energy Transition Analysis

Theory	Main Argument	Application to Nigeria
Energy Transition Theory	Energy systems transform through technological and institutional change	Explains movement from fossil fuels to renewables
Sustainable Development Theory	Development must balance economy, society and environment	Supports clean energy development
Environmental Kuznets Curve Theory	Economic growth initially increases pollution but may reduce it through cleaner technologies	Explains Nigeria's growth-emission relationship

Source: Authors' compilation based on Smil (2022), Cherp et al. (2021), Mensah (2019), Stern (2017)

3.4 Theoretical Integration and Relevance to the Study

The three theories offer complementary explanations to Nigeria's energy transition challenge. ETT is a theory that describes the structural change from fossil fuel based to renewable energy based systems. Sustainable Development Theory emphasizes the importance of balancing economics, environment, and social issues. The Environmental Kuznets Curve Theory is used to interpret the relationship between economic development and energy use and environmental effects.

A combination of these theories indicates that Nigeria's path to environmental sustainability will require energy transition and continued economic growth goals. As renewable energy sources are utilized more, carbon emissions can be lowered and sustainable development encouraged, while reliance on fossil fuels can lead to greater environmental strain. So, an integrated approach is needed to develop policies that integrate technological innovation, economic diversification, institutional strengthening and environmental governance for a successful transition to a new energy landscape.

4. Review of Empirical Literature

In recent years, the connection between the pattern of energy use and environmental sustainability has been a topic of significant interest, in the wake of growing concerns about climate change, carbon emissions, and the need for sustainable energy systems. Previous empirical research has explored the relationship between renewable energy use, fossil fuel use, economic growth, and energy policies and environmental impacts. This section covers relevant empirical evidence on renewable energy consumption and carbon emission reduction, fossil fuel dependence and environmental degradation, challenges and opportunities of Nigeria's energy transition.

4.1 Renewable Energy Consumption and Carbon Emission Reduction

Empirical studies have shown that renewable energy use is significant in environment-friendly and carbon emission reduction. Renewable energy sources have much lower GHG emissions than fossil fuel based energy systems, and are therefore critical to global GHG mitigation strategies.

A number of cross-country studies have corroborated the inverse relationship between the use of renewable energy and carbon emissions. Danish and Ulucak (2021), for instance, investigated the relationship between renewable energy use and technological innovation with environmental quality in the developing economies. They found that higher renewable energy use is beneficial to carbon emission reduction for it complements the traditional fossil fuel based energy sources. Likewise, Usman et al. (2021) concluded that renewable energy development has a positive impact on the environment by decreasing the reliance on fossil fuel energy system.

Khan et al. (2022) showed that the use of renewable energy has a significant impact on lowering carbon emission in a wider study of emerging economies, especially if the country has a favorable environmental policy along with technological growth. The study highlighted that whilst transitioning to RE can be the first step, it is not enough; there is a need for effective institutional framework and investments.

International energy organisations have also emphasised the contribution of renewable energy to climate mitigation. Renewable energy technologies have become more cost-competitive, and they stand out as one of the best ways of cutting emissions from power generation, according to the International Renewable Energy Agency (IRENA, 2023). Likewise, the International Energy Agency (IEA, 2023) highlighted the critical need to step

up the deployment of renewables to meet global targets for net zero emissions.

Based on the empirical evidence in the context of Nigeria, there is a big potential for renewable energy to enhance the environmental sustainability. Nigeria has great potentials of solar, hydropower, and biomass power that can be utilized for reducing reliance on petroleum-based generation systems. Adebayo and Kirikkaleli (2021) found that investment in renewable energy can help in lessening the environmental pressures in the developing economies by increasing the diversity of energy.

But notwithstanding the benefits of renewable energy for the environment, the contribution of renewable energy in Nigeria is rather limited. Renewable energy deployment is impeded by numerous studies which have identified barriers such as inadequate investment, limited electricity infrastructure, lack of technological capacity, and regulatory uncertainty (Oyedepo, 2021). These difficulties hinder the country in fully leveraging the potential of renewable energy resources to reduce emissions.

Hence, it is clear from the empirical evidence that there is a positive link between renewable energy consumption and environmental sustainability. But without supportive policies, infrastructure development, financial mechanisms and technological innovations, it is difficult to achieve significant carbon reduction.

