

Electrical Engineering Approaches to Achieving a Sustainable Environment in Nigeria: Problems and Prospects.

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Abstract- Nigeria, Africa's most populous country, faces a pressing environmental crisis characterized by energy poverty, pollution, and climate change. Environmental degradation and energy challenges pose serious threats to sustainable development in Nigeria. Environmental sustainability is a pressing global challenge due to increasing pollution, climate change, and resource depletion. Environment itself is the source of all the resources needed by an organization to accomplish its objectives. But its negligence has triggered environmental degradation and energy challenges which pose serious threats to sustainable development in Nigeria. Electrical engineering presents a viable pathway to achieving a sustainable environment and offers promising solutions to these challenges through innovations in renewable energy, smart grid technologies, energy efficiency, and waste-to-energy systems. This paper examines the environmental problems facing Nigeria, evaluates the role of electrical engineering in addressing them, and explores the challenges and prospects of implementing sustainable engineering solutions. By analyzing the current challenges to implementation and highlighting the prospects and opportunities, the paper provides practical recommendations to harness electrical engineering for sustainable development in Nigeria. Together, these innovations can significantly reduce environmental footprints, promote cleaner energy usage, and enhance resource management toward a sustainable future.

I. INTRODUCTION

Sustainable development is at the forefront of global discourse, and has become imperative for nations worldwide, especially in developing nations like Nigeria where energy access and environmental preservation remain critical issues. As the backbone of modern technological development, electrical engineering holds the key to mitigating environmental degradation while fostering socio-economic growth. The discipline offers innovative

approaches in power generation, distribution, automation, and control- contributing directly to the pursuit of environmental sustainability. The increasing human demand for energy and resources has led to widespread environmental degradation, threatening ecosystems and human health. Fossil fuel consumption is the primary driver of greenhouse gas emissions contributing to global warming. Unsustainable waste management and transportation systems further exacerbate environmental problems. In response, technological innovations are critical to transitioning toward sustainability. This paper presents a detailed analysis of the environmental challenges in Nigeria and explores electrical engineering approaches as both a problem-solving and developmental tool to address environmental challenges and enhance sustainability through efficient resource utilization, pollution reduction, and ecosystem protection.

Nigeria potential for environmental sustainability and sustainable development remains unfulfilled and its future is being hampered by environmental degradation and deteriorating economic conditions. This transpires when nature's resources are being consumed faster than nature can replenish them, when pollution results in irreparable damage inflicted on the environment, or when human beings destroy the ecosystem in the process of development. (Ugochukwu Ertel, & Schmidt, 2008). Environmental degradation occurs as a result of oil spillage, gas flares, oil exploration and exploitation etc. Oil spillage in Nigeria occurs because of sabotage, unsustainable extraction of natural resources, corrosion of pipes and storage tanks, recklessness during oil production operations and oil tankers incessant accidents. In Nigeria, fifty percent (50%) of

oil spills is due to corrosion, twenty eight percent (28%) to sabotage by restive youths and twenty one percent (21%) to oil production operations (DPR, 1999). One percent (1%) of oil spills emanate from engineering drills, inability to adequately control oil wells, incapacitation and inefficiency of machines, and carelessness in loading and unloading oil vessels (Nwilo and Badejo, 2005). Sabotage is perceived as one of the major causes of oil spillage in Nigeria. This is because inhabitants of oil producing states in Nigeria like Niger Delta region have been allegedly accused of being instrumental in causing oil spillages through their nefarious and precarious activities such as damaging of the oil pipelines. Nigeria as one of the largest oil producing countries in the world has really felt the impacts of environmental degradation since the inception of oil in 1954 at Oloibiri in Niger-Delta. Naturally, the extraction of oil has its negative impact on the environment. The exploration and exploitation of oil have caused a lot of havoc because farmlands, fishes, food production are severely affected as a result of oil spills and gas flares which are not economically viable, sustainable, healthy and palatable to humans.

Oil spillage and gas flares have been a source of nuisance to our environment. In the same vein, modern mining operations have been disastrous. Gas flaring in Nigeria has significantly contributed to more greenhouse gas emissions than all other sources in Sub-Saharan Africa put together. The UNDP/World Bank figure of 70 million tones of carbon dioxide would have made Nigeria the world's 42nd biggest emitter of carbon dioxide from fossil fuel and cement manufacture in 2000, ahead of Portugal, Switzerland, Sweden and Norway (WRI, 2007). Report indicated that the annual financial loss to Nigeria from gas flared in the Niger-Delta has been put at about \$2.5 billion. World Bank (2003). Also, World Bank (2005) suggests that gas flaring from just one part of the Niger-Delta (Bayelsa State) would likely cause 49 premature deaths, 4,960 respiratory illnesses among children, and 120 asthma attacks annually. Based on this backdrop, this study sets out to identify challenges militating against environmental sustainability in Nigeria and also highlights the key strategies for achieving

environmental sustainability and development in Nigeria.

