

The Role of Renewable Energies for Sustainable Energy Governance and Environmental Policies for the Mitigation of Climate Change in Nigeria

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Abstract

This paper examines the critical role of renewable energy in promoting sustainable energy governance and mitigating climate change in Nigeria. As one of the largest greenhouse gas emitters in Africa, Nigeria's dependence on fossil fuels contributes significantly to environmental degradation, energy insecurity, and economic instability. Despite the potential for abundant renewable energy sources, such as solar, wind, hydropower, and biomass, the adoption of renewable energy technologies remains hindered by weak regulatory frameworks, inconsistent policies, and insufficient infrastructure. Using secondary research and qualitative content analysis, this study analyzes Nigeria's energy landscape, existing policies, and governance structures. It underscores the importance of integrating renewable energy into the national energy mix. The paper argues that the successful transition to a sustainable energy system requires strengthened policy enforcement, enhanced financial mechanisms, and strategic public-private partnerships. The findings emphasize the need for comprehensive climate policies, including emission reduction strategies, promotion of clean energy technologies, and sustainable urban development practices, to ensure a resilient and low-carbon future for Nigeria. Ultimately, the research concludes that fostering renewable energy adoption is essential to achieving sustainable development, enhancing energy security, and meeting Nigeria's climate commitments.

Keywords: *Renewable Energy, Sustainable Energy Governance, Environmental Policies, Climate Change, Nigeria*

1. Introduction

Nigeria, Africa's most populous nation, has long relied on fossil fuels as the backbone of its energy sector, with crude oil and natural gas accounting for the majority of energy production and export revenues (Olawuyi, 2022). This dependence on fossil fuels has contributed to severe environmental challenges, including greenhouse gas (GHG) emissions, oil spills, and deforestation, leading to significant ecological degradation (Akinbami, 2021). The country's continued reliance on fossil fuels not only exacerbates climate change but also threatens energy security due to fluctuating global oil prices and declining fossil fuel reserves (Odeh et al., 2020). In recent years, the Nigerian government has implemented policies and legislative initiatives to diversify its energy sources and promote renewable energy. One key initiative is the Renewable Energy Master Plan (REMP), developed by the Energy Commission of Nigeria, which seeks to raise the share of renewable energy in the national energy mix from 13% in 2015 to 23% by 2025 and 36% by 2030 (Energy Commission of Nigeria, 2022). Furthermore, the introduction of the National Renewable Energy and Energy Efficiency Policy (NREEEP) in 2015 established a strategic framework for advancing renewable energy development and enhancing energy efficiency. Nigeria is already experiencing the adverse effects of climate change, which continue to escalate due to rising global temperatures and unsustainable environmental practices. The impacts of climate change in Nigeria are evident in increased temperatures, desertification, coastal erosion, and extreme weather events such as floods and droughts, all of which pose serious threats to livelihoods, food security, and economic stability (Nwankwo et al., 2023). According to the Nigerian Meteorological Agency (NiMet), the country has recorded a steady rise in annual mean temperatures over the past few decades, with extreme heatwaves becoming more frequent, particularly in urban centers (NiMet, 2022).

The northern regions, particularly states in the Sahel zone such as Borno, Yobe, and Sokoto, are witnessing rapid desert encroachment, exacerbated by deforestation and unsustainable agricultural practices (Oladipo et al., 2021). This loss of arable land has heightened food insecurity and increased competition for dwindling resources, fueling conflicts between farmers and herders (Bello et al., 2020). Similarly, unpredictable rainfall patterns and prolonged dry seasons have reduced crop yields, further threatening the livelihoods of millions who depend on agriculture (Adefolalu et al., 2021). In the southern coastal regions, rising sea levels and coastal erosion present severe risks to communities in the Niger Delta, where many depend on fishing and farming for survival (Ebeku, 2020). The Intergovernmental Panel on Climate Change (IPCC) projects that sea levels along Nigeria's coastline could rise by 0.5 to 1 meter by the end of the century, increasing the risk of coastal flooding and displacement of vulnerable populations (IPCC, 2021). Additionally, frequent oil spills and gas flaring have already degraded the

region's ecosystem, compounding the challenges faced by local communities (Ugochukwu & Ertel, 2022). Urban areas are also experiencing climate-related challenges, with Lagos, Nigeria's largest city, facing severe flooding due to poor drainage infrastructure and unregulated urban expansion (Adelekan, 2019). The increasing frequency of flash floods in cities like Lagos and Port Harcourt has resulted in economic losses, property damage, and displacement of residents (Olanrewaju et al., 2022). These worsening climate-related challenges underscore the urgent need for a transition to sustainable energy solutions that reduce dependence on fossil fuels and mitigate environmental degradation. A shift towards renewable energy, alongside effective environmental policies, is essential to build climate resilience and ensure a sustainable future for Nigeria.

Despite Nigeria's heavy reliance on fossil fuels, the country has immense untapped renewable energy potential that could support a sustainable energy transition. Nigeria is endowed with abundant solar energy, receiving an average solar radiation of approximately 5.5 kWh/m² per day, with some regions experiencing even higher levels (Aliyu et al., 2018). The northern states, particularly Sokoto, Katsina, and Borno, receive the highest solar intensity, making them ideal for large-scale solar photovoltaic (PV) and solar thermal energy projects (Ohunakin et al., 2014). The implementation of solar mini-grid systems in off-grid rural communities has already demonstrated the viability of solar energy in improving electricity access and reducing reliance on diesel generators (Olaleye et al., 2021). Nigeria also has significant wind energy resources, particularly in the northern and coastal regions. Studies indicate that states such as Kano, Katsina, Sokoto, and Plateau exhibit wind speeds suitable for electricity generation, with average wind speeds ranging from 4 to 7 m/s at a height of 10 meters (Shaaban & Petinrin, 2014). The potential for offshore wind energy along the Gulf of Guinea further presents an opportunity for large-scale wind power deployment (Adaramola et al., 2014). However, the lack of infrastructure and investment in wind technology has hindered its widespread adoption. Hydropower is another major renewable resource in Nigeria, yet it remains underutilized despite contributing to the national grid. The country has an estimated hydropower potential of 14,750 MW, but only about 2,000 MW is currently being utilized, primarily from large-scale plants such as the Kainji, Jebba, and Shiroro dams (Ikejemba et al., 2017). Small and mini-hydropower projects have the potential to enhance rural electrification efforts, particularly in riverine areas where grid expansion is challenging (Musa et al., 2020).

However, climate variability and inconsistent water flow pose risks to hydropower generation, highlighting the need for integrated water resource management. In addition to solar, wind, and hydropower, biomass and bioenergy present viable alternatives for decentralized energy generation. Nigeria generates over 144 million tons of biomass annually, primarily from agricultural residues, animal waste, and forestry by-products (Adepoju et al., 2022). Technologies such as biogas digesters, bioethanol production, and biomass gasification can convert organic waste into sustainable energy sources for rural electrification and cooking fuel, reducing dependence on firewood and kerosene (Garba & Kishk, 2021). Biomass energy can also play a critical role in addressing deforestation and indoor air pollution caused by the extensive use of traditional biomass for cooking (Nnaji et al., 2012). If effectively harnessed,

these renewable energy resources can significantly enhance Nigeria's energy security, reduce carbon emissions, and create economic opportunities. Investments in renewable energy infrastructure, policy incentives, and capacity building are crucial to accelerating the transition to a sustainable energy future. Integrating renewable energy with existing energy policies and aligning them with Nigeria's climate commitments under the Paris Agreement can facilitate long-term environmental and economic benefits (Ebhotu & Tabakov, 2021).