4.2 Fossil Fuel Dependence and Environmental Degradation

One of the main reasons for carbon emissions and environmental degradation is fossil fuel dependence. Many empirical studies have proven that fossil fuel consumption is positively related with greenhouse gas emissions because of the carbon intensive nature of fossil fuel combustion.

Nathaniel and Iheonu (2019) examined the linkage between natural resource dependence, energy consumption and environmental quality in developing countries. Their study found that such a heavy reliance on fossil fuel resources puts additional ecological strain due to the rapid increase in carbon emissions. The study contended that in countries relying on extractive industries, the economic growth is more likely to get entangled with the exploitation of the resources and therefore, the environmental problems are more likely to be encountered.

Likewise, Usman et al., (2021) investigated the connection between fossil fuel use and environmental sustainability and concluded that a higher fossil fuel consumption has a significant impact on environmental degradation. The scientists pointed out that carbon emissions are still high in energy-intensive economic sectors including industrial production and transport.

Nigeria is a good example of the environmental impact that comes with reliance on fossil fuels. Nigeria was one of the biggest producers of oil and its economy has traditionally been dependent on oil. While the oil industry makes high contribution to national income, the activities of the oil and gas industry have since generated enormous environmental issues, especially in the Niger Delta region.

Adewuyi (2020) revealed that, the activities of the oil exploration in Nigeria have led to environmental pollution with oil spills, gas flaring and ecosystem destruction. Flaring of gas is a key issue due to the emissions of carbon dioxide and methane, which increase climate change and impact on the air quality and health of human beings.

Moreover, Nigeria's electricity sector is also highly dependent on natural gas generation. While natural gas produces fewer emissions than coal and oil, continued dependence on gas infrastructure may delay the transition towards renewable energy systems. To achieve long-term climate goals, developing economies need to incrementally and steadily decarbonize while increasing the share of clean energy sources (IEA, 2023).

This empirical evidence thus suggests that dependence on fossil fuels produces major environmental problems. In Nigeria, mitigating carbon emissions will demand a step-wise transition toward an energy system that adopts more renewable energy, advances energy efficiency, and diversifies the economy away from petroleum dependence.

4.3 Nigeria's Energy Transition Challenges and Opportunities

The energy transition pathway of Nigeria has an abundance of opportunities and challenges. Despite the country's significant renewable energy resources, a number of structural challenges constrain deployment of clean energy resources.

A major challenge is lack of energy infrastructure. Nigeria is still grappling with the problem of power supply deficiency as it has been faced by low generation capacity, transmission limitation and distribution deficiency. These are some of the limitations in the infrastructure that hinder integration of renewable energy technologies in the national electricity systems. The Energy Commission of Nigeria (2024) has noted that to ensure high penetration of renewable energy and reliable electricity supply, there is a need to enhance energy infrastructure.

Another significant challenge to energy transition is financial. Renewable energy projects also typically require high up-front investments, and access to low-cost finance is a hurdle in many developing nations. Research has also revealed that high capital costs, investment risks, and limited financial incentives decrease the level of participation by the private sector in renewable energy development (Bhattacharyya, 2021).

The institutional and policy landscape also impacts Nigeria's energy transition journey. While Nigeria has adopted various renewable energy policies such as the Renewable Energy Master Plan and Energy Transition Plan, the implementation faces challenges like regulatory uncertainty, poor coordination among institutions, and limited monitoring mechanisms (Federal Government of Nigeria, 2022).

Nevertheless, Nigeria has a range of opportunities for promoting energy transition. Its solar energy potential is one of the highest across Africa, and can be utilised for decentralised power generation, especially in rural areas. Expansion of renewable energy may enhance access to electricity, decrease energy poverty, generate job opportunities and foster economic diversification.

As per the latest studies, decentralised renewable energy systems such as solar mini-grids and standalone systems can deliver solutions for communities not on the national electricity grid (IRENA, 2023). The above methods are especially relevant in Nigeria, as millions of citizens are still deprived of access to reliable electricity.

Furthermore, Nigeria's roadmap towards becoming a net zero carbon economy by 2060 creates a critical policy framework for fast-tracking energy transition. The Nigeria Energy Transition Plan highlights the measures and steps needed to reduce emissions and achieve economic growth and development through renewable energy investments, clean technology adoption and energy efficiency improvements (Federal Government of Nigeria,

2022).

