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Assessment of Diversity within the Nigeria Power Generation Technologies

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Abstract
The protracted imbalance and shortage in electricity supply in Nigeria has being adjudged to be multidimensional: ranging from generation to billing, due to inability to diversify our power generation technologies away from hydro and gas. Thus, this paper attempts to assess the extent of diversification of power generation technologies within the industry. Shannon Wiener diversity index was adapted to measures the extent of energy diversity among current and potential power generation technologies available to Nigeria. The result revealed an index value less than 1.5 indicating that the current energy mix has not been fully diversified, while the cumulative energy diversity indices estimated was 0.6, 1.3, 1.7 and 2.0 for year 2015, 2020, 2025, and 2030 respectively. It is expected that the introduction of other conventional and renewable resources into the mix will increase diversity and boost supply.

Keywords: Power Supply, Energy Diversity Indices, Shannon Diversity Index, Generation Technologies, Energy Resources

1.0 INTRODUCTION

Nigeria is endowed with abundant energy resources that are sufficient to meet her present and future developmental requirements. But the inability to diversify and expand her capacity to generate reliable and affordable electricity for her growing population is unimaginable, after decades of power sector reform. Due to these technological and policy limitations, other fossil and renewable resources are still poorly exploited and most of the power generation plants still depends on gas [1], leading to huge gap between the demand and supply of electricity.

The OECD/IEA in 2010, reported that most countries with fossil fuel resources will necessarily focus on using their available resources to satisfy their energy need and alleviating themselves from energy poverty [2]. However, the failure of Nigeria to put to optimum use her several energy resources has been accompanied with severe consequences. For instance, despite the abundant energy resources (renewable and non-renewable) at her disposal, electricity generations in Nigeria are dominated by thermal capacity and are majorly fueled by gas. These gas-dominated electric grid experienced frequent collapse largely due to inadequate gas supply and vandalization associated with resource control-linked militancy in the oil producing Niger Delta [3].

At present Nigeria only has about 12.5 GW of installed grid capacity, of which only 3500 – 5000 MW is available [4], which is by far less than the 31,240 MW current demands for electricity, which has been projected to hit 250,000 MW by 2030 [5]. This low power generation growth relative to the total installed generation capacity reflects the poor state [6], and dismal performance of electric utility in Nigeria.

The “curse of electricity” is apparently more vivid in the intractable black-outs and brown-outs and pervasive reliance on self-generated electricity that have battered the Nigerian economy in recent decades [2]. This is because the recent power sector reform has not been structured to address and facilitate the needed diversification of electricity generation. No wonder the nation have ended up with inappropriate energy infrastructure mix that could not satisfy the growing demand for energy [7].

While Nigeria presently requires a robust and strategic policy framework that is deliberately targeted at exploiting alternative energy technologies, which will guarantee her present and future energy needs and eliminate electricity poverty. The need for a paradigm shift

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from the old order of over dependence on electricity generation from gas and hydro, which have continuously proven to be insufficient to produce the required energy capacity for Nigeria to achieve desired energy security cannot be undermined [8].

It is from this vintage view point, that this studyinvestigates the extent of diversification in the Nigerian energy mix and its implications, to provide empirical evidence to support or refute the debate on diversification of energy sources. The remaining sections of this paper after this introduction examined the concept of energy diversity, application of Shannon Diversity Index to measure energy diversity, results and discussion.

2.0 THE CONCEPT OF ENERGY DIVERSITY

The concept of diversity has long been central to economics, as the basis for consumer choice and a prerequisite for competition [9]. In other fields of knowledge, a growing list of authors have defined diversity and investigated the various types, dimensions, determinants, importance and framework of diversity. However, the pursuit of deliberate diversification has nowhere been more prominent than in the field of energy policy [9], given the global challenge of climate change.

Diversity is an attribute of any system whose elements may be apportioned into categories [10]; it consists of three properties: a system, variety, balance and disparity [11]. However, diversity in the context of electricity production has been broadly defined as avoiding excessive reliance on any single technology, fuel or other factor [12].

The security of energy supply sometimes drives promotion of specific energy strategies [13], as energy planners strive to maximize the limited energy resource at their disposal. This is why in the energy sector; diversity is widely seen to provide greater strength in guarding against unforeseen events [14], by reducing the potential impact of interruptions in any single energy source and by providing additional options for its replacement [15].

