Assessment of Renewable Energy and its Role for Sustainable Development in Nigeria

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ABSTRACT

Energy diversification is a panacea for energy deficiency and an essential precursor for energy security and sustainability but has not received due attention in Nigeria. This study assessed renewable energy and its role for sustainable development, with a view to examining its renewable energy trends and providing strategic assessments for sustainable energy development. This is important because Nigeria has been battling energy deficiencies and its conventional energy sources pose high levels of risks to human health and the environment. To assess diversification index, the energy mix concentration index method (a modified version of the Herfindahl–Hirschman index) was used and the diversification trend (2000–2018) was examined using data from Our World in Data and Macro Trends, and compared to top African economies. Nigeria was one of the least diversified countries with an index of 0.74. Pearson's correlation was also used to test the relationship between Nigeria's gross domestic product and renewable energy transitions, and it showed no significant effect. The pattern of renewable energy trends in Nigeria reflects the multiple fuel-use hypothesis rather than the energy ladder and leapfrogging hypotheses. Policy makers in Nigeria should commit to increasing investments in renewable energy, create awareness and implement workable frameworks to facilitate energy diversification. This report highlights the need to pursue clean, renewable energy rather than dependence on harmful fossil fuels, in line with the attainment of the Nations' sustainable development goals.

Keywords: clean energy, energy mix, renewable energy, sustainable development goals,sustainable energy

INTRODUCTION

Energy has long shaped global geopolitics; determining great powers, alliances and outcomes of wars. Notably, every international order in modern history has been based on an energy resource. Today, the world is undergoing an historical energy transition, driven by increasingly strong decarbonization policies and quick low-carbon technology developments (Hafner and Tagliapietra, 2020).Energy is pivotal to sustainable development and it is essential to the social, economic and environmental development of every nation including livelihoods, access to water, agricultural productivity, health, population, education and gender-related issues (Umar and Abubakar, 2014). The fact that energy is required in every sector of the economy means that access to uninterrupted power supply is not only a key factor for building a robust economy but is a critical issue for all countries. Today, future economic growth crucially depends on the long availability of energy from sources that are affordable, accessible and environmentally friendly, which is the very essence of sustainable development goal 7 (SDG-7) (Oyedepo, 2013). The global quest for sustainable development has dramatically increased in our modern times and this raises the issues of sustainable economic development and growth.

The fast-growing human population of the world means energy will continue to be in demand and every nation will continue to strive to attain energy security. The human need for energy is growing beyond the carrying capacity range, which has increasingly led us into sourcing for energies that have polluted the atmosphere as a result of their greenhouse gas effects, which depletes the ozone layer. More so the conventional energy source, 'fossil fuel', is depletable and unsustainable hence, an alternative energy resource for energy security is necessary (Pandey, 2021). In light of this, Owusu and Asumadu-Sarkodie (2016) stated that there is a need for a paradigm shift from the conventional to an alternative source that is eco-friendly and sustainable, to keep the climate safe.

In sub-Saharan Africa, however,600 million people (IEA,2018) and, globally, over 1 billion (World Bank,2023)lack energy access. The International Energy Agency(2018) reports that although the overall electrification rate in sub-Saharan Africa has 'almost doubled since 2000, rising by 20% points to 43%' yet six people out of ten remain without electricity and have no promising prospects for improving their conditions any time soon. Considering that energy is the main enabler of economic development and an essential component of several sustainable development goals (SDGs), if universal energy access in sub-Saharan Africa continues to be a distant objective, a large partof the 2030 agenda for sustainable development will remain out of reach, depriving the region of the possibility to build a prosperous future. This is particularly problematic not just for the achievement of SDG-7, but also for the achievement of several other SDGs. Thus, guaranteeing energy access ought to be the priority of sub-Saharan countries, and the transition from fossil fuels to cleaner forms of energy should be a complementary priority (Pistelli, 2020).

