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The Technical and Policy Challenges of Renewable and Sustainable Energy Transition in Nigeria

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Abstract - The idea of creating strong, efficient, and effective energy sectors in Nigeria without sacrificing current and future socio-environmental security is sometimes referred to as a sustainable energy transition. This is a novel and worthwhile initiative given its multi-faceted benefits. In this wise, several nations have worked remarkably hard to accomplish this crucial goal with limited success stories, mostly in the developing countries of the world. Nigeria, for instance, relies heavily on energy to achieve the Sustainable Development Goals (SDGs) by 2030, as predicted by the UN. Unfortunately, hydrocarbon is known to be the oxygen of the country's power supply. They, therefore, examine the factors impeding the country's shift to clean energy use. The paper's findings revealed that weak and old infrastructure servicing the energy sector of the country is to be blamed for the slow transition to clean energy. Furthermore, a lack of intentional and proactive policy directives in this regard was also implicated in the study.

Keywords: Nigeria, renewable energy, transition, policy and technical challenges
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I. INTRODUCTION

In all stages of the human environment, initiatives that support sustainable growth and development are essential to the planet's continuous existence [4]. As the expression goes, "Corporate spending is like a burden when one party has not," which is why the UN Program for Sustainable Development was established. The biggest challenge to the calm, just, and sustained coexistence of the globe, aside from uncontrollable natural events, is the variety of undirected human activity. A situation where many people live in extreme poverty while many have enough to throw away represents a glaring disparity in the concept of social equality. Therefore, sustainability may be summed up as making the most of what is accessible, such as the abundant natural and human resources found in states, thereby utilizing most of the expensive, such as socioeconomic and political disparities [5].

Accordingly, every action contributing to meeting existing requirements in every part of the world without endangering our planet's future is sufficiently characterized as sustainable development [6]. The UN objectives (SDGs) were developed by the aforementioned definitions. These 17 integrated goals were established in 2015 to improve human civilization by 2030 [7]. Even though these objectives are quite high and ambitious, achieving them depends heavily on the will to implement the required political will and sociocultural renaissances, which vary by location.

Similarly, the economic prosperity of any country is largely a function of its energy reserve and sustainability. The future availability of clean energy is central to the economic growth and prosperity of any country especially in this 21st century [8].

Energy is crucial to man's survival. It is the driving force that enables human activities to be carried out from everyday activities like cooking, transportation, lighting, communication and to more industrial activities like production, manufacturing, service delivery, etc. Energy is the backbone of productive activities in agriculture, mining, finance, etc. A lack thereof will lead to poverty and contribute to economic decline.

[9] opine that energy is the backbone of productive activities in agriculture, mining, finance, etc. A lack thereof will lead to poverty and contribute to economic decline. In today's world, most of the energy requirements are fulfilled by conventional energy, natural gas, and petroleum-based products. Since the Industrial Revolution that ushered the world into an era of the preponderance of fossil fuels as the major source(s) of energy in virtually all nations of the world, fossil fuels have been the major conduits for which production and manufacturing activities have been carried out in the world today [10], [11].

However, with the continuous increase in the population of citizens of various countries across the globe, the vast advancement of technology and modernization, the ever-increasing and volatile cost of fossil fuels internationally as well as the disastrous consequences of continued fossil fuel use on the environment, many countries in the international system are looking at branching out into renewable and sustainable sources of energy that would meet the increasing demand of energy in their countries as well as cleaner and more eco-friendly sources of energy to preserve their environment [12].

[13] contends that many countries of the world have indeed begun actively making use of renewable, sustainable, and cleaner sources of energy that will at the same time cater to their energy needs. One of the countries leading the transition from hydrocarbon to clean sources of power is Germany. According to [9], Germany is leading the globe with a clean power source usage of 12.74% of its sum-up power use. The European superpower aims at alternating its hydrocarbon with air and solar technology which has earned the support of the scientific committee as they believe every country must adopt it to prevent climate disasters all over the world. Germany has drastically reduced its coal use, seeing as between January to June 2019 Germany adopted more clean power sources to manufacture power/electricity than other means put together [14].

Comparatively, Sweden is another country that is dogged in its efforts toward transitioning from hydrocarbon to clean energy. In 2015, it came up with the lofty ambition of eliminating hydrocarbon from power production by 2040. Bringing it closer to home, Kenya is looking at using alternative renewable energy sources to power its future and thus reducing its dependence on expensive electricity imports. The United States of America, Morocco, China, Denmark, Uruguay, Scotland, Nicaragua, Costa Rica, Brazil, Spain, Italy, Turkey, Australia, and the United Kingdom are among some of the bandwagons of countries that are leading the charge for the use of renewable sources of energy within their respective countries and in the international system as a whole [15].