Customarily, energy diversity means adding variety to a power system's fuel and technology mix in order to enable the system to withstand fuel price volatility, fuel supply or delivery disruptions, or technical disturbances on the system [16]. In other words, energy diversity is concerned with increasing dependence of the nation's generation mix from one or two technologies, as a more diverse system is perceived as having a number of benefits that make it preferable to one that is less diverse.

The primary justification for fuel diversification lies with the objective of reducing risk [17]. This is why diversity is considered to contribute to achieving energy security since disruption of any one source will have a smaller impact on overall energy supply [12]. Similarly, the effects of price volatility are likely to be mitigated where an increasing range of sources is employed in electricity production. Thus, energy diversity provides a form of insurance against price spikes and events that would threaten electricity service reliability.

Diversity in energy (fuel) type and geographic sources is thought to be an important means of hedge against supply risks and is used frequently as a key indicator to assess energy security [18, 19, 20, 21]. Diversity of energy system can enhance the energy efficiency and open up the channels for the cooperation of energy use [21]. As a diversified energy system, it is therefore considered to be more resilient and adaptable to cope with disturbances, supply disruption and price volatility [21 & 13].

There is increased awareness on the need to consider renewable energy in Nigeria, going by the low level of socio-economic development attained through the over reliance on fossil fuel [22]. But the perennial under investment in alternative energy sources to complement existing generation capacity remains a major impediment to diversification of Nigeria's energy mix.

3.0 METHODOLOGY

To measure the range of diversity among Nigeria power generating technologies, a long-term energy supply indicator the Shannon Diversity Index was used. The Shannon Wiener Index is a statistical tool developed by [23] and published in 1949 by Shannon and Warren Weaver. Diversity index originated from the field of information theory and it measures the order (or disorder) observed within a particular system. The index is popular and has been frequently used to measure diversity.

The Shannon–Wiener Index is usually given as:

$$\mathrm{H} = -\sum_{i} \mathrm{P}i \ln \mathrm{P}i$$

Where$\mathrm{P}i$represents the fractional share of electricity generation technology from the energy resources i in the mix.

From the above equation, the higher the value of the H' the more diverse the system is, and the index H' rises monotonically with increasing variety and balance. However, the typical index values are generally between 1.5 and 3.5 in most studies and are rarely greater than 4 [24]. For this analysis, we assumed that if all power generation came from the following fuel source gas, coal, nuclear, large and small hydro, solar PV, and wind, then the maximum diversity would reflect generation that is evenly spread across all seven energy sources in terms of variety and balance, with an approximately P_i of 0.117, which yields a diversity indicator value of 2.0.Conversely a minimum diversity indicates that all generation comes from one source and will yield a diversity indicator of 0.

3.1 Data Source

Secondary data was adopted for the analysis, based on the Federal Ministry of Power projected capacity data sets from 2014 -2030 for the following fuel technologies: gas, nuclear, coal, hydro (large and small), solar PV and wind.

The analysis expands upon the body of literature and focused on simplified perspective of key theoretical assumptions, and Microsoft excel was the major tool for data analysis.