To reverse the trend and ensure universal energy access, the IEA (2018),foresees that the growing electricity needs in sub-Saharan Africa will have to bemet by using a combination of domestic gas and renewable energy sources; reducing, as much as possible, the use of oil and coal in power generation. Also, the use of biomass will have to be substituted with improved biomass cookstoves and liquefied petroleum gas (LPG) as clean cooking options. The importance of energy in achieving sustainable development made it the heart of SDGs as expressed in goal 7 (Birol, 2018). In addition, renewable energy is said to be a viable energy source since the traditional energy source has impurities, which are unsafe for the planet. Through the SDG-7, renewable energy can be easily achieved since renewable energy technology has all the attributes to spawn economic development and improve environmental sustainability (Barmelgyet al., 2020). Ensuring access to renewable energy is therefore crucial to achieving the SDGs.

The role of energy in every sector of the economy in Nigeria is huge because it requires energy to create value for whatever goods it produces or services it provides, and this in turn is expected to improve standard of living and reduce poverty, especially in Nigeria where it is a vital tool for development (Shaaban and Petinrin, 2014). With a population of over 211 million people; out of which 50% live in rural settlements, and estimated population growth projected to hit 401 million by the end of 2050 (UNCT-Nigeria, 2022), the economic and environmental importance of renewable energy cannot be overemphasized.

In a bid to ensure that Nigeria is not left behind in the achievement of the SDGs, the Nigerian government has conceived, in its national development plan, the idea of leapfrogging the conventional path to energy development by shifting directly to renewables and this is starting to gain traction (African Energy,2019).Even though transformations of the energy structure determine energy transitions, the diversification of energy mixes per se has not been studied from a long-term comparative perspective, making use of concentration indicators. It is pertinent, therefore, that the government ensures that its citizens have access to renewable energy sources through the implementation of sustainable development goals by enabling development processes and promoting progress paths. Sadly, the situation of energy in Nigeria, over the years, has not improved even with the renewable energy projects and pledges over the decade. The backdrop of this does not portend well for the country. In this regard, there is a need not only to create awareness but to find the true situation of things in the renewable energy sector. To this end, this study seeks to assess Nigeria's performance metrics in renewable energy for sustainable development.

CONCEPTUAL FRAMEWORK

Nigeria is the most populous country in Africa but it is among the countries with the lowest electricity consumption per source (EI, 2023). Its electricity generation across the various available sources is not enough to cater to its growing power demands. Although Nigeria's annual investment in its energy sector over the years has been huge, this has not translated to energy security (EI, 2023). This challenge has contributed to the growing rise in demand for off-grid power sources (non-renewables) as most Nigerians depend on self-generating diesel plants, which impact negatively on the environment. It is noteworthy that less than 60% of Nigerians have access to electricity in 2020(US-EIA, 2023),and the gap between electricity demand and supply gets wider on a yearly basis as industrialization and population increase. Renewable energy, therefore, offers the opportunity to improve access to modern energy services for the poorest members of society, which is crucial to the achievement of the 17 SDGs. It is notable that access to affordable energy has been highlighted as one of the major ways of eradicating poverty in the local population (Akinwale et al., 2013).

A large percentage of Nigerians living in the rural areas have no access to electricity (US-EIA, 2023)and live below the poverty line. They cannot afford to self-generate power for their households. Despite the abundance of renewable energy resources in Nigeria, it still faces an energy crisis due to gross energy insufficiencies to meet the ever-growing demands. To date, the national energy supply in Nigeria is entirely dominated by fossil fuels while renewable energy resources are highly underutilized (PA-Nigeria, 2021).

The global call for energy transition to sustainable energy sources is bringing attention to and adoption of renewable energy, which presents a great opportunity for energy diversification for sustainable development. However, the presence of various energy sources and technologies to harness them alone does not engender energy diversification and transition (PA-Nigeria, 2021). Also, several theoretical assertions have been advanced in a bid to explain how renewable energy sources may be introduced into the energy mix for energy security. Among these theoretical perspectives are the energy-ladder hypothesis, fuel-stacking model and leapfrogging theory (Hosier and Dowd, 1987; Masera et al., 2000).