[16] notes that Nigeria can be described as the behemoth of energy in Africa (as can be said of most natural resources). It is the region’s top producer of oil and is directly responsible for two-thirds of the continent’s energy reserves alongside Libya and has overtaken Algeria to rank first in natural gas reserves with 625.6 trillion cubic feet to Algeria's 203 trillion cubic feet. [17]. There are many available energy resources available in Nigeria. Nigeria ranked the globe's eleventh-largest oil reserves at 36.9 million barrels.

Ironically, the country is rich in a plethora of clean energy assets, some of which are biomass, hydropower, wind, the sun, etc. This has prompted many scholars to look into the prospect of clean energy assets in the country. [18], in his analysis estimated solar energy's technical potential in the country with a 5% device conversion efficiency put at 15.0 x 10^5^ kJ (i.e., 15,210,000 joules) of yearly power use. This is equal to about 258.62 million barrels of oil annually which is even more than Nigeria's yearly hydrocarbon production. As of GW/h (Gigawatt hours), this will translate to about 4.2 x 10^5^ GW/h of electricity production annually, which is more than the recent annual electricity production of 8,751 GW/h [15]

The findings of [19], [20], and [21] respectively, have attested to the truism that the country is well endowed with the prospects of gathering wind for power manufacturing. Most importantly, in the northern states, mountainous areas of the central and eastern states as well as offshore areas where the wind is plentiful all year round. [22] has reported that the aggregate electricity reserves of Nigeria were projected to be about 8,824 MW with a yearly generation production prospect of over 36,000 GW/h. [23] has identified biofuel as a reliable form of renewable energy in Nigeria, stating "sugarcane, cassava, plant seed and waste materials being possible feedstocks for bioethanol and biodiesel production".

The reports above saliently point out the fact that in line with all these potentials and endowments, Nigeria should not be a nation that lacks electricity across all levels of the state. However, the reality could not be any different as Nigeria is constantly being faced with energy crises that have been a major contributor to the poverty rate of the country as well as its paralyzed industrial and commercial activities. The lack of electricity in many regions of the country has resulted in the constant use of backyard generators of different shapes and sizes that in no small way expose the health of people to carbon emissions [24].

Sources of renewable energy in Nigeria are wind, solar, hydroelectric, marine, geothermal, and biomass energy. Which are available in commercial quantity. Unfortunately, opportunities for these cost-effective and eco-friendly sources have not received deserved attention and have not even been fully explored by the Nigerian government. The overwhelming technical and policy hiccups standing the way against the full utilization of renewable energy and the economic potential it offers deserve scholarly attention, hence the need for this study.

II. STATEMENT OF THE PROBLEM

Climate change and its implications on global warming should be given more than enough reasons why renewable energy sources should be actively sought after. Biofuels for example have been cited to reduce greenhouse emissions by 78% [25]. Our planet is under serious threat of burning up as scientists have warned over the years, most governments of the world have been swift in their shifting from hydrocarbon to sustainable and clean energy sources and have found them to be indeed better than their counterparts [15]. Some of these countries include the U S and Germany which themselves have large reserves of fossil fuels. It is thereby concerning and appalling why Nigeria is not as proactive as these countries are! Could the aging and unreliable grid manifest in frequent national grid collapsing and lack of effective policy direction, hindering the ability to integrate intermittent renewables like solar and wind be the cause for an easy transition to renewable and sustainable energy resources in Nigeria?

III. LITERATURE REVIEW

The universe as it were is increasingly shifting to become a global community as its population grows and its daily energy requirements increase [26]. The prosperity, health, and social and economic growth of individuals are becoming more reliant on energy and associated services. Astonishingly, a large percentage of the world's population lacks access to hydropower, with another high percentage of the world's population living in rural areas. Therefore, it is anticipated that the percentage of village people who rely on the use of renewable and sustainable energy such as biomass will rise astronomically [27].

Due to the dominance of hydrocarbon during the last few decades, energy consumption has skyrocketed. The surge in (CO2) emissions on a global basis has generated problems. Considerable ozone layer depletion is one of the major problems over the years. If attempts are made to change the contemporary energy mechanisms, its disastrous impacts may still be mitigated [28]. Clean and sustainable energy sources have the prospect of significantly cutting the effects of hydrocarbon production, hence slowing ozone layer depletion. Shifting away from hydrocarbon sources and towards clean and sustainable ones such as bioenergy, direct solar energy, geothermal energy, hydropower, wind, and ocean energy (tide and wave) will help the world achieve sustainability in the long run [26].