4.0 RESULT AND DISCUSSION

4.1 Nigeria Energy Diversity Indicator

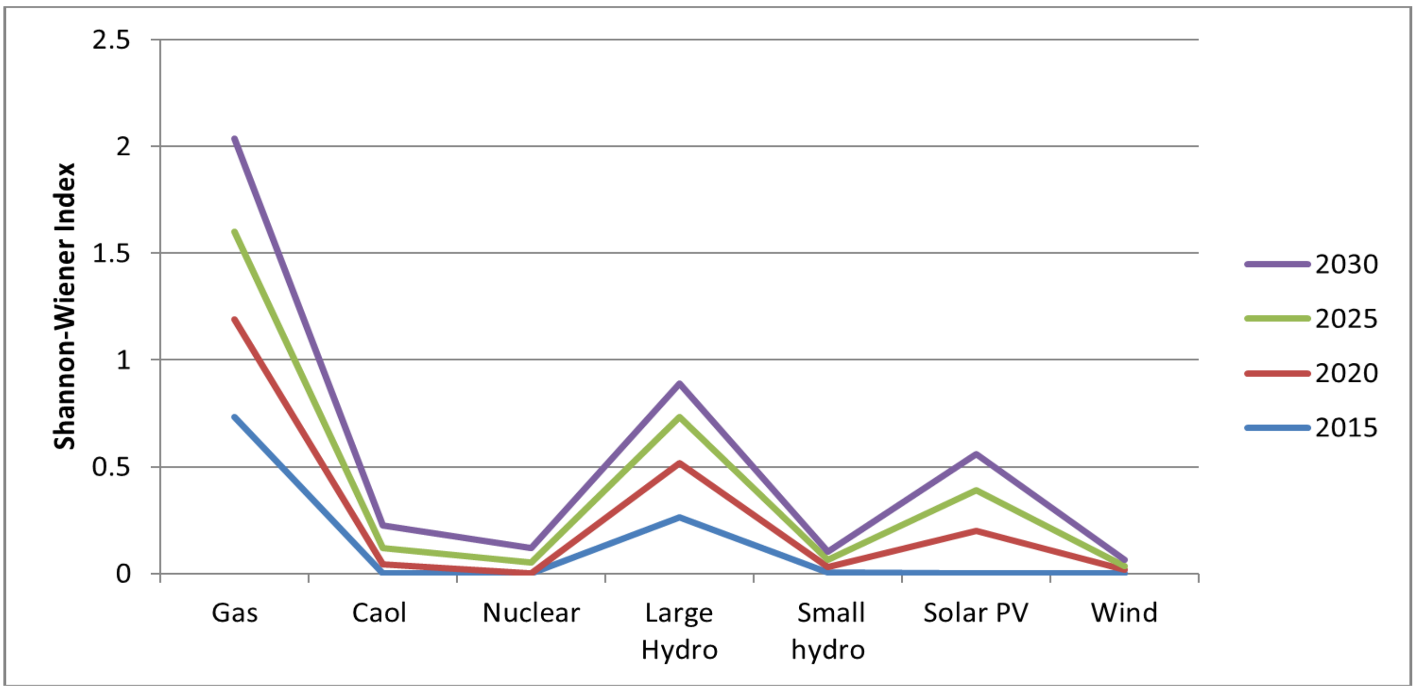

Figure 1: Shannon Wiener Index

Figure 4.1, shows that the Shannon-Wiener Index for 2015 scenario is less than 1.5, while the projected capacity for 2020 also assumed a value less than 1.5; indicating a system that is highly susceptible to frequent power supply interruptions or disturbances. But the projected capacity for 2025 indicated an element of partial diversification in the mix, by assuming a value greater than 1.5 but less than 2.0; which implies that supply security can be threatened by disruptions from one or more dominant fuel sources. Conversely, with an index above 2.2, the 2030 portfolio mix revealed a higher diversity, and depicts a system that can withstand the attendant risks threatening power supply security.

Table 4.1 presents the baseline diversity indicator for year 2015, 2020, 2025, and 2030, in addition to the percentage change in diversity indicator for individual fuel technology for the same period. Analysis estimated the cumulative energy diversity indices as 0.6, 1.3, 1.7 and 2.0 for year 2015, 2020, 2025, and 2030 respectively, thus implying that the energy portfolios between 2015 and 2020 are not sufficiently diversified.

The result from each fuel scenario analysis also shows that, as at 2015 energy fuel mix had not been fully diversified, with gas and large hydro resources having 73% and 26% shared in the mix respectively. From 2020 it is expected that the introduction of other conventional and renewable resources (such as coal power technology (46%), small hydro power (3%), solar PV (20%) and Wind power (2%)) will increase the number of technologies in the mix to six, thereby decreasing the share of gas in the mix from 73% to 46% while large hydro remains unchanged.

Table 1: Diversity Indicator and Changes under Different Fuel Technologies

Year	Baseline Shannon Diversity Index	Changes under Gas scenario	Changes under Coal scenario	Changes under Nuclear scenario	Changes under Large Hydro scenario	Changes under Small Hydro scenario	Changes under Solar PV scenario	Changes under Wind scenario
2015	0.60	0.73	0.00	0.00	0.26	0.00	0.00	0.00
2020	1.33	0.46	0.04	0.00	0.26	0.03	0.20	0.02
2025	1.56	0.41	0.08	0.05	0.22	0.03	0.19	0.02
2030	1.60	0.43	0.11	0.07	0.16	0.04	0.17	0.03