II. CHALLENGES MILITATING AGAINST ENVIRONMENTAL SUSTAINABILITY IN NIGERIA

2.1.1 Pollution and Environmental Degradation

It is explicitly obvious that modern mining operations have been very disastrous and destructive as far as our environment is concerned. This has manifested itself in the magnitude of environmental degradation we witness on daily basis in Nigeria. The removal of a non-renewable energy resource such as crude oil usually causes some environmental damage. For aboriginal (indigenous) people the effect on native fauna and flora on which the subsistence component of their economy hinges on, are of concern (Ebeku, 2005). The extraction of oil is bound to have some negative impacts on the environment especially in the Niger-Delta and its environs. Many communities in the Niger Delta believe that local gas flares causes acidic rain which corrode the metal sheets used for roofing. The toxic substances which have been emitted in the flares for over 40 years, including benzene and particulates have exposed Niger Delta communities to health risks and property damage, in violation of their human rights. The flares affect their livelihood, destroy aquatic lives and expose them to an increased risk of premature deaths, noise pollution, child respiratory illness, asthma and cancer. Unregulated industrial emissions, open waste burning, and inefficient fuel combustion contribute to air and water pollution. Noise pollution from generators is another rising concern, especially in the urban areas.

2.1.2 Energy Poverty and Dependence on Fossil Fuels

Despite being rich in energy resources, Nigeria faces chronic electricity shortages. Over 85 million Nigerians live without grid electricity, leading to widespread use of petrol and diesel generators. This does not only limit economic productivity but also increases greenhouse gas emissions and environmental pollution. Nigeria's energy sector is plagued by low electricity access, with over 40% of the population lacking reliable grid connection.

Consequently, diesel and petrol generators are widely used, contributing significantly to carbon emissions and air pollution. The overreliance on fossil fuels not only endangers the environment but also strains household incomes due to high fuel costs.

2.1.3 Climate Change Vulnerability

Frequent droughts, floods and soil erosion are climate change symptoms that affect agriculture, housing and health. These are exacerbated by deforestation, poor land management, and carbon emissions from energy systems. Nigeria is increasingly vulnerable to climate change, experiencing rising temperatures, erratic rainfall, floods and desertification. These effects are intensified by unsustainable energy consumption, deforestation, and poor urban planning threatening agriculture, livelihoods and public health.

III. STRATEGIES FOR ACHIEVING SUSTAINABLE ENVIRONMENT IN NIGERIA

Sustainability is a feature of a dynamic system that maintains itself over time. Environmental sustainability refers to the long-term maintenance of valued environmental resources in an evolving human context. The best approach to define and measure sustainability in the environmental perspective is to focus on natural resource depletion and whether the current rates of resource use can be sustained into the distant future (Goldemberg, 2000). The over-arching importance of sustainable development is geared towards the improvement of the quality of life in all its ramifications, provided that environmentally sound policies are vigorously pursued and adhered to by society. The World Commission on Environment and Development (WCED, 1987) defines sustainable development as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Theoretically, the long-term result of environmental degradation would result in local environments that are no longer able to sustain human populations to any degree. Such degradation on a global scale would, if not addressed, mean extinction for humanity. In the short-term, environmental degradation leads to declining standards of living, the extinctions of large

numbers of species, health problems in the human population, conflicts, sometimes violent between groups fighting for a dwindling resource, water scarcity and many other major problems, all these are evident in the Niger Delta region of Nigeria. The issue of sustainable development in Nigeria is still far fetch, although most of the foundations have been laid by government for example: the formation of local Agenda 21 committees at the federal and state levels; inauguration of Environmental Action Plan at all levels of government; being a signatory to the Kyoto protocol and other international Treaties involved in environmental management; (Federal Environmental Protection Agency-FEPA) into a full fledged ministry (Federal Ministry of Environment-FMENV); introduction of poverty eradication programs; and the commitment of the government to investing in environmental management strategies. Nigeria will start reaping the dividends of sustainable development only when the above programs and strategies are fully implemented. The interdependencies of the economic, environmental, and social elements of our world require new ways of thinking critically and strategically about things and taking action that will truly create a future where human society and nature co-exist with mutual benefits, and where the suffering caused by natural resource abuse is eliminated. Sustainable development calls for improving the quality of life for all of the world's people without increasing the use of our natural resources beyond the Earth's carrying capacity.