The energy-ladder hypothesis is premised on the concept that households tend to move to a more sophisticated fuel as their economic situations improve. Invariably, a country is likely to switch to a modern energy source as its wealth increases (Hosier and Dowd, 1987) while the fuel-stacking (multiple-fuel-use) model, also known as 'energy stacking', argues that switching to a cleaner energy is not linear as suggested by the energy-ladder hypothesis; instead, households tend to use multiple energy sources as their income increases without foregoing the inferior ones(Masera et al., 2000). Users are more disposed to this theory as they tend to benefit from the various energy sources in their energy mix, which reflects users' behavior as asserted by Harrington et al. (2020).

The leapfrogging theory, on the other hand, suggests that developing countries can expand their economies with available low-carbon energy technologies instead of following the pathway of the developed countries whose reliance on fossil fuel for economic growth is significant (Verbruggen et al., 2011). In addition, Mahfoud hand Mohamed (2014), state that there exists a strong line between energy consumption and a country's wealth. Conversely, the energy consumption of a country is proportional to its economic growth. However, according to the International Monetary Fund (IMF, 2021), Nigeria is the largest economy (GDP) in Africa, which invariably makes it the wealthiest in Africa but it has the lowest energy consumption. Henriques and Sharp (2016),however, differ with this opinion as they believe that a country with a lower amount of energy consumption tends to diversify faster than a country with a higher amount of energy consumption.

In all of these three theories, which are centered on various pathways for energy transition in order to attain energy security, the fuel-stacking model is said to be more influential as it engenders diversification. Consequently, this study, which is based on the fuel-stacking model, attempts to contribute to the body of evidence on the subject using Nigeria as a case study to test if gross domestic product (GDP) influences transition and diversification; relying on these models as illustrated in Figure 1, which shows the relationship between the models, GDP growth and sustainable development.

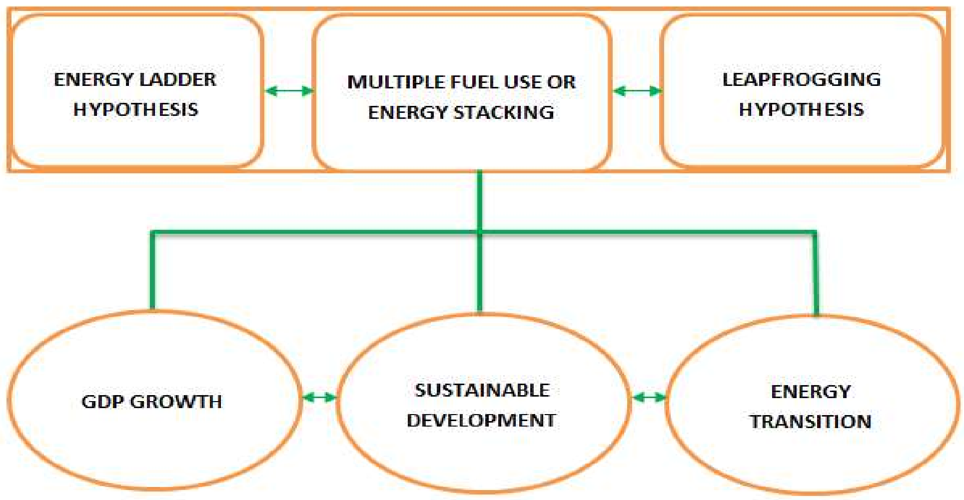


Figure 1: Relationship between gross domestic product (GDP) and energy transitions

DATA AND METHODS

Data Collection

This work used an exploratory research method to collect data from previously published statistical reports (secondary data) to analyze Nigeria's energy profile with emphasis on renewable energy performance, energy mix and GDP performance from 2000 to 2018. Data for the study was sourced from Our Worldin Data; a global energy data hub (OWD, 2023) and Macro Trends; a global financial website. Different categories of energy sources in the energy mix were identified using the Our World in Data database available for different countries.

A total of ten categories, namely: natural gas, coal, nuclear, hydro, fuel oil, gas/diesel oil, geothermal, wind, solar and biomass/waste, were identified. For each of these categories, data was collated from 2000 to 2018.

3.2 Data Analysis

A mixed approach involving qualitative and quantitative data analysis was used for the study.