To facilitate a successful transition to renewable energy, Nigeria requires robust energy governance and well-structured environmental policies. However, the country faces significant challenges that hinder the effective implementation of a sustainable energy framework. Weak regulatory structures, policy inconsistencies, and a lack of coordination between government agencies have created bottlenecks in renewable energy adoption (Oyedepo, 2012). While Nigeria has introduced policies such as the National Renewable Energy and Energy Efficiency Policy (NREEEP) and the Renewable Energy Master Plan (REMP), poor enforcement and regulatory inefficiencies have limited their effectiveness (Sambo, 2015). One major issue is the inconsistent policy environment, where frequent changes in government leadership often result in shifting energy priorities and delays in project execution (Sule et al., 2020). For instance, despite the Nigerian Electricity Regulatory Commission (NERC) establishing the Feed-in Tariff (FiT) framework to attract private investments in renewables, unclear guidelines and bureaucratic delays have discouraged investor confidence (Ogunbiyi, 2019). Additionally, the lack of financial incentives, such as subsidies and tax breaks for renewable energy developers, has further slowed the deployment of solar, wind, and hydropower projects (Aliyu et al., 2018). Another critical challenge is Nigeria's inadequate infrastructure for integrating renewable energy into the national grid. The country's electricity grid is outdated, fragile, and prone to frequent breakdowns, making it difficult to accommodate the variability of renewable energy sources (Ikejemba et al., 2017).

Limited grid capacity in rural areas has also prevented decentralized renewable energy solutions, such as mini-grids and off-grid solar systems, from reaching underserved populations (Olaleye et al., 2021). Moreover, the dominance of fossil fuel subsidies, particularly for petroleum products, distorts energy pricing and makes renewable energy less competitive (Ebhotu & Tabakov, 2021). This paper examines the role of renewable energy in achieving sustainable energy governance and environmental policies aimed at mitigating climate change in Nigeria. It explores the challenges associated with renewable energy adoption, evaluates existing policy frameworks, and proposes strategic measures for a sustainable and climate-resilient energy sector. By transitioning to a renewable-based energy system, Nigeria can not only meet its growing energy demands but also align with global climate action efforts to reduce GHG emissions and promote sustainable development.

2. Methodology

This study employs a secondary research methodology to investigate the role of renewable energies in sustainable energy governance and climate change mitigation policies in Nigeria.

Secondary research involves the systematic collection, analysis, and synthesis of existing data, scholarly articles, government reports, and other credible resources to address the research objectives. This approach is particularly suited to the study as it provides access to a broad range of data sources and insights into long-term trends, policies, and practices related to renewable energy and climate change mitigation. Data for this study were gathered from a variety of secondary sources, including government reports, international organization publications, academic journal articles, and industry reports. Key sources include Nigeria's National Energy Policy, renewable energy strategies from the Energy Commission of Nigeria, and relevant publications from organizations such as the International Renewable Energy Agency (IRENA) and the World Bank. The data were analyzed using a qualitative content analysis approach, with a focus on identifying and categorizing themes related to renewable energy governance, policy frameworks, and their role in mitigating climate change in Nigeria. A comparative analysis was also employed to assess the effectiveness of Nigeria's renewable energy policies in comparison with those of other countries facing similar climate challenges. The data were critically evaluated for reliability and relevance to ensure that only credible and context-specific information was used in the analysis.

3. Nigeria's Energy Landscape and Climate Change Challenges

3.1. Fossil Fuel Dependence and Environmental Impacts

Nigeria's energy sector is heavily reliant on fossil fuels, particularly crude oil and natural gas, which contribute significantly to the country's economy. As one of the largest oil producers in Africa, Nigeria derives over 90% of its export earnings and a substantial portion of government revenue from petroleum resources (Nwankwo & Ogagarue, 2011). However, this dependence on fossil fuels has led to severe environmental challenges that threaten both ecological stability and human well-being.

Greenhouse Gas (GHG) Emissions from Oil and Gas Flaring

Gas flaring is a major source of greenhouse gas (GHG) emissions in Nigeria, releasing significant amounts of carbon dioxide (CO₂), methane (CH₄), and other pollutants into the atmosphere. According to the World Bank (2021), Nigeria is among the top countries globally in terms of gas flaring, despite various policies aimed at reducing the practice. The continuous flaring of associated gas contributes to climate change by increasing atmospheric temperatures and disrupting local weather patterns (Odeh & Onakoya, 2018). Additionally, pollutants released during flaring, such as black carbon and volatile organic compounds, have been linked to severe respiratory diseases in communities near oil production sites (Ite et al., 2013). Oil Spills Contaminating Water Bodies and Agricultural Lands. The Niger Delta, home to one of the largest wetlands in the world, has been severely affected by frequent oil spills, resulting in extensive environmental, economic, and social damage. The region, which accounts for the majority of Nigeria's crude oil production, has experienced thousands of spill incidents over the decades, primarily due to aging infrastructure, poor maintenance, operational failures, and acts of

vandalism (UNEP, 2011; Amnesty International, 2018).



Figure 1. Greenhouse Gas (GHG) Emissions (Source: Hero Future Energies (2024))

Between 1976 and 2001, over 6,800 oil spill incidents were recorded in Nigeria, with approximately 3 million barrels of crude oil released into the environment (UNEP, 2011). The National Oil Spill Detection and Response Agency (NOSDRA) reported that between 2006 and 2021, Nigeria experienced over 16,000 oil spills, leading to severe environmental contamination (NOSDRA, 2022). These spills have resulted from pipeline corrosion, equipment failure, and sabotage. According to research by Oghenekaro et al. (2020), about 50% of oil spills in the Niger Delta are attributed to equipment failure and corrosion, while sabotage and oil theft account for another 30-40%. Oil spills in the Niger Delta have caused significant contamination of rivers, creeks, and groundwater sources. Studies indicate that hydrocarbons such as benzene, toluene, and polycyclic aromatic hydrocarbons (PAHs) persist in the water for years, making them unsafe for consumption and destroying aquatic ecosystems (Ugochukwu & Ertel, 2008). In areas like Bodo, Ogoniland, and Goi, communities have reported the total collapse of fisheries due to crude oil pollution, leading to food insecurity and loss of livelihoods (UNEP, 2011).

A case study in Ogoniland, conducted by the United Nations Environment Programme (UNEP, 2011), found that hydrocarbon levels in groundwater exceeded safe drinking limits by 900 times, with benzene concentrations far surpassing World Health Organization (WHO) guidelines. This contamination has led to widespread health issues, including cancer, skin diseases, and respiratory illnesses, among local populations (Ebeku, 2020). Crude oil spills degrade soil

quality, reducing agricultural productivity and threatening food security. Research by Nwilo and Badejo (2006) found that hydrocarbons penetrate deep into the soil, leading to loss of soil fertility, acidification, and the destruction of microbial life essential for plant growth. Cassava, yam, and maize farms in affected communities have suffered severe declines in yield due to the toxic effects of crude oil (Adebayo & Olajide, 2021). In some areas, such as Ijaw and Itsekiri communities, farmland abandonment has become common due to recurring oil pollution. The loss of fertile land has forced many farmers to migrate, exacerbating poverty and social unrest in the region (Eweje, 2006).

The economic impact of oil spills on fishing and farming communities in the Niger Delta is profound. Small-scale fishers, who rely on rivers and creeks for their livelihoods, have seen their incomes plummet due to mass fish deaths, bioaccumulation of toxic substances in seafood, and habitat destruction (Ashton et al., 2010). Similarly, subsistence farmers have lost their means of survival, leading to increased dependence on external aid and worsening socioeconomic conditions (Okonkwo & Igwe, 2022). Beyond economic losses, oil spills have fueled social unrest and violent conflicts in the Niger Delta. Communities affected by pollution have engaged in protests and legal battles against oil companies, demanding compensation and environmental remediation. However, cases such as the Bodo community lawsuit against Shell in 2015—where the company agreed to pay \$83.5 million in damages—highlight the ongoing struggles for justice and environmental restoration (Amnesty International, 2018).