In conclusion, the empirical analysis indicates that while Nigeria's energy transition is feasible, it will need holistic solutions to overcome technological, financial, institutional, and social challenges. Governance, investments and policy consistency need to be effective to support renewable energy expansion.

Table 3: Summary of Empirical Evidence on Energy Transition and Environmental Sustainability

Author(s)	Study Focus	Main Findings	Relevance to Nigeria
Danish & Ulucak (2021)	Renewable energy and environmental quality	Renewable energy reduces emissions	Supports renewable expansion
Usman et al. (2021)	Energy consumption and sustainability	Renewable energy improves environmental outcomes	Highlights clean energy benefits
Khan et al. (2022)	Renewable energy in emerging economies	Renewable energy lowers carbon emissions	Applicable to developing countries
Adewuyi (2020)	Fossil fuel exploitation in Nigeria	Oil activities contribute to environmental degradation	Explains Nigeria's fossil fuel challenge
Oyedepo (2021)	Renewable energy development in Nigeria	Infrastructure and policy barriers limit adoption	Identifies transition constraints

Source: Authors' compilation based on reviewed empirical studies

4.4 Research Gap

While a vast number of studies have been conducted on the connection between energy consumption and environmental sustainability, there are still several gaps. One, most of the literature is general and at the regional or global level, which means it gives little insight into the energy transition problems and opportunities in Nigeria. Unique dependence of oil resources, growing energy demand and development priorities of Nigeria call for country specific analysis.

Secondly, past research has tended to focus on renewable energy usage or fossil fuel reliance alone, not on the joint effects of renewable energy and fossil fuel use on Nigeria's environmental sustainability. A holistic picture must be developed that takes into account the interaction between continued fossil fuel dependence and the increased use of renewables in the energy system of the country.

Third, existing studies have highlighted the role of renewable energy, but there are limited studies that critically examine the institutional, financial, and policy barriers that affect Nigeria's potential for achieving a successful energy transition.

Hence, the present study adds to the knowledge base by giving an integrated review on renewable energy consumption, fossil fuel dependence and carbon emission and sustainability issues in the energy transition pathway of Nigeria.

5. Discussion: Energy Transition Pathways for Environmental Sustainability in Nigeria

Nigeria's energy transition is a complicated transformation process of technological, economic, institutional, and environmental governance change. The country is facing balancing the demands for energy for economic growth and also to decrease carbon emissions due to fossil fuel dependence. It has been noted that the literature reviewed shows that the expansion of renewable energy sources has great potential to increase environmental sustainability, however the use of fossil fuels is still one of the main limitations to reach climate goals. In this section, key pathways to Nigeria's sustainable energy transition are discussed.

5.1 Renewable Energy Potential and Energy Security

Nigeria has significant renewable energy resources that can be utilised for fossil fuel saving and national energy security. The country's geographical location has a great potential of solar energy with average solar radiation suitable for both grid connected and decentralised energy systems. Furthermore, Nigeria possesses a vast hydropower potential, biomass potential from agricultural activities, and emerging wind energy development potentials (Energy Commission of Nigeria, 2024).

Scaling up renewables can help achieve environmental sustainability through decreasing the carbon intensity of Nigeria's energy system. The production of electricity from fossil fuels is still a major source of GHG emissions, especially natural gas. Renewable energy penetration can help to reduce emissions by replacing carbon-intensive generation sources and enhancing electricity generation sustainability (IRENA, 2023).

In addition to environmental gains, renewable energy can enhance energy security, the diversity of energy supply, and reduce reliance on scarce fossil fuel resources. Nigeria's reliance on energy security is heightened given that oil price changes have a direct impact on government revenues and economic stability. A diversified energy system comprising of several renewable energy resources can minimize the vulnerability to external energy shocks.

Renewable energy also provides opportunities for expanding electricity access. Many people, especially in rural and remote areas of Nigeria, are still inadequately served with reliable electricity supply. In areas where grid extension is economically challenging, decentralised renewable energy systems such as solar home systems (SHS) and mini-grid technologies can offer a cost-effective solution to deliver electricity (IEA, 2023).