To measure the level of energy diversity in Nigeria, some African countries were selected in order to carry out a comparative analysis using the Herfindahl-Hirschman Index (HHI) for energy mix concentration index (EMCI). The EMCI is a quantitative indicator of concentration of the energy mix based upon the HHI and focuses on the major energy sources in the energy systems. It is used to compare the evolution of the diversification (versus concentration) of energy mixes in the long-term in order to reveal the transformations of the energy structures, which determine energy transitions. It indicates how to aggregate energy carriers in the calculation of a quantitative index of concentration of the energy mix and compare alternative specifications (with or without pre-modern energy carriers)(Rubio-Var as and Muñoz-Delgado, 2019).The HHI is calculated by squaring the market share of each firm competing in a market and then summing the resulting numbers with a formula, according to equation (1):

$$HHI = 10000 \sum_{i=1}^{n} (ms_i)^2 \quad (1)$$

Where: ms_i is the market share percentage of firm i expressed as a whole number, not a decimal.
That is, it is measured by the sum of the squares of the market shares of each energy source in any given period.

Smaller values of the HHI indicate greater diversification, with 0 been the minimum concentration and 1 been the maximum concentration (in case the shares are expressed as fractions, where the aggregation of all the portions sum one i.e., 10% would be considered as 0.1) (Kander et al., 2014).

The EMCI, which is the adapted HHI, follows the same principles. It is measured by the sum of the squares of the market shares of each energy source in any given period, which corresponds to the formula in equation (2):

$$EMCI = 10000 \sum_{i=1}^{t} {p_i}^2 \quad (2)$$

Where t is the individual consumption output being compared, i is the total consumption output, p_i is the share of energy source i in the energy mix.

Lower EMCI values indicate greater diversification, where 0 is the minimum concentration and 1 is the maximum concentration. EMCI values of below 0.1 (or 1000) is unconcentrated, EMCI values of 0.1–1.8 (1000–18000) is moderately concentrated while EMCI values greater or above 1.8 (18000) is highly concentrated. Pearson correlation was used for testing the relationship between gross domestic product (GDP) and renewable energy transition.

RESULTS AND DISCUSSION

An exploratory research tool was used to gather preliminary data that helped define the problems within the framework of the suggested hypothesis. This approach involved the use of quantitative approach to collect data, which was then analyzed to get a clear understanding of the problem and help come up with possible solutions. The results are presented and discussed below.

The energy mix of Nigeria and the selected African countries comprise of a variety of conventional and modern energy sources; of which hydro, fuel and solar are the most common sources of electricity. Nuclear energy is uncommon in Africa and found only in South Africa. Consequently, South Africa has the highest number of energy sources in its energy mix, with Egypt, Algeria and Morocco having the same number of energy sources while Nigeria has the least energy source as shown in Figure 2.

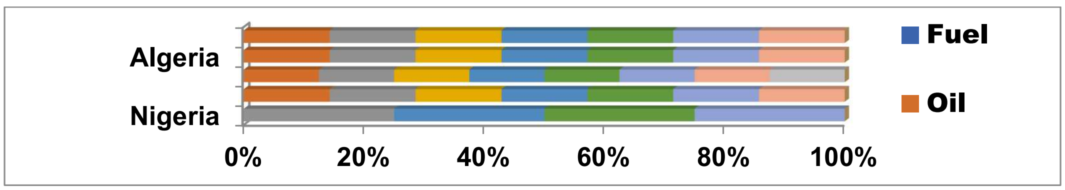
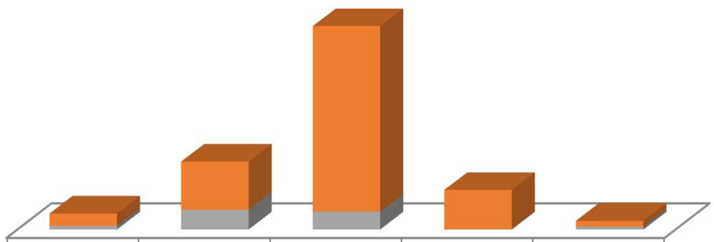


Figure 2:Energy mix in Nigeria and selected African countries.