Deforestation Due to Reliance on Biomass for Cooking and Heating

In Nigeria, a significant portion of the population, particularly in rural areas, depends on biomass—mainly firewood, charcoal, and crop residues—for cooking and heating. This dependence is driven by energy poverty, lack of access to modern energy sources, and the high cost of alternatives such as liquefied petroleum gas (LPG) and electricity (Adewuyi & Oyejide, 2022). As a result, the demand for firewood and charcoal has accelerated deforestation, leading to severe environmental consequences, including habitat destruction, biodiversity loss, and increased carbon emissions. Nigeria has one of the highest deforestation rates in the world. The Food and Agriculture Organization (FAO, 2020) estimates that the country loses between 350,000 to 400,000 hectares of forest annually, primarily due to logging, agricultural expansion, and fuelwood harvesting. Between 1990 and 2020, Nigeria lost over 19 million hectares of forest cover, reducing its forested land area from 17% to less than 10% of the total landmass (World Bank, 2021).

The excessive reliance on firewood and charcoal as household energy sources contributes significantly to this deforestation trend. According to Global Forest Watch (2022), over 80% of Nigerian households, particularly in rural communities, rely on wood fuel for cooking. In states such as Benue, Kogi, Taraba, and Cross River, large portions of natural forests have been depleted due to unchecked logging and firewood collection (Ogunwusi & Jolaoso, 2021). Deforestation in Nigeria has led to widespread habitat destruction, threatening the survival of many plant and animal species. The country's tropical rainforests, particularly in Cross River

State, are home to endangered species such as the Cross River gorilla (*Gorilla gorilla diehli*), forest elephants, and pangolins (Ijeomah et al., 2019). The loss of tree cover reduces nesting sites, food sources, and migration corridors for these species, increasing the risk of extinction.

Additionally, deforestation has disrupted watershed ecosystems, leading to increased soil erosion and desertification, especially in the northern parts of Nigeria (Abubakar & Attah, 2021). The encroachment of the Sahara Desert into states like Borno, Yobe, and Katsina has been linked to unsustainable tree-felling practices, further exacerbating environmental degradation (Nwankwo & Njoku, 2020). Forests act as crucial carbon sinks, absorbing atmospheric CO₂ and mitigating climate change. However, the continuous depletion of Nigeria's forests has reduced this carbon absorption capacity, leading to a rise in greenhouse gas (GHG) emissions. Research shows that deforestation accounts for about 20% of Nigeria's total CO₂ emissions, making it a major contributor to global warming (Okonkwo & Olajide, 2022). Moreover, the inefficient burning of biomass fuels releases high levels of black carbon (soot) and methane, both of which have a greater warming potential than CO₂ (Jacobson et al., 2019). These emissions not only contribute to climate change but also deteriorate air quality, posing severe health risks to rural households.

The reliance on biomass for cooking has significant public health implications, particularly for women and children who are most exposed to indoor air pollution. According to the World Health Organization (WHO, 2021), exposure to smoke from firewood and charcoal stoves leads to respiratory diseases such as chronic obstructive pulmonary disease (COPD), lung infections, and eye irritation. In Nigeria, biomass-related air pollution is responsible for approximately 64,000 premature deaths annually, making it one of the country's top environmental health risks (WHO, 2021). Furthermore, the time-consuming task of collecting firewood places a heavy burden on rural women and children, limiting their ability to engage in education, economic activities, or social development (Eguavoen, 2020). In many communities, women and children walk long distances—sometimes up to 10 kilometers daily—to gather firewood, exposing them to physical strain and security risks (Aina & Salami, 2021).

Air Pollution and Health Impacts in Nigeria

Air pollution remains a significant environmental and public health issue in Nigeria, driven primarily by fossil fuel combustion, industrial activities, and inefficient energy use. The burning of petroleum products in power generation, vehicular emissions, and industrial processes releases a range of harmful pollutants, including sulfur dioxide (SO₂), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), and particulate matter (PM_{2.5} and PM₁₀). These pollutants contribute to poor air quality, affecting millions of Nigerians, particularly in urban and industrialized areas.

Major Sources of Air Pollution in Nigeria

1. Transportation Sector

- Nigeria has a rapidly growing vehicle population, with many aged and poorly maintained cars emitting high levels of pollutants (Adebayo & Olalekan, 2021).

- The widespread use of low-quality fuel and diesel-powered generators further exacerbates emissions of PM_{2.5}, NO_x, and SO₂ (Okedere et al., 2022).
- Traffic congestion in major cities like Lagos, Kano, and Port Harcourt increases the concentration of ground-level ozone and smog, worsening respiratory conditions (Akinbami et al., 2020).

2. Industrial and Power Generation Emissions

- Industries, especially in Port Harcourt, Onitsha, and Kaduna, contribute significantly to air pollution through emissions of particulate matter, heavy metals, and chemical fumes (Ede & Edokpa, 2017).
- Gas flaring in the Niger Delta releases high amounts of carbon dioxide (CO₂), methane (CH₄), and black carbon, worsening both local air quality and climate change (Nnaji et al., 2021).
- Nigeria relies heavily on diesel and petrol generators due to unreliable electricity supply, leading to high emissions of CO, NO_x, and SO₂ in both residential and commercial areas (Ibitoye & Akinbami, 2022).

3. Household and Biomass Combustion

- Over 80% of Nigerian households depend on biomass fuels like firewood and charcoal for cooking and heating, especially in rural areas (Adelaja & Adeolu, 2020).
- Indoor air pollution from inefficient stoves and open fires exposes women and children to PM_{2.5} and black carbon, increasing the risk of chronic respiratory diseases (WHO, 2021).
- The burning of waste and refuse in urban slums releases toxic chemicals, further degrading air quality (Ugwueze & Nnorom, 2022).

Health Impacts of Air Pollution

Exposure to airborne pollutants has severe health consequences, particularly for vulnerable groups such as children, the elderly, and individuals with pre-existing health conditions. Studies have shown a strong correlation between air pollution and the following health conditions:

1. Respiratory Diseases

- Chronic exposure to PM_{2.5}, NO_x, and SO₂ is a leading cause of respiratory diseases such as asthma, bronchitis, chronic obstructive pulmonary disease (COPD), and lung infections (Obioh et al., 2013).
- A study by Akinbami et al. (2020) found that children in Lagos and Port Harcourt have a higher prevalence of asthma and pneumonia due to prolonged exposure to vehicular and industrial emissions.
- Indoor air pollution from biomass fuel use contributes to acute lower respiratory infections (ALRIs), a leading cause of mortality among Nigerian children under five (WHO, 2021).

2. Cardiovascular and Neurological Disorders

- Air pollutants such as PM_{2.5} and carbon monoxide have been linked to increased risks of hypertension, heart attacks, and strokes due to their impact on blood

circulation (Ezeh et al., 2018).

- Long-term exposure to air pollution contributes to neurodevelopmental disorders, cognitive decline, and increased risk of dementia, especially among the elderly (Okafor et al., 2021).

3. Premature Deaths and Reduced Life Expectancy

- The Global Burden of Disease Report (2022) estimates that air pollution is responsible for over 150,000 premature deaths annually in Nigeria, ranking it among the top environmental health risks in the country.
- A study by Ede and Edokpa (2017) found that poor air quality contributes to a reduction in life expectancy in highly polluted cities like Port Harcourt and Lagos by up to 3–5 years.