But for these benefits to come, they must be planned. Investment in transmission, energy storage, technical capacity building and enabling policies are required to support renewable energy deployment. In the absence of these complementary investments, renewable energy's potential to transform

Nigeria's energy system could be capped.

Table 4: Opportunities and Barriers Affecting Renewable Energy Transition in Nigeria

Renewable Energy Opportunity	Current Barrier
High solar radiation availability	Limited investment
Hydropower resources	Poor infrastructure
Biomass availability	Limited technology capacity
Rural electrification potential	Weak grid systems
Green employment creation	Skills gap
Private-sector participation	Regulatory uncertainty

Source: Authors' compilation based on IRENA (2023), Oyedepo (2021), Bhattacharyya (2021)

5.2 Barriers to Renewable Energy Deployment

Although Nigeria has great potential, there are many factors that are still hindering the uptake of clean energy technologies. The barriers are interdependent and consist of financial constraints, infrastructure, technological constraints, and institutional weaknesses.

A major problem is a lack of funding. Renewable energy systems typically have significant initial costs relative to traditional energy systems. There are still challenges to access long-term financing for renewable technologies in developing countries like Nigeria, despite the cost of these technologies having reduced over the years, because of the economic risks, uncertain investment environment, and financial incentives (Bhattacharyya, 2021).

Limits of infrastructure are also a big hurdle. However, Nigeria's transmission infrastructure is not sufficiently developed and is plagued by technical inefficiencies and limited electricity grid coverage, which hinder the ability to integrate large amounts of renewable energy. In addition, because renewable energy sources like solar and wind power are variable, they need better energy storage solutions. The future growth of renewables could be limited without modern grid infrastructure and storage capacity.

Technological capacity is another important challenge. Building up renewable energy development needs skilled personnel, research facilities, maintenance and indigenous manufacturing. Projects with high reliance on importing renewable energy equipment are more expensive and have long-term sustainability issues. Building local know-how is thus crucial in relating to a successful energy transition.

The weaknesses of institutions also have an impact on renewable energy development. The introduction of renewable energy policies in Nigeria, however, has been inconsistent because of the lack of policy enforcement, overlapping institutional functions, and regulatory ambiguity. To make renewable energy policies result in real environmental and economic impacts, strong governance mechanisms must be in place.

However, the barriers to renewable energy need to be addressed through a coordinated effort from the government, private-sector investors, international development partners, and local communities. Energy transition cannot be done with technology only, it needs institutional transformation and effective policy implementation.

5.3 Policy and Institutional Challenges

Policy and institutional framework are critical to the success of Nigeria's energy transition. Nigeria has several policies and strategies in the energy and climate change sector over the years to facilitate the development of renewable energy and reduce emissions. These range from the National Renewable Energy and Energy Efficiency Policy, Renewable Energy Master Plan, Climate Change Act 2021 and the Nigeria Energy Transition Plan introduced in 2022.

The Climate Change Act is significant as it offers institutional groundwork for climate governance and gives direction to move towards Nigeria's net zero emissions goal of 2060. The Energy Transition Plan, on the other hand, offers a roadmap for emission reduction, while tackling energy poverty and economic growth (Federal Government of Nigeria, 2022).

But policymaking is not enough to realize energy transition goals. There are still many obstacles to effective implementation, such as the lack of institutional capacity, funding, coordination between government agencies and monitoring mechanisms. Measurable goals and accountability mechanisms must be in place for the implementation of policies.

Moreover, the energy governance architecture in Nigeria has been tilted towards fossil fuel development due to the significant economic value of oil and gas. This generates institutional opposition to speedy energy transition. Energy policies need to be adjusted and increasingly invest in renewable energies and low carbon solutions, although fossil fuels will continue to be in use in the transition period.

Institutions need to be strengthened therefore. There is a need for better technical capacity, coordination and reliable environmental and energy data for government agencies responsible for energy and climate management. Transparent governance mechanisms can also facilitate private investments as it lowers uncertainty and boosts investor confidence.

5.4 Balancing Economic Growth and Carbon Reduction

One of the major challenges in Nigeria is to strike a balance between economic development and environmental sustainability. Nigeria as a developing nation, with its huge population and increasing energy demand, needs reliable and affordable energy to facilitate Industrialisation, Job creation and Poverty eradication. But if energy use is increased via fossil fuel systems, this adds extra environmental pressures.