InFigure2, Nigeria seems to have the lowest energy source utilizing only four sources while South Africa has the highest energy generation sources utilizing eight sources, and Egypt, Algeria and Morocco have seven energy sources, respectively, out of the ten energy resources available, namely: fuel, oil, gas, coal, hydro, solar, wind, biomass, nuclear and geothermal. Also, Figure 3 shows that other countries rank above Nigeria in terms of energy generation and share of renewable energy. These countries have a greater variety in their energy mix and also a higher renewable energy share than Nigeria despite its highest GDP. This implies that these countries have a higher energy mix than Nigeria.



	Nigeria	Egypt	South Africa	Algeria	Morocco
Fossil Fuel	296.6	1192.6	4555	971.7	141.7
Renewable	87.8	478.5	429.6	6.9	67.7

Figure 3:Share of renewable energy vs. fossil fuel.

Figure 4 shows the energy mix concentration index of Nigeria and selected African countries (Egypt, Algeria, South Africa and Morocco) between 2001 and 2018.

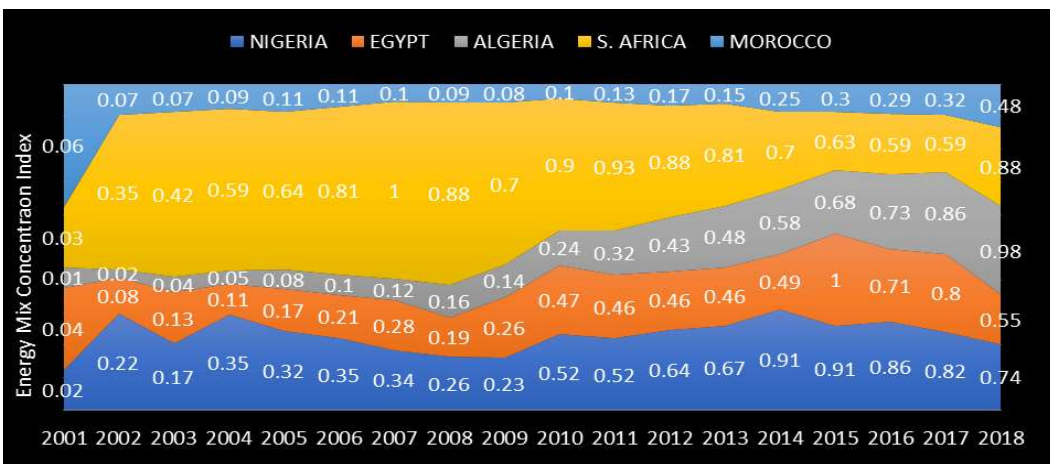


Figure 4:Energy Mix Concentration Index (EMCI), 2001–2018.

From the analysis in Figure 4, the result shows that energy diversification in Nigeria is insignificant and that wealth generation does not translate into diversification or adoption of modern energy as opined by the multiple-fuel model. Morocco ranks fifth and the lowest amongst the top African countries selected in terms of GDP but showed the most diversification, with the lowest concentration and an EMCI of 0.48. Egypt is the second most diversified in the EMCIs, with a diversity index of 0.55 while Nigeria, South Africa and Algeria were highly concentrated. This showed that Nigeria, South Africa and Algeria were overly dependent on one energy source and hence showed no balance in their EMCIs.