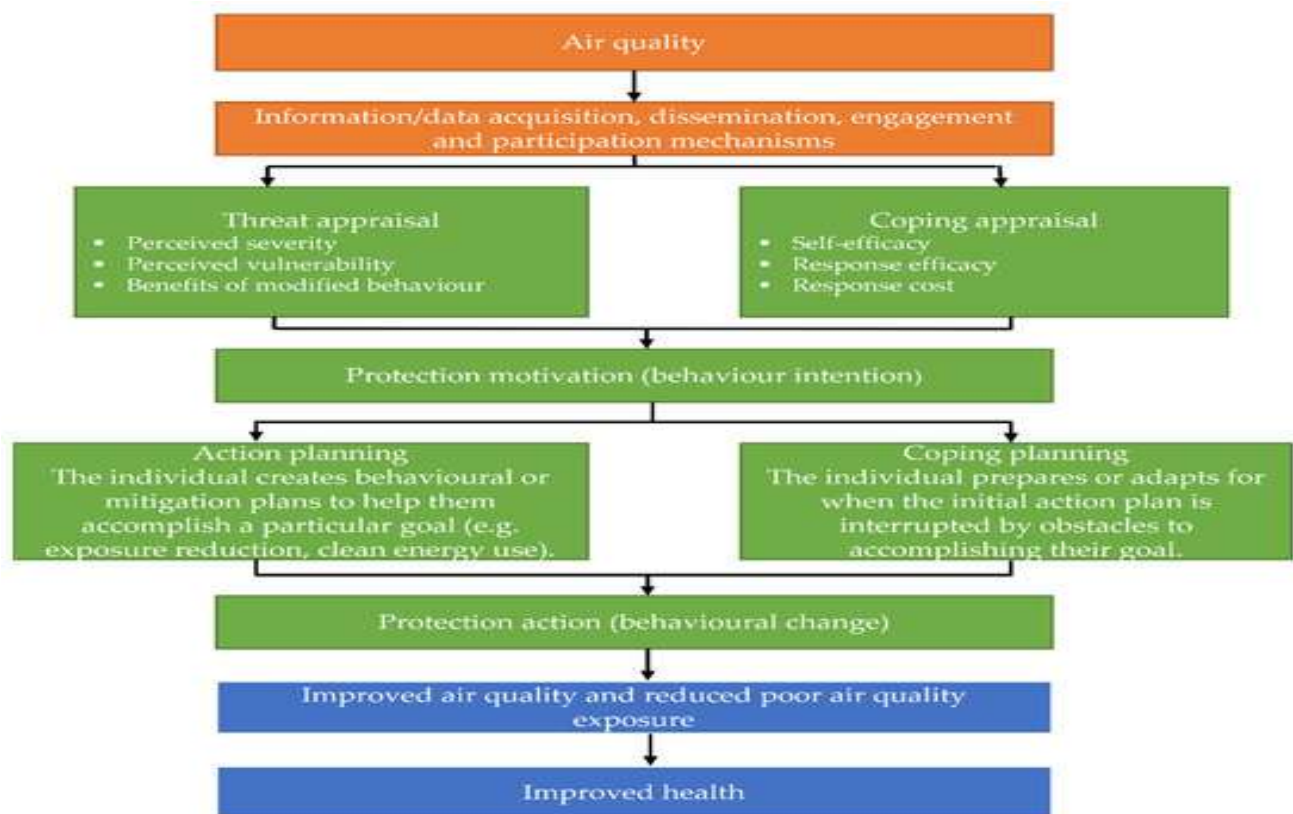


Figure 2. Conceptual mode of the hypothesized relationship between Air quality , individual actions and health.

Case Study: The Black Soot Crisis in Port Harcourt

- One of the most severe air pollution crises in Nigeria occurred in Port Harcourt, Rivers State, where residents have been experiencing persistent black soot pollution.
- The "Black Soot" phenomenon, first observed in 2016, is caused by illegal oil refining,

gas flaring, and industrial emissions (Ede et al., 2020).

- Studies show that the high PM_{2.5} concentration in Port Harcourt exceeds WHO safety limits by more than 10 times, increasing cases of cancer, lung diseases, and cardiovascular illnesses (Nnodim et al., 2021).
- Community reports indicate that clothing, rooftops, and water sources are often coated with black soot, making everyday living hazardous (Obioh et al., 2013).

3.2. Climate Change Effects in Nigeria

Nigeria is increasingly vulnerable to climate change, which has intensified environmental and socio-economic challenges across the country. Rising global temperatures, changing precipitation patterns, and extreme weather events have had severe consequences for agriculture, infrastructure, and human livelihoods. One of the most pressing issues is desertification, particularly in the northern region. Studies indicate that over 60% of Nigeria's landmass is affected by desertification, primarily due to rising temperatures, erratic rainfall, and unsustainable land-use practices (UNCCD, 2020). The Sahara Desert continues to expand southward, encroaching on fertile land and displacing rural communities (Oladipo, 2021). This process has led to declining agricultural productivity, food insecurity, and forced migration, as communities struggle to find habitable areas (Nwafor & Okereke, 2019). Poor irrigation methods and overgrazing further exacerbate land degradation, making it increasingly difficult for farmers to sustain crop and livestock production (Ibrahim et al., 2022). Coastal areas are also experiencing significant climate-related challenges. Rising sea levels threaten major cities like Lagos, Port Harcourt, and communities in the Niger Delta. Research suggests that sea levels along Nigeria's coastline are rising at an average rate of 3–5 mm per year, increasing the risk of coastal erosion, tidal surges, and saltwater intrusion into freshwater sources (Nwankwo & Amadi, 2020). The IPCC (2022) warns that continued sea-level rise could submerge up to 35% of Nigeria's coastline by the end of the century. This has serious implications for agriculture, fisheries, and human settlements, as saltwater intrusion reduces the fertility of farmlands and contaminates drinking water supplies (Ajibade et al., 2019). Communities in low-lying areas are already experiencing displacement, leading to increased migration to urban centers and heightened competition for resources (Okonkwo & Eze, 2020).

Unpredictable rainfall patterns have further complicated agricultural activities, making food production increasingly difficult. Nigeria's economy is heavily reliant on agriculture, and any disruption in rainfall patterns affects crop yields and food supply. In recent years, the Nigerian Meteorological Agency (NiMet, 2021) has reported significant shifts in the onset and cessation of the rainy season, causing confusion among farmers. Delayed rains, excessive downpours, and prolonged droughts have all contributed to reduced agricultural output and increased food prices (Ogbuabor & Egwuchukwu, 2020). The FAO (2022) estimates that climate change has already contributed to a 20% decline in Nigeria's annual crop production. Erratic weather conditions make farming less predictable, forcing many rural families to migrate in search of alternative livelihoods. The frequency and intensity of extreme weather events such as floods, droughts, and heatwaves have also risen sharply. Nigeria experienced one of its worst floods in 2022, which

affected over 3.2 million people, displaced more than 1.4 million, and caused at least 600 deaths (National Emergency Management Agency – NEMA, 2022). Flooding is particularly severe in urban areas like Lagos and Ibadan, where poor drainage systems and rapid urbanization have increased vulnerability (Adelekan, 2020). The overflow of the Niger and Benue rivers frequently submerges farms, homes, and infrastructure, resulting in widespread economic losses (Olanrewaju et al., 2021). At the same time, northern states such as Borno, Kano, and Jigawa face prolonged dry spells and worsening water scarcity. The shrinking of Lake Chad, which has lost over 90% of its surface area since the 1960s, has created resource conflicts, increased migration pressures, and contributed to regional instability (UNEP, 2020).