This is very pertinent to Nigeria as petroleum resources have traditionally ushered in economic development. A quick decline in fossil fuel consumption without other economic plans may cause economic problems, especially for those communities and industries that are relying on the oil

and gas industry.

Thus, Nigeria's energy transition needs to be a gradual and inclusive process. The nation should implement strategies to decrease the level of carbon intensity instead of the complete phasing out of fossil fuels. These can range from energy efficiency, to gas flare reduction, to renewable energy, green industries, and clean transportation systems.

The economic diversification is also important. The challenge of reducing oil revenue dependency involves investing in renewable energy production, agriculture, technology, and sustainable industries. These industries have the potential to generate jobs and also lower the dependence on environmentally damaging economic activities.

In addition, a just energy transition approach should be applied to ensure that the vulnerable groups are not impacted negatively. Skills development, alternative job opportunities and social protection for workers and communities relying on fossil fuel industries. So that environmental goals are met in conjunction with social and economic stability.

In general, an integrated approach to energy system development is needed in Nigeria, which considers the interdependencies between energy, economy and environment. Expansion of renewable energy must be considered as a transformation of the economy and sustainable development, as well as a climate strategy.

Table 5: Strategic Pathway for Nigeria's Sustainable Energy Transition

Stage	Transition Pathway	Expected Outcome
1	Fossil Fuel Dependence	High carbon emissions, environmental degradation, and vulnerability to climate change
2	Emission Reduction Strategies	Reduction of carbon intensity through improved efficiency, cleaner technologies, and emission control measures
3	Renewable Energy Investment	Increased deployment of solar, hydropower, biomass, and other clean energy technologies
4	Improved Infrastructure	Enhanced electricity networks, energy storage systems, and renewable energy integration capacity
5	Strong Governance and Climate Finance	Improved policy implementation, institutional coordination, investment mobilisation, and climate funding access
6	Low-Carbon Energy System	Diversified energy structure with reduced dependence on fossil fuels and lower greenhouse gas emissions
7	Environmental Sustainability	Improved climate resilience, cleaner environment, sustainable development, and long-term energy security

Source: Authors' conceptual framework developed from Energy Transition Theory, Sustainable Development Theory, and empirical literature reviewed in this study.

6. Policy Implications and Strategic Recommendations

The literature reviewed reveals that Nigeria's journey to environmental sustainability is significantly dependent on the effectiveness of its energy transition strategies. Renewable energy has great potential to decrease carbon emissions and provide energy security, but fossil fuel dependence, institutional barriers, financial constraints and infrastructure issues still constrain growth. Thus, a sustainable transition to an energy system needs comprehensive policy interventions that consider technological, economic, institutional and social aspects of the energy system.

6.1 Accelerating Renewable Energy Investment and Infrastructure Development

Nigeria must urgently invest more in renewable energy infrastructure to diversify energy sources away from fossil fuels and create energy sustainability. While the country has good potential for renewable energy resources, especially solar energy, hydropower and other renewables are also available, but the lack of infrastructure is a significant constraint in large-scale deployment.

There is a need to prioritise building and updating electricity infrastructure, such as electricity networks, renewable energy systems, and energy storage, through government policies. There is also a need to promote investment in decentralised renewable energy initiatives like solar mini-grids and off-grid solutions, especially in rural areas where access to electricity is still restricted.

Public private partnerships can be a key driver for mobilizing investment capital and technical know-how. The government must create a friendly environment for investments with the help of financial incentives, transparent regulations, tax advantages and risk reduction measures, so private sector investments can be encouraged in the field of renewable energy.

In addition, the establishment of local renewable energy industries should be prioritised. Development of domestic manufacturing capacity of renewable energy components, research and development (R&D) and technical training programmes can help in reducing dependence on imported

technologies and provide employment opportunities.

6.2 Reducing Fossil Fuel Dependence Through a Managed Energy Transition

One of the challenges to environmental sustainability in Nigeria is reliance on oil and gas. But, a sudden exit from fossil fuel activities could lead to economic and social issues, due to the importance of fossil fuels in the economy. Nigeria thus needs a well-planned transition approach to slowly mitigate the use of carbon-intensive energy and safeguard economic stability.