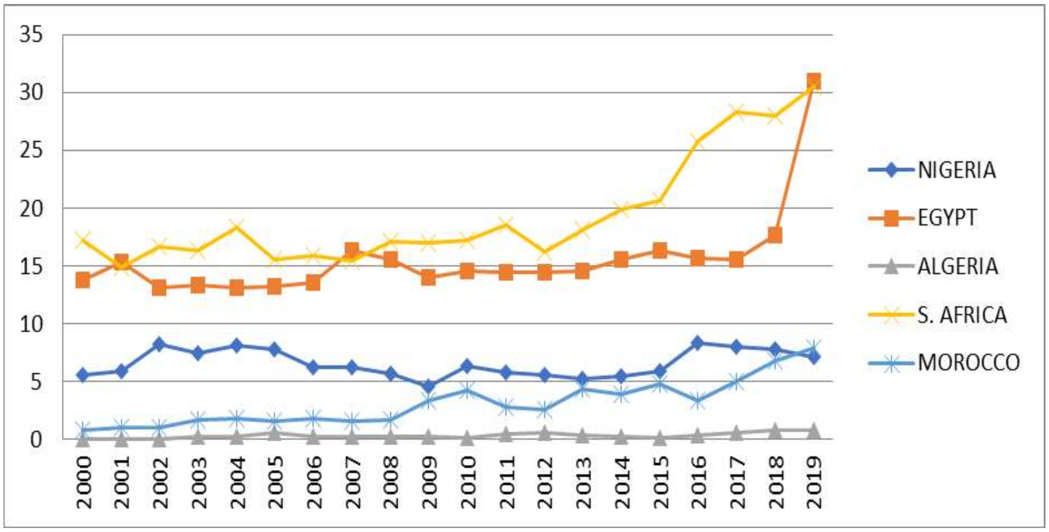


Figure 5: Renewable energy trends in selected African countries.

Renewable energy does not seem to be growing at a significant pace in Nigeria as the growth over two decades has not seen much difference. The transition patterns in Figure 5 show a big gap in energy security in Nigeria and there is no likelihood of achieving sustainable development by 2030. A country as big and populous as Nigeria should be able to boast of energy security, diversity and transition since these are essential drivers of sustainable development but none of these is currently happening in Nigeria. Figure 5 showed Nigeria's renewable energy performance to be below average with a downward trend while Morocco, the least amongst the selected African countries in terms of GDP, is heading upwards with a strong sign of adoption. Other countries in the study are far ahead of Nigeria in renewable energy transitions except Algeria. There are also no indications of improvement from observations of its renewable energy.

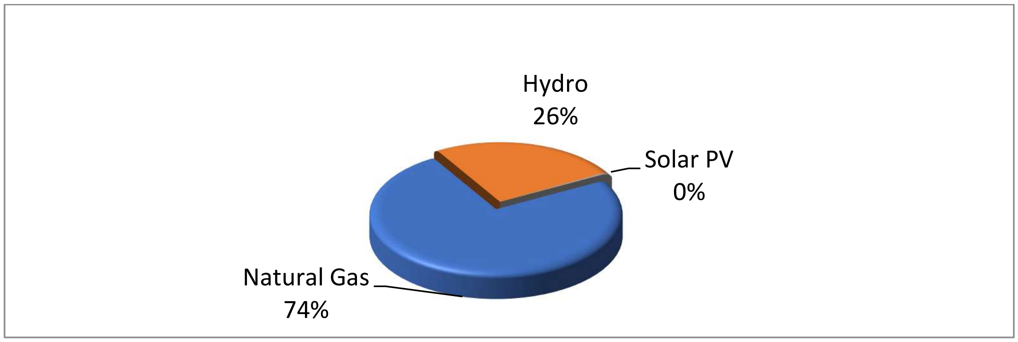


Figure 6: Total electricity generation by sources in Nigeria (2000–2021).

Fossil fuel continues to dominate Nigeria's energy sector; growing rapidly against renewable energy (Oyedepo, 2012). Even with the reliance on fossil fuel, Nigeria's total generating capacity is still far below sufficiency, and as such not capable of even sustaining half of its population. This is in spite of the huge sums appropriated for the energy sector over the last decade (Oyedepo, 2013).