Rising temperatures also pose health and economic risks. Studies show that Nigeria's average temperature has risen by 1.1°C since 1960, with extreme heat conditions becoming more frequent (Odekunle et al., 2021). Heat stress affects energy consumption, as higher temperatures drive up demand for cooling, straining the national power grid (Ibitoye, 2022). In addition, prolonged exposure to extreme heat increases the risk of heatstroke, cardiovascular diseases, and respiratory illnesses, particularly among vulnerable populations such as children and the elderly (Ajayi et al., 2021). The socio-economic consequences of climate change are far-reaching, with agriculture, water resources, and public health all being significantly affected. Nigeria suffers an estimated \$9 billion in annual economic losses due to climate-related disasters, including damage to infrastructure, reduced agricultural productivity, and disruptions in trade (World Bank, 2022). Rising food prices, land degradation, and water scarcity have contributed to increasing poverty levels, as many families lose their primary sources of income (Nwafor & Okereke, 2019). Moreover, competition over dwindling natural resources has intensified conflicts between farmers and herders, particularly in the Middle Belt region (Abubakar, 2021). The environmental crisis in Lake Chad has further fueled insecurity, with extremist groups like Boko Haram exploiting the situation to recruit vulnerable individuals (UNEP, 2020).

Addressing these challenges requires a combination of adaptation and mitigation strategies. Expanding afforestation and reforestation efforts, particularly through initiatives like the Great Green Wall Project, could help combat desertification and restore degraded lands (Ibrahim et al., 2022). Strengthening flood control measures, enforcing zoning regulations, and investing in early warning systems are critical to reducing the impact of extreme weather events (Nwankwo & Amadi, 2020). Promoting climate-smart agriculture, such as drought-resistant crops and improved irrigation techniques, could enhance food security and resilience (Ayanlade et al., 2018). Additionally, transitioning to renewable energy sources, including solar and wind power, could help reduce Nigeria's dependence on fossil fuels and lower carbon emissions (Ibitoye, 2022). Finally, improving disaster preparedness through stronger institutional responses and community-based adaptation programs will be essential in building long-term resilience (Adelekan, 2020). Nigeria faces significant climate challenges that threaten its economy, environment, and public health. Without urgent intervention, these issues will continue to worsen, placing millions of lives at risk. Sustainable policies, increased investment in climate resilience, and international cooperation will be essential in addressing the long-term effects of climate

change in Nigeria.

4. Renewable Energy as a Sustainable Solution

4.1. Renewable Energy Potential in Nigeria

Nigeria has significant renewable energy potential, yet much of it remains underutilized despite the country's growing energy demand and persistent electricity shortages. With a population exceeding 200 million and an electrification rate of approximately 55%, millions of Nigerians lack access to reliable and affordable energy (World Bank, 2022). Transitioning to renewable energy sources could provide a sustainable solution to Nigeria's energy crisis while reducing greenhouse gas emissions and mitigating environmental degradation.

Solar energy stands out as Nigeria's most promising renewable energy resource, owing to the country's high levels of solar radiation, particularly in northern states such as Sokoto, Kano, and Maiduguri. These regions experience solar intensity reaching up to 7.0 kWh/m²/day, which is among the highest levels globally (Sambo, 2020). Nigeria's theoretical solar power potential is estimated at over 400,000 MW, far surpassing the nation's current installed electricity capacity (Shaaban & Petinrin, 2014). Despite this vast potential, solar energy contributes less than 2% to Nigeria's overall energy mix (Aliyu et al., 2018). While the cost of solar panels has decreased over the years, the high initial investment required for large-scale solar energy systems remains a significant barrier. The cost of solar panels, batteries, and associated infrastructure (e.g., inverters and mounting systems) is often prohibitive for both private individuals and businesses, limiting widespread adoption (Aliyu et al., 2018). For example, the cost of a solar home system in rural areas can be as high as 150,000 NGN (approximately 350 USD), which many Nigerians cannot afford upfront. The lack of robust grid infrastructure is a major hindrance to solar energy integration. Nigeria's power grid is characterized by frequent outages, voltage fluctuations, and transmission losses (Ogunmodimu & Okoroigwe, 2022). These infrastructure challenges limit the ability to effectively distribute solar power across the country. Furthermore, the country lacks a national solar power grid capable of efficiently storing excess energy generated during peak sunlight hours. Although solar energy has the potential to meet a significant portion of Nigeria's electricity demand, large-scale solar power projects have faced difficulties in attracting sufficient investment. The Nigerian solar sector has been slow to develop due to regulatory uncertainties, lack of financial incentives, and insufficient private sector participation (Aliyu et al., 2018). The country currently has only a handful of operational solar farms, and the total installed capacity is insufficient to meet the demand of millions of Nigerians lacking access to electricity.

Although the Nigerian government has implemented several initiatives aimed at boosting solar energy adoption, such as the Solar Power Naija Program, which targets the installation of 5 million solar home systems by 2030 (Rural Electrification Agency, 2021), challenges persist in policy implementation. A lack of clear regulations for the renewable energy sector and the absence of long-term policy commitments have deterred potential investors (Sambo, 2020). The Nigerian government, in collaboration with international organizations, has made strides in promoting solar energy as a sustainable solution. The Solar Power Naija Program, for instance,

aims to distribute solar home systems to underserved rural communities, offering a low-cost, decentralized solution to the energy crisis (Rural Electrification Agency, 2021). By providing subsidies, grants, and financing options, the government seeks to make solar energy more affordable for households and small businesses. Additionally, various private sector initiatives and partnerships are underway to support the growth of the solar market in Nigeria. The rise of solar power service providers, such as Lumos Global and Daystar Power, has helped address the financing challenge by offering pay-as-you-go models that reduce the burden of initial investment (GIZ, 2021). Such business models have gained popularity in rural areas where grid power is unreliable, and residents are eager to adopt affordable solar solutions. To foster the continued growth of the solar energy sector, Nigeria needs to prioritize strengthening its energy infrastructure, especially in terms of improving grid capacity and integrating energy storage systems. Additionally, further policy reforms and long-term strategies are necessary to attract both domestic and foreign investments in the solar energy market. By addressing these challenges, Nigeria can unlock the full potential of solar energy and provide clean, reliable power to millions of its citizens.

Wind energy presents a significant opportunity for Nigeria, particularly in the northern and coastal regions where wind speeds range from 3.5 to 7.5 m/s at a height of 10 meters above ground level (Fagbenle et al., 2011). States such as Katsina, Sokoto, and the Jos Plateau exhibit the highest wind energy potential, with wind speeds in these areas being strong enough for commercial power generation (Adebayo et al., 2019). The northern region, in particular, benefits from consistent wind patterns that could support large-scale wind energy projects. Despite its potential, wind energy development in Nigeria faces numerous barriers, which have slowed the implementation of wind power projects. The country's first grid-connected wind farm, the 10 MW Katsina Wind Farm, has been plagued by significant delays and operational hurdles since its initiation, illustrating the difficulties faced in harnessing wind energy (Olanrewaju et al., 2022). The primary issue preventing widespread wind energy adoption is Nigeria's outdated and inadequate electricity grid infrastructure. The existing grid system is not capable of efficiently integrating renewable energy sources like wind power, which require flexible grid systems to accommodate their variable nature (Ogunmodimu & Okoroigwe, 2022). Wind farms, which generate power intermittently, must be supported by advanced grid management systems and energy storage solutions, which Nigeria lacks at present.