Government policies should emphasize reduction of emissions from the current fossil fuel operations by making them more efficient and by implementing stricter environmental regulations and by accelerating the reduction of gas flaring. Cleaner technologies for oil and gas industry should be adopted and environmental management practices should be improved.

In parallel, Nigeria's energy investment should be progressively moved towards RE systems and LC technologies. Strategically using fossil fuel money to invest in renewable energy, energy efficiency programmes and climate adaptation will allow for these investments. This would enable Nigeria to leverage on the available resources to drive the transition to a cleaner energy future.

This is especially crucial as millions of Nigerians are directly or indirectly reliant on fossil fuel based economic activities. Policies should include provisions for workforce retraining, employment diversification and social protection and help to contribute to a just energy transition.

6.3 Strengthening Energy Governance and Policy Implementation

For Nigeria to accomplish its energy transition goals, effective governance is key. Nigeria has several policies in place to promote renewable energy and combat climate change; however, implementation of these policies is a major challenge.

There is a need for better coordination, technical capacity and monitoring systems for government institutions responsible for energy and environmental management. To prevent overlaps in responsibilities and accountability for energy transition programmes, clear institutional responsibilities should be set.

Attracting investment is also essential and policy consistency is important in this regard. The uncertainty for renewable energy investors is caused by frequent changes in regulations, unclear approval processes and weak enforcement mechanisms. Stable and predictable regulatory frameworks would help to boost the investor confidence and participation of domestic and international stakeholders.

In addition, energy and environmental data systems should be established that are reliable. Effective planning, monitoring and evaluation of energy transition progress requires accurate data on energy consumption, emissions, renewable energy capacity and climate impacts.

6.4 Expanding Climate Finance and International Cooperation

The costs of the energy transition are high, especially for Nigeria and other developing countries. One of the challenges with implementing renewable energy projects and climate-related programmes is the limited financial capacity within the country. Thus, there is a need for Nigeria to enhance access to domestic and international climate finance.

The government needs to better access international climate funds, development financing and green investment opportunities. Institutions need to build more competencies in project preparation to enable the design of bankable renewable energy projects that can be supported through international means.

Private sector involvement in climate finance arrangements also needs to be encouraged by blended finance, guarantees, concessional loans, and green bonds. These financial instruments can help mitigate investment risks and enhance competitiveness of renewable energy projects for investors.

International cooperation is also essential as part of the energy transition, with access to advanced technologies, tech expertise, and knowledge transfer. International collaborations with other organisations, research institutions and renewable energy companies can assist Nigeria in building its capacity to deploy sustainable energy solutions.

6.5 Promoting Energy Efficiency and Sustainable Consumption

Expansion of renewable energy alone is not enough to achieve reductions in carbon emissions; so too is the enhancement of energy efficiency. Energy efficiency measures can contribute to reducing the demand for energy, operational costs, and strain on available energy systems.

There is a need to enforce tighter energy efficiency regulations in Nigeria, such as for buildings, industries, appliances, and transportation. Technologies and sustainable consumption habits are important elements that can help to reduce emissions.

Cleaner production techniques and energy conservation technologies should be promoted in the industrial sector. In the same way, transport policies should encourage the use of cleaner transport modes such as electric vehicles, better public transit services and fuel efficiency requirements.

Public awareness programmes should also be part of energy efficiency policies, as they raise awareness among citizens, businesses and institutions about how to consume energy responsibly. Behavioural changes are important because, in addition to technological transformation, addressing sustainable energy transition means changing energy-use practices.

6.6 Supporting a Just and Inclusive Energy Transition

Energy transition policies should not lead to further environmental goals and social disparities. The Nigerian energy transition should take into account the needs of communities, workers and vulnerable people impacted by energy sector transitions.

Skills development programmes should be part of a just transition framework to support workers transitioning from fossil fuel to renewable energy

sectors. Programmes in renewable energy engineering, energy management and skills related to climate should be established in universities, technical institutions and vocational training centres.

Rural communities should also be included in renewable energy initiatives as better energy access can help to drive education, health, agriculture and local economic development. Renewable energy policies that are inclusive can both alleviate energy poverty and contribute to other sustainable development goals.