IV. CHALLENGES OF ENERGY TRANSITION

The country is still the powerhouse of the continent in terms of population strength, among others. Nigeria also remains the largest on the continent in terms land mass, and share borders with some countries also in Africa.

With one of the strongest Gross Domestic Product (GDP) in Africa, Nigeria has some of the lowest purchasing power when it comes to international trade while being regarded as rather wealthy based on the amount of its total revenue and production output [30]. Nigeria's human development index (HDI), which ranks 157th out of 189 countries with a 2017 HDI value of 0.5320, clearly reflects the country's weak economy [31]. Due to its advantageous position and population, the future economic growth of Nigeria in Africa is bright and encouraging.

According to [32] and NERC [33], the Transmission Company of Nigeria estimates that the grid's current generating potential is 12,522 MW, making the poor state of the power sector the biggest obstacle to maximizing Nigeria's potential for sufficient socioeconomic growth. More so, as evidenced by the status of every production place now in operation, the nation's minimum daily available generation has remained below 4,000 MW due to a combination of inadequate servicing, insufficient operational management, and the erratic availability of primary fuels [34].

Given the enormous energy needs of the country, the 5,375MW national peak generation that was reported in February 2019 [35] is insufficient. According to this appalling state of the power sector, in a nation with a huge urban population, less than 50% of the population is supplied by the grid (86% urban and 41.1% rural), and just 4% of people have opportunity to use clean energy for domestic purposes [36]. With a projected annual small percentage of business growth rate and an urbanization rate of 3.8%, Nigeria's power demand, which is currently above 20,000 MW, is projected to increase in the coming years [37].

Production and transmission ability are woefully insufficient, and the electricity allocation and marketing channels are old and weak, making the country’s present power system unstable in both content and essence. Power losses, scheduled outages (load shedding), and forced outages (voltage collapses) are thus commonplace [8], [38]. According to [39] and the Advisory Power Team. [40], the minimum energy utility per person in Nigeria is 125 kWh, and during the last 31 years, there have been an estimated 23 system collapses on average [41], [42].

[43] explain the three instances of Investment Optimization Models for Large Solar PV Systems Incorporating Reliability Metrics that took into account the enhancement of voltage stability was examined for the current Nigerian national grid. The country’s present grid is determined to be extremely vulnerable to Voltage instability arising at a load demand of roughly 8000 MW, necessitating that average PV penetration be kept below 30% to ensure secure operation if sufficient grid augmentation has been guaranteed. The Federal Government started the process of partially privatizing power facilities and unbundling the power sector (decentralization) to improve the energy sector [44].

V. ATTAINING CLEAN ENERGY

To achieve the expected power model required to power the SDGs in Nigeria, huge capital and concerted effort are needed. However, even though the necessary financial support may be scarce or tied to prohibitive conditions, coordinated efforts at

both governmental and non-governmental levels can help foster energy sustainability in Nigeria. [45].

In addition to their financial might, industrialized countries' energy transition seems to be going smoothly because of their supportive legislative decisions, cost-effective and controlled business milieu, and enabling policy framework. Globally, the shift to sustainable energy and energy democratization is mostly driven by political considerations [46]. Following the environmental decarbonization and ozone layer depletion regulations, the amount of coal used to generate electricity in the U S has drastically decreased.

However, after carefully weighing the socioeconomic and political effects on the American economy in comparison to rival economies like China, Russia, Japan, etc., the United States recently withdrew from some energy international treaties. The renewed natural gas utilization policies are at the heart of their energy plan [47]. Making such a position in the face of divergent viewpoints from around the globe requires a strong political will. Nigeria and other countries in Africa can draw a lesson from this since it requires the deliberate actions of government leaders in the legislative, executive, and judicial branches to initiate sustained progress.

According to [6], the Indian model suggests that a socio-political campaign is necessary to ensure a feasible fairly inclusive, and balanced framework for government-owned, privately-owned, and community-owned energy systems is essential to facilitate a just and efficient energy transition, particularly in the remote regions of developing countries Establishing an investment climate that is profit- and benefit-oriented, with supportive laws and regulations that will advance clean eco-system and energy sustainability, is one method to do this. With no exorbitant financial or socio-political repercussions, these circumstances will readily draw investment in alternative energy sources from both domestic and international sources [48].