The regulatory environment for wind energy in Nigeria is still evolving, and wind energy projects are often subject to bureaucratic delays and inconsistencies. Despite the government's recognition of renewable energy's importance, regulatory bottlenecks continue to hinder the development of wind projects (Adebayo et al., 2019). The lack of a comprehensive and stable policy framework for the renewable energy sector further discourages both local and foreign investment in wind energy. The technical requirements for wind energy development, such as the need for specialized turbines and maintenance expertise, present a challenge to Nigeria's current energy sector capacity (Olanrewaju et al., 2022). Additionally, wind farms require substantial upfront capital investment, and the high cost of wind energy infrastructure is a significant deterrent for many potential investors. While the potential for wind energy is clear,

the financial and technical barriers need to be addressed to facilitate large-scale wind energy projects.

Wind energy can diversify Nigeria's energy mix, reducing the country's reliance on oil and gas, which are subject to market volatility. This is especially critical given Nigeria's over-dependence on fossil fuels, which exposes the country to economic instability due to fluctuations in global oil prices (Shaaban & Petinrin, 2014). A key benefit of wind energy is its ability to replace diesel-powered generators, which are widely used in Nigeria for electricity generation, especially in off-grid areas. Diesel generators are not only expensive but also contribute to air pollution and greenhouse gas emissions. Wind energy, in contrast, provides a clean and cost-effective alternative that can significantly reduce the country's reliance on diesel (Adebayo et al., 2019). The development of wind energy infrastructure has the potential to create jobs, especially in rural areas where wind farms are likely to be located. These jobs would include turbine manufacturing, installation, and maintenance, which could contribute to local economic development (Olanrewaju et al., 2022). For Nigeria to unlock the full potential of wind energy, it must address these challenges by improving grid infrastructure, developing a more favorable policy environment, and attracting investment in both large-scale and small-scale wind projects. Successful implementation of wind energy projects would significantly contribute to Nigeria's goal of achieving a more diversified, sustainable, and economically stable energy future.

Hydropower remains a significant component of Nigeria's renewable energy sector, contributing about 20% of the nation's electricity supply (Nigerian Electricity Regulatory Commission, 2021). The country has major hydropower plants, including the Kainji, Jebba, and Shiroro dams, with a combined installed capacity of approximately 2,000 MW. However, Nigeria's total hydropower potential is estimated at 14,750 MW, indicating that much of it remains untapped (Olaniran & Emetere, 2020). Small and medium-scale hydropower projects offer a viable solution to energy access in rural areas, as they can be developed at lower costs and with minimal environmental impact compared to large-scale dams (Aliyu et al., 2017). Investments in mini-hydropower systems could improve electrification in off-grid communities and reduce dependence on unsustainable energy sources. Biomass and bioenergy also provide a viable renewable energy option, given Nigeria's vast agricultural and industrial waste resources. The country generates millions of tons of organic waste annually, including crop residues, animal dung, and municipal solid waste, which can be converted into biogas and biofuels for electricity generation (Akinbami et al., 2020). Studies estimate that Nigeria has a biomass energy potential of over 144 million tons per year, capable of generating about 2,000 MW of electricity (Sulaiman et al., 2021). Bioenergy projects, such as ethanol production from cassava and sugarcane, could provide clean alternatives to fossil fuels while promoting rural industrialization and job creation (Olugbemi & Diji, 2019). However, challenges such as inefficient waste management systems, technological constraints, and policy inconsistencies hinder the widespread adoption of bioenergy in Nigeria.

4.2. Benefits of Renewable Energy for Climate Change Mitigation

Despite its vast renewable energy potential, Nigeria faces several obstacles in transitioning to a sustainable energy future. Key barriers include inadequate financing, weak policy implementation, and insufficient technical capacity (Sambo, 2020). The lack of a stable regulatory framework has also deterred private sector investment in renewables, as investors face uncertainties regarding tariffs, grid access, and power purchase agreements (Adelaja et al., 2022). Strengthening the regulatory environment, providing incentives such as tax credits and subsidies, and fostering public-private partnerships could accelerate the deployment of renewable energy technologies in Nigeria.

Expanding renewable energy adoption is crucial for Nigeria's energy security, economic growth, and environmental sustainability. Investing in solar, wind, hydropower, and biomass technologies will not only enhance electricity access but also reduce the country's carbon footprint and dependence on fossil fuels. To achieve this, the government must prioritize infrastructure development, streamline regulatory processes, and encourage innovation in the renewable energy sector. By leveraging its abundant natural resources and implementing effective policies, Nigeria can transition to a cleaner, more sustainable energy system that benefits both the economy and the environment.

5. Sustainable Energy Governance and Policy Frameworks

5.1. Existing Energy Policies in Nigeria

Nigeria has implemented a range of policies and frameworks aimed at fostering sustainable energy governance, with a particular emphasis on renewable energy. One of the foundational documents in this regard is the National Energy Policy (NEP), which was first introduced in 2003. The NEP prioritizes the diversification of Nigeria's energy mix, highlighting the importance of integrating renewable energy sources, such as solar, wind, biomass, and hydropower, alongside traditional fossil fuels like oil and natural gas. The policy's goal is to ensure that Nigeria has a reliable, sustainable, and equitable energy system that can meet the growing demands of the population while also addressing environmental concerns related to fossil fuel dependence (Federal Ministry of Power, 2003). In line with these objectives, the Renewable Energy Master Plan (REMP) was developed by the Energy Commission of Nigeria (ECN). This plan, which was officially launched in 2005, aims to increase the contribution of renewable energy to the national energy grid, setting a target of 30% renewable energy generation by 2030. The REMP focuses on both large-scale renewable energy projects and decentralized, off-grid systems for rural electrification, especially in underserved areas. The implementation of REMP also includes the creation of the necessary infrastructure and regulatory frameworks to support renewable energy development (Energy Commission of Nigeria, 2016).

Moreover, Nigeria's commitment to addressing climate change is evident in its Nationally Determined Contributions (NDCs), which were submitted under the Paris Agreement. The NDCs

outline Nigeria's intention to reduce its greenhouse gas (GHG) emissions by 20% unconditionally and by 45% conditionally by 2030. These targets are contingent on international support, including financial assistance, technology transfer, and capacity building. Achieving these goals requires a significant transformation in the energy sector, particularly through the scaling up of renewable energy projects and improving energy efficiency across various industries (Federal Ministry of Environment, 2020). Through these policy initiatives, Nigeria is working towards a more sustainable energy future, balancing economic growth with environmental stewardship and global climate obligations.

5.2. Challenges to Renewable Energy Adoption

While Nigeria holds significant potential for renewable energy, several challenges hinder the widespread adoption of these technologies. One major obstacle is weak policy implementation. Although the country has established policies like the National Energy Policy and the Renewable Energy Master Plan (REMP), their effectiveness is often undermined by inadequate enforcement mechanisms. The lack of robust monitoring and accountability structures has led to slow progress in renewable energy deployment, as these policies are not always fully implemented or adhered to at both national and regional levels. As a result, the expected growth in renewable energy adoption remains limited despite the existence of well-intentioned frameworks (Federal Ministry of Power, 2003; Energy Commission of Nigeria, 2016).

Another significant barrier is financial constraints. The high initial capital costs associated with renewable energy infrastructure pose a substantial challenge. While renewable energy technologies, such as solar panels and wind turbines, have seen decreasing costs globally, the upfront investment required for large-scale projects in Nigeria remains prohibitively expensive. This is compounded by the limited access to financing for both public and private sector actors involved in renewable energy projects. Many potential investors are deterred by the perceived high risk of such ventures, particularly in a market where energy demand is not always stable and predictable (Energy Commission of Nigeria, 2016; International Renewable Energy Agency [IRENA], 2020).