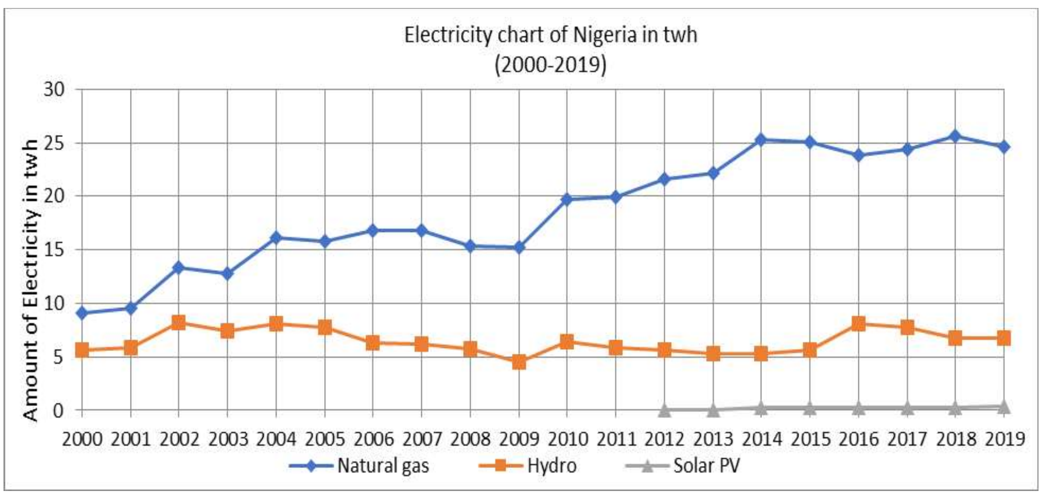


Figure 7: Nigeria's electricity performance chart (2000–2019)

Renewable energy in the Nigerian energy sector continues to record a disproportionate performance to the investments and attention it has received, over the years. It can be observed from Figure 7 that the fossil fuel source trend is clearly upwards and would continue to dominate its energy mix while the renewable energy source trend takes an undulating pattern with no growth in sight. This indicates that its dependence on fossil fuel sources would continue and natural gas will continue to take the largest energy proportion in its energy mix for years to come. We can also deduce from Figure7 that achieving sustainable development via renewable energy in the nearest future is impossible because the pattern does not project a positive trend.

More so, Nigeria's energy sources are small and limited, and the energy it produces is insufficient for half of its population (Oyedepo, 2012). With fossil fuel sources contributing over 80% of its energy generation and renewable energy contributing less than 20%, Nigeria's energy mix is not balanced and energy security will continue to be a challenge since the country depends majorly on one energy source with no other complementary source in the event of downtime (Adisianya, 2010). A country that intends to achieve sustainable development should have great variety and diversity in its energy mix, which is something Nigeria observably lacks. Various assertions have claimed that wealth influences the diversification or adoption of modern energy while others suggested that as one's wealth increases so does the likelihood of modern energy adoption into one's energy mix. This means that wealthy countries are more likely to transition to modern (renewable) energy than poor countries (IMF, 2021). This was tested to see if there was a correlation between Nigeria's GDP and transitions using Pearson's correlation. The correlation coefficient that indicates the strength of the relationship between two variables can be found using the following formula:

$$r_{xy} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2(y_i - \bar{y})^2}} \tag{3}$$

Where $\boldsymbol{r_{xy}}$ is the correlation coefficient of the linear relationship between the variables $\boldsymbol{x}$ and $\boldsymbol{y}$, $\boldsymbol{x_i}$ is the value of the $\boldsymbol{x}$-variable in a sample, $\boldsymbol{\bar{x}}$ is the mean of the values of the $\boldsymbol{x}$-variable, $\boldsymbol{y_i}$ is the value of the $\boldsymbol{y}$-variable in a sample, and $\boldsymbol{\bar{y}}$is the mean of the values of the $\boldsymbol{y}$-variable.

To determine if a correlation coefficient is statistically significant, the corresponding *t*-score and *p*-value was calculated. The formula to calculate the *t*-score of a correlation coefficient (*r*) is:

$$t = r\frac{\sqrt{n-2}}{\sqrt{(1-r^2)}} \tag{4}$$

Table 2: Correlation between Nigeria's GDP and EMCI (2001–2018)