More so, Inconsistency is the primary issue with the deployment of VREs; talks about originality and dependability of the provided power are impacted by the degree of oscillations in both clean and renewable energy sources output, which are wildly uncertain. Only VRE innovation can be supported by an energy storage solution at a reduced level of installed capacity. Most tried-and-true storage technologies become too big and costly for comfort at any capacity higher than this. Large-scale VRE generation, particularly solar PV, that is properly conditioned and connected to the current grid infrastructure is therefore an appropriate strategy that has been implemented in both industrialized and some developing nations [49].

In addition to providing storage, the grid acts to bolster the impact of intermittent electricity failure. Planning for this approach can consider additional costs for grid enhancement and intermittency effects, given that developing countries' current grid networks are underdeveloped and vulnerable to voltage instability [50]. Comparatively speaking, this expense is lower than that of adding utility-scale storage facilities. All parties involved in the energy market are subject to externally imposed cost components that are determined by the degree of production fluctuation of VREs and their impact on grid stability and dependability [51].

Nigeria has only utilized roughly 17% of its power capacity and a minimal percentage of its small electricity capacity. When it comes to economy of scale, operation and maintenance, and returns on investment, hydropower is still one of the most dependable energy sources. Therefore, increasing funding for hydroelectric plants can be quite beneficial for attaining environmental and energy sustainability. Another option for utilizing the nation's rich hydro resources is to implement a pumped hydro energy storage system (PHESS) that utilizes a reversible pump turbine and a reservoir located at an elevated position, either a natural or man-made dam. When energy generation from renewable or non-renewable sources is inexpensive, the system stores excess energy by pumping water to the upper reservoir for later electricity generation. When the cost of energy production from existing generation facilities increases or their output falls short—such as during peak demand periods—the stored water can be released to generate electricity for the grid by reversing the pump-turbine operations.

Finding a suitable location and the initial investment/construction costs are the main obstacles to the deployment of both the PHESS and the traditional hydroelectric generating system. The PHESS facility can be built on high/elevated lands and at reliable locations, but sufficient topographical, water-related, and geographical samples and capturing of the affected areas of the nation must be completed. The PHESS now holds the largest proportion of large-scale energy storage systems worldwide because of its inexpensive operating cost Using the Australian Renewable Energy Agency’s (AREMI) GIS-based mapping platform, approximately 530,000 potential PHESS sites have been identified, offering a combined energy storage capacity of 22 million GWh. Currently, PHESS accounts for over 90% of the storage capacity supporting large-scale wind and solar energy integrations [52]. ."An initial site viability study for Nigeria identified several locations with PHESS capacities ranging between 2 GWh and 150 GWh."

[53] conclude that making the best use of the available energy resources is the goal of energy resource management. These accessible energy bearers are frequently disregarded, wasted, and contribute to environmental annoyances. The gas-to-grid model, which was covered in detail in the preceding section, is a dependable model for enhancing power. As previously said, Italy's success story and that of other industrialized nations serve as a model for attaining sustainable environment and energy goals.

It is important to consider various aspects of energy resource management, including the adoption of efficient waste-to-energy models for the disposal of agricultural and certain non-toxic organic wastes from residential and commercial sources. The University of Nigeria Nsukka has advanced this initiative through the establishment of a recently commissioned 100 kVA

refuse-derived fuel (RDF) gasification power plant on its main campus[54]. For a nation like Nigeria, this action encourages a credible accomplishment by all standards; additional initiatives are needed from all of the nation's energy research institutes as the country seeks effective pathways toward environmental and energy sustainability.

VI. CONCLUSION

Conclusion and Recommendation

The foundation for the safe and timely development of a comprehensive business milieu in the country and other nations in Africa is thought to be a sustainable approach to establishing an economical and environmentally friendly energy framework. Therefore, an empirical inventory of Nigeria's energy status has been conducted for this research from the perspective of available socio-environmental, technological, and political infrastructure as well as resource assessment. Some of the obstacles that the country's power sector has faced thus far in its efforts to shift from hydrocarbon usage to a renewable and clean energy source, and potential solutions to reduce these obstacles and reach sustained progress in a short time are explored. Nigeria may continue to rely on energy from hydrocarbon to generate power and transportation until the cost-effectiveness and dependability of sustainable sources and innovations are established, both in volume and effectiveness, even with the adoption of contemporary sustainable innovations. The paper examines, critically, the sufficiency and availability of sustainable and clean energy in Nigeria. Several socio-political and technical barriers to Nigeria's energy sector maturity drive have been examined, and important technological, socio-environmental, and economic measures to overcome these obstacles in Nigeria are covered. The successful experiences of other emerging countries across continents have yielded important lessons in the shape of policy recommendations and implementations. Research and energy project developments, particularly those about developing countries' efforts to transition to a sustainable energy source, can greatly benefit from this paper.

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