In addition to financial challenges, infrastructure deficiencies further impede the integration of renewable energy into Nigeria's energy mix. The country's grid infrastructure is largely outdated and poorly equipped to handle the variable nature of renewable energy sources like wind and solar power. The limited grid connectivity in rural areas, where renewable energy could have the greatest impact, also complicates efforts to extend electricity access through decentralized renewable solutions. This gap in infrastructure means that even where renewable energy projects are feasible, their integration into the national grid system is often delayed or unfeasible (World Bank, 2020).

Lastly, regulatory uncertainty is a persistent issue. While Nigeria has developed renewable energy policies, the country continues to face inconsistencies in government policies, often influenced by changing political leadership and priorities. Bureaucratic delays and the lack of a coherent regulatory framework further exacerbate these challenges, creating an unstable

environment for investors and developers. The frequent changes in policy direction and the absence of a clear, long-term strategy for the energy sector discourage investment and complicate efforts to foster sustainable energy practices (Federal Ministry of Power, 2003; International Energy Agency [IEA], 2021).

5.3. Recommendations for Strengthening Energy Governance

To foster a more robust and sustainable energy governance framework in Nigeria, several key actions need to be taken to address existing barriers and accelerate the transition to renewable energy. These actions should focus on strengthening policy enforcement, enhancing financial support, and developing critical infrastructure.

1. Strengthen Policy Implementation

One of the most pressing needs in Nigeria's energy sector is the effective implementation of renewable energy policies. While the country has made strides in formulating ambitious policies like the National Energy Policy (NEP) and the Renewable Energy Master Plan (REMP), these frameworks have not been fully operationalized due to weak enforcement mechanisms. To enhance energy governance, Nigeria should prioritize the establishment of stronger regulatory frameworks that include monitoring and accountability systems to ensure that policies are implemented as intended. This could involve the creation of an independent body or agency dedicated to overseeing renewable energy projects, ensuring compliance with national standards, and holding relevant stakeholders accountable. This would also require revisiting and updating existing policies to address emerging challenges and ensure alignment with international best practices (Federal Ministry of Power, 2003; Energy Commission of Nigeria, 2016).

2. Increase Financial Incentives

The financial barriers to renewable energy adoption are a significant challenge for both investors and developers in Nigeria. High upfront capital costs, limited access to financing, and perceived risks discourage the necessary investments in the sector. To overcome these obstacles, Nigeria should introduce targeted financial incentives such as subsidies, tax credits, and low-interest loans for renewable energy investors. These incentives can help reduce the initial cost burden and make renewable energy projects more attractive to both domestic and international investors. Additionally, government-backed loan schemes or green bonds could be introduced to finance renewable energy initiatives. International partnerships and funding from climate finance mechanisms could further support these efforts, helping to bridge the financing gap for large-scale renewable projects (IRENA, 2020; World Bank, 2020).

3. Develop Infrastructure

A significant barrier to the widespread adoption of renewable energy in Nigeria is the lack of adequate infrastructure to support its integration into the national energy grid. Nigeria's electricity grid is outdated and unable to accommodate the variable nature of renewable energy sources like solar and wind. To strengthen energy governance, Nigeria must focus on expanding the national grid and modernizing its infrastructure to make it

more resilient, flexible, and capable of integrating renewable energy. This expansion should also include investments in energy storage systems, which can help smooth out the intermittency of renewable energy sources. Furthermore, off-grid renewable energy solutions—such as solar mini-grids and wind turbines—should be prioritized, especially for rural and underserved communities where grid connectivity is limited or non-existent. By investing in both grid and off-grid solutions, Nigeria can improve energy access, enhance energy security, and provide a foundation for sustainable development (World Bank, 2020; IEA, 2021).

These recommendations aim to create a more effective governance structure that supports the transition to a sustainable energy future in Nigeria. By strengthening policy enforcement, improving financial incentives, and developing the necessary infrastructure, Nigeria can overcome its current challenges and unlock the full potential of renewable energy to drive economic growth and mitigate climate change.

6. Environmental Policies for Climate Change Mitigation

6.1. Strengthening Environmental Regulations

To address climate change and reduce environmental degradation, Nigeria needs to reinforce its environmental regulations. This can be achieved by implementing stricter policies and measures that reduce greenhouse gas emissions, promote sustainable land use, and encourage the adoption of green technologies. Key areas where Nigeria can improve its environmental policies include emission control, gas flaring, and afforestation programs.

1. Implement Strict Emission Controls on Industries and Power Plants

One of the main contributors to Nigeria's carbon emissions is its industrial and power sectors, particularly oil refineries, gas plants, and thermal power stations. Nigeria should adopt stricter emission standards for these industries and power plants. Implementing mandatory emission reduction targets, backed by regular monitoring and penalties for non-compliance, would incentivize companies to adopt cleaner technologies. The introduction of policies such as a carbon tax or cap-and-trade system could also encourage industries to reduce their carbon footprints. Additionally, the government could promote the use of cleaner energy alternatives in industrial production by offering incentives for the adoption of renewable energy technologies. According to the International Energy Agency (IEA, 2021), such measures can lead to significant reductions in industrial emissions while boosting the green economy.

2. Ban Gas Flaring and Promote Carbon Capture Technologies

Gas flaring, the practice of burning off natural gas produced during oil extraction, is a major source of both carbon emissions and environmental pollution in Nigeria. The country has committed to eliminating gas flaring by 2030, yet enforcement of this goal has been weak. To strengthen environmental regulations, Nigeria should fully implement the ban on gas flaring by adopting strict monitoring mechanisms and enforcing penalties for violations. Additionally, promoting carbon capture and storage (CCS) technologies

could help mitigate the harmful effects of industrial emissions. CCS involves capturing carbon dioxide emissions from power plants and other industrial sources and storing them underground to prevent their release into the atmosphere. The Nigerian government should incentivize the development and deployment of CCS technologies through subsidies and tax breaks for companies investing in these solutions (World Bank, 2020).

3. Support Afforestation and Reforestation Programs to Absorb CO₂ Emissions

Nigeria's deforestation rate is one of the highest in the world, contributing to the loss of valuable carbon sinks and exacerbating the impacts of climate change. To mitigate the country's greenhouse gas emissions, Nigeria should significantly scale up its afforestation and reforestation programs. These initiatives focus on planting trees in degraded areas and restoring forests to absorb CO₂ emissions from the atmosphere. By supporting large-scale tree planting initiatives, Nigeria can enhance its capacity to capture and store carbon, improve biodiversity, and protect against soil erosion and flooding. In addition to government efforts, private-sector participation and community-based forestry programs can help boost the success of these initiatives (Food and Agriculture Organization [FAO], 2021). Furthermore, these programs should be integrated into the country's broader climate action plans and funded through domestic and international climate finance mechanisms.

6.2. Promoting Sustainable Urban Development

To mitigate the impacts of climate change and foster long-term sustainability, Nigerian cities must adopt strategies that reduce their environmental footprint while improving the quality of life for urban dwellers. These strategies should focus on energy-efficient designs, waste management, and clean energy solutions for transportation. Key actions to promote sustainable urban development in Nigeria include adopting green building codes, improving waste management, and developing efficient public transportation systems powered by clean energy.

1. Adopt Green Building Codes and Energy-Efficient Designs

One of the most effective ways to reduce the carbon footprint of cities is through the construction of energy-efficient buildings. Nigerian cities should adopt and enforce green building codes that require new buildings to meet specific environmental standards. These codes should prioritize the use of energy-efficient materials, renewable energy sources like solar panels, and designs that minimize the need for heating and cooling. Buildings should also incorporate energy-efficient lighting, water-saving technologies, and waste reduction systems to minimize their environmental impact. By ensuring that both residential and commercial buildings follow these codes, Nigerian cities can significantly reduce energy consumption and greenhouse gas emissions. Green building standards have been successfully implemented in many countries, and similar frameworks could be tailored to Nigeria's unique climate and urban development needs (UN-Habitat, 2020). Additionally, energy-efficient building designs can reduce utility costs for homeowners and businesses, contributing to economic savings in the long term.