YEAR	EMCI(x)	GDP (BILLION USD)	GDP (y)	a(Y- Ȳ)	b(X-X̄)	(a*b)	$(a)^2$	$(b)^2$	$(a)^2 * (b)^2$
2001	0.02	74,030,364,472	0.7	2.5	0.5	1.18	6.1	0.23	1.3939
2002	0.22	95,385,819,321	1.0	2.2	0.3	0.63	5.0	0.08	0.3955
2003	0.17	104,911,947,834	1.0	2.2	0.3	0.71	4.6	0.11	0.5038
2004	0.35	136,385,979,322	1.4	1.8	0.2	0.28	3.4	0.02	0.0759
2005	0.32	176,134,087,150	1.8	1.4	0.2	0.26	2.1	0.03	0.0671
2006	0.35	236,103,982,432	2.4	0.8	0.2	0.13	0.7	0.02	0.0158
2007	0.34	275,625,684,969	2.8	0.4	0.2	0.07	0.2	0.03	0.0050
2008	0.26	339,476,215,684	3.4	-0.2	0.2	-0.05	0.0	0.06	0.0022
2009	0.23	295,008,767,295	3.0	0.2	0.3	0.07	0.1	0.07	0.0046
2010	0.52	361,456,622,216	3.6	-0.4	0.0	0.01	0.2	0.00	0.0001
2011	0.52	404,993,594,134	4.0	-0.8	0.0	0.02	0.7	0.00	0.0003
2012	0.64	455,501,524,575	4.6	-1.4	-0.1	0.19	1.8	0.02	0.0360
2013	0.67	508,692,961,937	5.1	-1.9	-0.2	0.32	3.6	0.03	0.1029
2014	0.91	546,676,374,568	5.5	-2.3	-0.4	0.93	5.1	0.17	0.8637
2015	0.91	486,803,295,098	4.9	-1.7	-0.4	0.68	2.8	0.17	0.4677
2016	0.86	404,650,006,429	4.0	-0.8	-0.4	0.30	0.7	0.13	0.0929
2017	0.82	375,746,469,539	3.8	-0.6	-0.3	0.18	0.3	0.10	0.0318
2018	0.74	397,190,484,464	4.0	-0.8	-0.2	0.19	0.6	0.06	0.0343
						6.09	**38.0**	**1.33**	**50.3973**
							1443.88	**1.75907**	**7.0991**

Ȳ= 3.2, X̄=0.5

Table 3: Correlation Coefficient

	Pearson Correlation	Significance (Two-Tailed)
Nigeria	0.12	0.6

Correlation is significant at $\alpha = 0.05$ (2-tailed).

The coefficient indicates that Nigeria's GDP and EMCI have a correlation coefficient of 0.12 (Table 2), which falls between 0 and 1. This should indicate a low positive correlation but in the context of the energy mix concentration index, as stated earlier, GDP influence on EMCI can only exist if there is a perfect negative correlation. Table 3 shows that the influence of GDP over energy diversification to modern energy in Nigeria is statistically not significant because its significance value of 0.6 is greater than the significance level of 0.05. Nigeria's GDP growth does not improve its energy diversification and as a result of this, energy security will continue to be a lingering issue that will limit its economic growth.

CONCLUSION

The world's quest to achieve the United Nations' sustainable development goals is borne out of its desire to reduce/eliminate poverty, provide sustainability for all and keep the planet safe for future generations. Nigeria is a country that is blessed with abundant conventional and non-conventional energy resources but with untapped potentials, and the demand for electricity far outstripping supply. Hence, there is a need to focus on other sources of energy, such as renewable energy, which has huge advantages over conventional energy solutions. Its adoption will lead to internal reduction in fossil fuel consumption, support rural development, reduce pollution, climate change, improve standards of living, create more jobs and better the economy. Nigeria's transition patterns correspond to the multiple-fuel-use model that encourages the continuous usage and dependence on older energy sources while other modern fuel sources are added even when wealth generation increases than the energy-ladder and leapfrogging models that encourage absolute transitions to modern energy as the country's wealth generation increases.

Furthermore, there is an urgent need for capacity building, both at institutional and personnel levels, for acquiring technical, entrepreneurial, organizational and managerial skills. The federal, state and local governments should establish institutions with the mandate of training, developing, researching, sensitizing and regulating renewable energy adoption. They should ensure that stakeholders follow up on productivity in the renewable energy subsector and make necessary recommendations for modifications or/and improvements from time to time.

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