6.7 Summary of Strategic Recommendations

Based on the analysis, the following strategic actions are recommended:

1. **Increase renewable energy investment** through improved infrastructure development, private-sector participation, and domestic renewable energy capacity building.
2. **Gradually reduce fossil fuel dependence** through emission reduction measures, reduced gas flaring, cleaner technologies, and economic diversification.
3. **Strengthen energy governance** by improving institutional coordination, policy implementation, regulatory stability, and energy data management.
4. **Expand climate finance opportunities** through international cooperation, green financing mechanisms, and investment-friendly policies.
5. **Promote energy efficiency and sustainable consumption** across industrial, residential, and transportation sectors.
6. **Ensure a just energy transition** by protecting vulnerable groups, creating green employment opportunities, and improving renewable energy access.

These are measures that can help Nigeria achieve the transition to a low carbon energy system without compromising on economic development goals and the environment.

7. Conclusion

Nigeria's energy system is at a pivotal moment where choices around energy development pathways will have a critical impact on the country's future environmental, economic and social outcomes. The study focused on energy transition, Renewable Energy consumption, Fossil Fuel dependency, Carbon Emission and their relationship in Nigeria in an all-encompassing manner from both the theoretical and empirical lens. The analysis shows that although fossil fuels have so far been a backbone of economic growth and national development, the reliance on energy systems based on petroleum has led to rising carbon emissions, environmental deterioration and susceptibility to climate change effects.

The study highlights the potential of renewable energy as a key strategy for Nigeria to achieve environmental sustainability and overcome energy challenges. The nation possesses huge renewable energy potential in solar, hydropower, biomass resources and can leverage these resources for transitioning to a cleaner and resilient energy system. Higher uptake of renewable energy can lead to lower carbon emissions, both by substituting for carbon-intensive energy, by increasing energy efficiency, by enhancing energy security, and by increasing electricity access, especially in communities that are underserved.

But the shift to renewable energy is still hampered by a number of obstacles: the lack of infrastructure, insufficient investment, technological dependence, low institutional capacity, and inconsistent policy implementation. These barriers suggest that energy transition is not just a technological challenge, but also an institutional, financial and socioeconomic transformation process. Hence, the transition pathway in Nigeria must entail the coordinated actions of government institutions, private sector actors, international partners, and local communities.

The research also emphasizes the need for a step-by-step and inclusive approach to phasing out fossil fuels. An immediate phase out of fossil fuels could lead to economic instability and social problems, due to the economic significance of oil and gas resources. To instead Nigeria should aim for a managed transition, that lessens carbon intensity, boosts efficiency in fossil fuel sector, diversifies economy and reallocates resources towards renewable energy projects.

Theoretically, the results corroborated the relevance of the three theories namely, Energy Transition Theory, Sustainable Development Theory and Environmental Kuznets Curve Theory in addressing Energy and environmental issues facing Nigeria. The two theories, Energy Transition Theory and Sustainable Development Theory, highlight the significance of the structural change in energy systems as well as balancing economic growth with environmental sustainability and social welfare. The Environmental Kuznets Curve view also calls attention to the need to switch to cleaner technologies and more robust environmental policies to dis-link economic growth from carbon emissions.

The study makes contributions to the current literature due to the integrated understanding it offers of the relationship between renewable energy adoption and fossil fuel dependence and their impact on environmental sustainability in the Nigeria specific socioeconomic context. This review is unique in its emphasis on the interrelatedness of energy choices, economic development, institutional capacity and climate outcomes, rather than investigating energy sources individually.

Therefore, Nigeria needs to invest in renewable energy, strengthen its climate governance, invest in energy infrastructure, increase access to climate finance, and increase energy efficiency in order to have a successful energy transition. In addition, policies should be inclusive, including measures to foster job creation, assist impacted workers and communities, and provide access to affordable and reliable energy.

To conclude, Nigeria's journey to environmental sustainability is hinged on the capacity to transition the energy system from a fossil fuel dominant one to one that is diverse, renewable and less carbon intensive. Thus development of renewable energy should not only be considered as a need of the environment but as an opportunity for economic transformation, energy security, technological innovation and sustainable national development. With proper planning and inclusiveness, Nigeria can achieve long-term socio-economic progress and a reduction of carbon emissions through a transition towards energy.