Figure 3. Sustainable urban development—incorporating ten major global urban sustainability rankings/standards with different focal areas.

2. Improve Waste Management and Promote Recycling

Effective waste management is critical to promoting sustainability in urban areas. Nigerian cities face significant challenges in waste management, with large quantities of waste often ending up in landfills or being burned, releasing harmful pollutants into the atmosphere. To combat this, cities should develop comprehensive waste management strategies that focus on reducing waste generation, improving waste segregation, and increasing recycling rates. Policies should encourage businesses and households to separate organic waste, plastics, and other recyclables at the source. Municipalities should provide infrastructure for waste collection, sorting, and processing, and promote the establishment of recycling facilities to ensure that valuable materials are repurposed instead of discarded. Additionally, organic waste should be composted to create nutrient-rich soil for agriculture, reducing the need for chemical fertilizers. Several countries have successfully implemented national recycling programs, and these can be adapted to Nigeria's context (World Bank, 2020). A circular economy approach that promotes waste reduction and material reuse can contribute to reducing greenhouse gas emissions and conserving natural resources.

3. Develop Efficient Public Transportation Systems Powered by Clean Energy

Transportation is one of the largest contributors to urban air pollution and greenhouse gas emissions in many cities worldwide, including Nigeria. To reduce the environmental impact of urban transportation, Nigerian cities should develop efficient, affordable, and sustainable public

transportation systems that are powered by clean energy. These systems should prioritize electric buses, trains, and other forms of transportation that produce little to no emissions. Additionally, the development of dedicated lanes for bicycles and pedestrians can encourage people to opt for greener alternatives to car travel, reducing congestion and pollution. Policies should incentivize the adoption of electric vehicles (EVs) through subsidies, tax credits, and the development of charging infrastructure. Public transportation systems should also be designed for accessibility, ensuring that they are inclusive for people with disabilities, women, and other vulnerable groups. Cities like Addis Ababa and Cape Town have made strides in developing electric public transport networks, and Nigeria can draw on these experiences to build efficient, sustainable urban mobility systems (IEA, 2021).

6.3. Community Engagement and Awareness

Public participation is vital for the successful implementation of environmental policies, especially those related to renewable energy and climate change mitigation. To ensure the long-term sustainability of these initiatives, Nigeria must engage its citizens in meaningful ways. This can be achieved through education campaigns, behavioral change programs, and support for grassroots renewable energy projects. Key strategies to promote community engagement and awareness include educating citizens on the benefits of renewable energy, encouraging energy conservation practices, and supporting grassroots renewable energy initiatives.

1. Educating Citizens on the Benefits of Renewable Energy

One of the fundamental barriers to the adoption of renewable energy in Nigeria is the lack of awareness about its benefits, both for the environment and for personal and community well-being. To address this, the government and relevant stakeholders should prioritize public education campaigns that highlight the advantages of renewable energy, such as lower energy costs, reduced pollution, and enhanced energy security. These campaigns should target different segments of society, from schoolchildren to business owners, and should be delivered through various channels, including television, radio, social media, and community outreach programs. Educational programs should also focus on the technical aspects of renewable energy, providing practical information about the installation and maintenance of solar panels, wind turbines, and other green technologies. Research shows that public education initiatives can play a significant role in increasing the adoption of renewable energy and fostering public support for clean energy policies (IRENA, 2020). In Nigeria, such efforts can be tailored to local contexts, considering the diverse energy needs and challenges of rural and urban areas.

2. Encouraging Behavioral Changes, Such as Energy Conservation

In addition to increasing awareness of renewable energy, it is equally important to promote energy conservation practices that can help reduce the overall demand for fossil fuels and lower carbon emissions. Nigeria's rapidly growing population and expanding urbanization have led to higher energy consumption, particularly in urban areas where power outages and inefficiencies are common. To address this, citizens should be encouraged to adopt energy-saving behaviors,

such as turning off appliances when not in use, utilizing energy-efficient lighting, and reducing energy consumption during peak demand hours. Programs that incentivize households and businesses to use energy-efficient appliances and practices, such as offering rebates for energy-efficient lighting or providing smart meters to monitor energy usage, can also help reduce energy consumption. Behavioral change campaigns have proven effective in various countries, and Nigeria can benefit from such initiatives to complement its renewable energy strategies (UNEP, 2018). Moreover, fostering a culture of energy conservation helps to reduce energy poverty and ensures that available energy resources are used sustainably.

3. Supporting Grassroots Renewable Energy Initiatives

Grassroots initiatives are essential in expanding the adoption of renewable energy, particularly in rural areas where access to electricity is limited. Local communities are often best positioned to understand their unique energy needs and can play a significant role in designing and implementing energy solutions. Nigeria should provide support for community-led renewable energy projects by offering financial incentives, technical assistance, and access to training on renewable energy technologies. Community-based solar microgrids, biogas projects, and wind energy initiatives are examples of renewable energy solutions that can be implemented at the grassroots level. These projects can provide off-grid electricity to remote communities, improve livelihoods, and contribute to climate change mitigation efforts. Additionally, local renewable energy cooperatives can be established to manage these projects and ensure their sustainability. Successful grassroots renewable energy initiatives in countries like India and Kenya provide valuable lessons for Nigeria in scaling up community-driven solutions (World Bank, 2020).

By educating citizens about renewable energy, encouraging energy conservation, and supporting grassroots renewable energy projects, Nigeria can build a strong foundation for a sustainable and inclusive energy future. These strategies not only foster public engagement but also contribute to the success of national climate goals by ensuring that citizens are active participants in the transition to renewable energy.

7. Summary of Findings

This paper has explored the critical role of renewable energy in addressing Nigeria's energy and climate challenges. The key findings include:

- **Energy Landscape and Challenges:** Nigeria's dependence on fossil fuels has led to significant environmental degradation, including air pollution, deforestation, and greenhouse gas emissions. Climate change effects are exacerbating these issues, leading to desertification, flooding, and unpredictable weather patterns that threaten agriculture and livelihoods.
- **Renewable Energy Potential:** Nigeria has abundant renewable energy resources, including solar, wind, hydro, and biomass, that remain largely untapped. These resources hold immense potential for addressing energy insecurity and reducing greenhouse gas emissions, offering a cleaner and more sustainable alternative to fossil fuels.

- **Existing Policy Frameworks:** Several policies have been introduced to promote renewable energy, including the National Energy Policy, the Renewable Energy Master Plan, and the country's Nationally Determined Contributions (NDCs). However, challenges such as weak policy implementation, financial constraints, and infrastructure deficiencies hinder their effectiveness.
- **Environmental Policies for Climate Change Mitigation:** Nigeria's environmental policies need reinforcement, particularly in enforcing stricter emission controls, banning gas flaring, and promoting carbon capture technologies. Sustainable urban development and community engagement are crucial for addressing climate change at the local level.
- **Recommendations for Strengthening Energy Governance:** To enhance the adoption of renewable energy, Nigeria must strengthen policy enforcement, provide financial incentives, develop infrastructure, and encourage public-private partnerships. Additionally, investing in research and development will help accelerate technological advancements in renewable energy.

8. Conclusion

Renewable energy presents a viable solution for sustainable energy governance and climate change mitigation in Nigeria. By implementing robust policies, strengthening infrastructure, and fostering public-private partnerships, Nigeria can transition to a low-carbon economy while enhancing energy security and environmental sustainability. A commitment to renewable energy adoption and effective environmental policies will not only combat climate change but also drive economic growth and improve the quality of life for Nigerians.

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