3.2 Electrical Engineering Solutions for Environmental Sustainability

3.2.1 Renewable Energy Technologies:

Nigeria has vast untapped renewable resources. Solar photovoltaic systems can be deployed in rural and urban areas, while wind turbines are suitable for the coastal regions. Small hydroelectric and biomass energy systems offer additional options. Electrical engineers play a crucial role in system design, installation, and maintenance, ensuring efficiency and scalability. Renewable energy technologies harness natural resources such as solar, wind, hydro, biomass and geothermal for electricity and heat generation. Unlike fossil fuels, they emit little to no greenhouse gases. Solar photovoltaic panels, wind turbines and

mini-hydro systems are increasingly deployed globally. These technologies not only reduce carbon footprints but also promote energy security and rural electrification.

3.2.2 Energy Efficiency and Conservation

Electrical engineers contribute to designing energy-efficient systems, including LED lighting, efficient motors, HVAC systems, and smart energy management devices. Adoption of smart meters and energy audits also helps consumers monitor and reduce energy use. Implementing energy-efficient technologies is vital for reducing energy demand and lowering emissions. Electrical engineers develop smart appliances, LED lighting systems, and energy-efficient motors. Energy audits, conducted by engineers, help identify energy wastage and recommend corrective measures, leading to cost savings and environmental benefits.

3.2.3 Smart Grid and Modern Power Infrastructure

Smart grids enable real-time communication between supply and demand systems, improving energy distribution, reducing losses, and integrating distributed renewable energy. Electrical engineers design control systems, sensors, and data analytics frameworks for grid optimization. Smart grids incorporate digital communication, control systems, and automation to optimize electricity distribution and consumption. They enable real-time monitoring, reduce transmission losses, and facilitate integration of decentralized renewable energy sources. Electrical engineers design and implement these systems, contributing to a more resilient and adaptive power network.

3.2.4 Electric Vehicles and Sustainable Transportation

Transitioning to electric mobility can reduce urban pollution and fossil fuel dependence. Electrical engineers are involved in battery management systems, motor drives, and charging infrastructure essential for electric vehicles (EVs). The adoption of electric vehicles (EVs) can significantly reduce greenhouse gas emissions in Nigeria's transport sector. Electrical engineers design EV powertrains, charging infrastructure, and battery management systems. Encouraging the transition to EVs,

especially in public transport, can enhance air quality and reduce dependence on imported fuel.

3.2.5 Waste-to-Energy Technologies

Waste-to-energy (WTE) systems convert municipal, agricultural, and industrial waste into usable energy. Techniques like anaerobic digestion, incineration with energy recovery, and gasification offer dual benefits of waste management and energy generation. Electrical engineers contribute to the design, automation, and control of these systems, ensuring environmental compliance and efficiency. Technologies such as anaerobic digestion, gasification, and incineration with energy recovery transform organic and municipal waste into electricity and heat. Electrical engineers play a role in designing and automating these systems for efficiency and safety. Waste-to-energy technologies convert municipal solid waste, agricultural residues, and industrial waste into electricity, heat, or fuel through processes like incineration, anaerobic digestion, and gasification. These technologies reduce landfill use, mitigate methane emissions, and provide an alternative energy source. They also help in managing waste sustainably in urban and rural settings. Electrical and electronic instrumentation enables real-time monitoring of environmental parameters such as air quality, water purity, and emissions. Integration of IoT devices and AI algorithms enhances decision-making in environmental management.

3.2.6 Environmental Monitoring Systems

Electrical and electronic instrumentation enables real-time monitoring of environmental parameters such as air quality, water purity, and emissions. Integration of IoT devices and AI algorithms enhances decision-making in environmental management. Electrical engineering supports the deployment of instrumentation and sensors for real-time environmental monitoring. IoT-based systems can track air and water quality, noise levels, and emissions, aiding in data-driven decision-making. Such systems empower regulatory agencies to enforce standards and promote transparency.

IV. RECOMMENDATIONS

To harness the full potential of electrical engineering for a sustainable environment in Nigeria, the following actions are recommended.

- Government should encourage universities and institutions to develop indigenous sustainable technologies.
- Government should enforce energy efficiency standards, incentivize renewable projects and streamline regulatory processes.
- Electrical engineering education and technical training in renewable energy and smart systems should be promoted.
- There should be collaboration between government, private investors, and civil society in implementing green projects.
- Government should launch campaigns to educate the public on energy conservation and the benefits of clean technologies

4.2 CONCLUSION

Electrical engineering is central to achieving a sustainable environment and provides practical and scalable solutions to Nigeria's environmental challenges. Through strategic deployment of renewable energy systems, smart grid technologies, energy efficiency measures, and waste-to-energy solutions, Nigeria can address its pressing environmental challenges and transit toward a more sustainable and prosperous future while advancing economic development. However, success requires coordinated efforts among stakeholders, supportive policies, adequate funding, and investment in education and innovation. With the right approach, electrical engineering can play a transformative role in building a green and resilient nation and lead Nigeria toward a cleaner and more sustainable future.

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