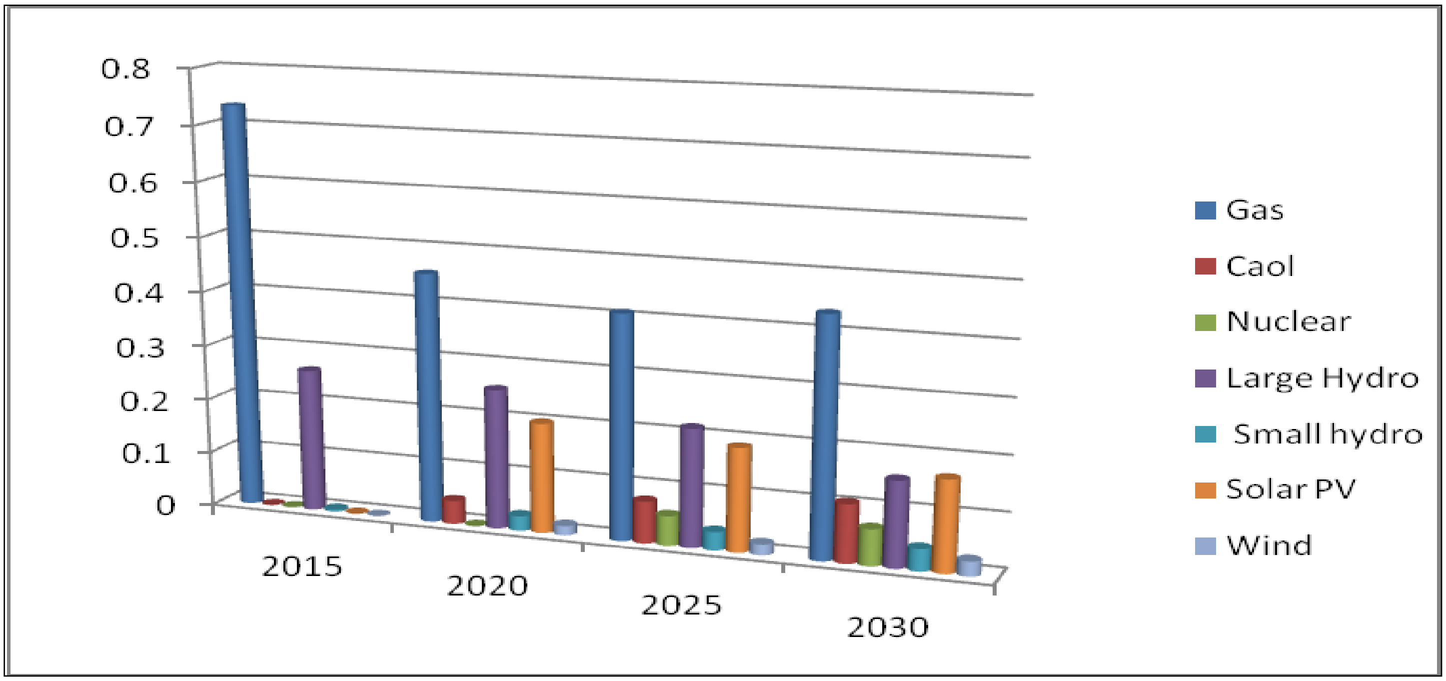

Figure 2: Projected Relative Change in Fuel Mix from 2015 -2030 Scenario

Similarly, the 2025 scenario analysis shows further diversification with the introduction of nuclear energy with 5% share into the mix. This further reduced the share of gas power to 41%, large hydro to 22% and solar PV to 19%, while the share of wind and small hydro power technologies remain constant at 2% and 3% respectively; and the share of coal power grew to 8%. By 2030 the scenario analysis revealed the highest level of diversification with increase in the share of gas powered technology (43%), coal power (11%), nuclear (7%), small hydro power (4%) and wind power (3%). The reduction in the share of large hydro (16%) and solar PV (17%) also revealed new changes in the already diverse system.

5.0 CONCLUSION

Statistical analysis apparently shows that Nigeria's current energy portfolio mix lacks diversity with a Shannon-Wiener Index less than 1.5, while the projected capacity for 2020 also indicated a similar trait by assuming a value less than 1.5; indicating a system that is highly susceptible to frequent supply interruptions.

Similarly, the projected capacity for 2025 indicated an element of partial diversification in the mix, assuming a value greater than 1.5 but less than 2.0. This implies that supply security can be threatened by disruptions from one or more dominant fuel sources.

Conversely, with an index above 2.2, the 2030 portfolio mix revealed a higher diversity, and can withstand the attendant risks threatening power supply security. This shows that going by the current projected power sector plan, Nigeria will have to wait until 2030 for an efficiently diversified energy system, despite the abundant energy resources at the country's disposal. Therefore, we recommend that the future planning and selection of energy resource should reflect an increase in the diversity of energy resource to ensure an efficiently diversified energy portfolio mix.

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