REFERENCES

- Adebayo, T. S., & Kirikkaleli, D. (2021). Impact of renewable energy consumption, globalization, and technological innovation on environmental degradation in developing economies. *Environmental Science and Pollution Research*, 28, 54345–54358. <https://doi.org/10.1007/s11356-021-14478-2>
- Adewuyi, A. O. (2020). Environmental implications of fossil fuel exploitation and energy consumption in Nigeria. *Energy Reports*, 6, 254–262. <https://doi.org/10.1016/j.egyr.2020.01.009>
- Acheampong, A. O., Adams, S., & Boateng, E. (2021). Do globalization and renewable energy contribute to carbon emissions mitigation? Evidence from global economies. *Energy Economics*, 95, 105099. <https://doi.org/10.1016/j.eneco.2020.105099>
- Bhattacharyya, S. C. (2021). *Energy economics: Concepts, issues, markets and governance* (3rd ed.). Springer.
- Brundtland Commission. (1987). *Our common future: Report of the World Commission on Environment and Development*. Oxford University Press.
- Cherp, A., Vinichenko, V., Jewell, J., Suzuki, M., & Antal, M. (2021). Integrating techno-economic, socio-technical and political perspectives on national energy transitions. *Energy Research & Social Science*, 75, 102059. <https://doi.org/10.1016/j.erss.2021.102059>
- Danish, Khan, N., Baloch, M. A., Saud, S., & Fatima, T. (2020). The effect of renewable energy consumption on carbon emissions: Evidence from developing economies. *Renewable Energy*, 147, 267–276. <https://doi.org/10.1016/j.renene.2019.08.067>
- Energy Commission of Nigeria. (2024). *National energy statistics and renewable energy development report*. Energy Commission of Nigeria.
- Federal Government of Nigeria. (2022). *Nigeria energy transition plan*. Federal Government of Nigeria.
- Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *Quarterly Journal of Economics*, 110(2), 353–377. <https://doi.org/10.2307/2118443>
- International Energy Agency. (2023). *World energy outlook 2023*. International Energy Agency. <https://www.iea.org/reports/world-energy-outlook-2023>
- International Renewable Energy Agency. (2023). *World energy transitions outlook 2023: 1.5°C pathway*. International Renewable Energy Agency. <https://www.irena.org/publications>
- Intergovernmental Panel on Climate Change. (2023). *Climate change 2023: Synthesis report*. IPCC. <https://www.ipcc.ch/report/ar6/syr/>
- Khan, I., Hou, F., Le, H. P., & Ali, S. (2022). Do natural resources, renewable energy, and economic growth improve environmental quality? Evidence from emerging economies. *Renewable Energy*, 190, 645–655. <https://doi.org/10.1016/j.renene.2022.03.105>
- Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action. *Cogent Social Sciences*, 5(1), 1653531. <https://doi.org/10.1080/23311886.2019.1653531>
- Nathaniel, S., & Iheonu, C. O. (2019). Carbon dioxide emissions, urbanisation, and economic development in Africa: Evidence from panel data. *Environmental Science and Pollution Research*, 26, 2064–2076. <https://doi.org/10.1007/s11356-018-3650-3>
- Oyedepo, S. O. (2021). Sustainable energy development in Nigeria: The role of renewable energy technologies. *Energy Reports*, 7, 337–352. <https://doi.org/10.1016/j.egyr.2021.06.050>
- Smil, V. (2022). *How the world really works: The science behind how we got here and where we're going*. Viking.
- Stern, D. I. (2017). The environmental Kuznets curve after 25 years. *Journal of Bioeconomics*, 19, 7–28. <https://doi.org/10.1007/s10818-017-9243-1>
- United Nations. (2023). *The Sustainable Development Goals report 2023*. United Nations. <https://unstats.un.org/sdgs/report/2023/>
- Usman, M., Kousar, R., Makhdam, M. S. A., Yaseen, M. R., & Nadeem, A. M. (2021). Do environmental innovation and renewable energy promote sustainable development? Evidence from global economies. *Environmental Science and Pollution Research*, 28, 47885–47899. <https://doi.org/10.1007/s11356-021-14092-8>
- World Bank. (2023). *Nigeria development update: Turning the corner*. World Bank. <https://www.worldbank.org/en/country/nigeria>