(online) = ISSN 2285 – 3642
ISSN-L = 2285 – 3642
Journal of Economic Development, Environment and People
Volume 9 , Issue 4, 2020

URL: http://jedep.spiruharet.ro
e-mail: office_jedep@spiruharet.ro

Towards Sustainable Power Supply and Consumption of an Emerging Economy (Nigeria)

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Abstract
Electricity supply offers significant and immense benefits to human society, and it is instrumental in driving economic growth, increased standard of living, and technological developments. Its sustainable supply and consumption is related to many ecological discussions, and thus, present emphasis on renewable sources, such as solar and hydro. In Nigeria, however, challenges associated with electricity generation, transmission, distribution, and consumption have not been adequately tackled. Poor electricity supply has adversely impacted the economy resulting in poor production, higher prices of goods and services, closure of industries, and loss of competitive advantage of Nigerian businesses. Conversely, energy-inefficient, and non-conservation consumption behavior of Nigerian electricity consumers contribute to the electricity demand - demand gap. Energy-efficiency and conservation is a sustainable tool for an efficient power system. The paper shows that the use of mostly post-paid and unmetered billing system is implicated in energy-inefficient consumption. The paper advocates for deployment of pre-paid meters to every electricity consumer; fiscal management, enforcement of energy-saving policies such as the use of compact fluorescent lamps (CFL); and emphasis on renewable energy (hydro and solar) sources, for electricity generation.

JEL Codes: *L9, L94, L98*

Keywords: Power Supply, Consumption, Sustainability, Energy-efficiency, Conservation, Nigeria

How to cite : OKAFOR, Chukwuebuka Chukwujindu et al. Toward Sustainable Power Supply and Consumption of an Emerging Economy (Nigeria). **Journal of Economic Development, Environment and People**, [S.l.], v. 9, n. 4, dec. 2020. ISSN 2285-3642. DOI : https://doi.org/10.26458/jedep.v9i4.674

1. Introduction

Nigeria's population is estimated at 201 million. From 2015 to 2030, it is expected to grow at 2.3 to 2.6% per annum[1]. Nigeria has great hydrocarbon resources. However, the electricity infrastructure is very poor. Per-capita electricity consumption of Nigeria (136KWh) is lower than that of her regional neighbors - Ghana (309KWh) and Ivory Coast (174KWh) [2]. Comparatively, South Africa, with a

(online) = ISSN 2285 – 3642
ISSN-L = 2285 – 3642
Journal of Economic Development, Environment and People
Volume 9 , Issue 3, 2020

URL: http://jedep.spiruharet.ro
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population of 45 million generates about 40,000 megawatts (MW), while Nigeria generates 3,000MW which is very poor [3]. Grid electricity consumption in Nigeria shows the following distribution – households (51.3 percent), commercial (26.7 percent) and industries (22 percent) [4]. A relationship exists between electricity consumption and economic growth. Thus, an insufficient supply of electricity significantly contributes to Nigeria's poor economic growth. Furthermore, a positive relationship between quality of life and energy consumption [5].

Sustainable (quality) electricity supply and consumption have beneficial economic, social, environmental, and well-being implications. Conversely, poor electricity supply has adverse implications. The relationship between electricity supply and economic growth has been established. The low productivity of Nigeria's SMEs and economic sectors has been attributed to poor electricity infrastructure and supply. In a single year (2009), more than 800 companies shut down operations and 83,000 jobs were lost because of the poor supply. The loss decreased the contribution of the manufacturing sector to GDP. The situation has continued over the years in the country [6]. The poor supply has also resulted in heavy dependence on self-generation by Nigerian residential, government, and manufacturing sectors. In 2005,

Nigeria accounted for 35% (US$152million) of $432.2million expended by African nations on the import of power generators [7]. For example, GBI Research reported that Nigeria imported power generators valued at $450million (71.55billion Naira at then ₦150/$1), in 2011. It was projected to reach 950.7million (₦332.7billion at a current exchange rate of ₦350/$1) by 2020 [8]. The following population of some Nigerian cities uses power generators - 66.6% of Benin, Edo State [9]; 73.2% of Ayingba, Kogi State [10]; 89.9% of Kaduna [11]; 84.9% of Port Harcourt [12]; 54% of Lagos and Osun States [13]; 78.6% of Ogbomosho, Oyo State [14]; and 72.9% of Nnewi North LGA, Anambra State [15]. Nationally, over 86% and 25% of Nigerian businesses and households, respectively have power generators [16]. In 2016, more than 6.7 million generators are owned by Nigerian households [17].

Critical sustainable tools, which have produced reliable energy supply and consumption in advanced countries are energy-efficiency and conservation. The two tools reduce the per-capita consumption of the available electricity supply and hence improves the situation of power supply. In Nigeria, the inefficient energy supply and consumption becomes critical considering that the country has a high yearly population growth rate (3.2%). The high population growth rate and poor funding of the electricity sector imply that the country will continue to experience the current stasis in the power sector. This poses a critical challenge to industrialization and economic development and the welfare of the people of the country [1, 5, 13].

This work, therefore, studied the current status of the Nigerian electricity industry, its critical challenges, the sustainable concept of energy efficiency and conservation, its importance to Nigeria's electricity supply and consumption, and finally discussed the way forward.

2.Status of Nigerian Electricity

In 1973, the National Electric Power Authority (NEPA) was established by the Supreme Military Council Decree No. 24 of 1972. NEPA was charged with the generation, transmission, and transmission of electricity in Nigeria [18]. In 2005, Nigeria's power industry reformation led to the re-naming of NEPA to Power Holding Company of Nigeria (PHCN). This was enabled by an act of parliament (Electric Power Sector Reform Act). PHCN was restructured and unbundled, into eighteen separate companies. Six are generation companies (GENCOs), one Transmission Company of Nigeria (TCN), and eleven distribution companies (DISCOs) [19]. The Nigerian electricity industry is networked (grid). The three arms of the Nigeria electricity industry operate at a defined Voltage (V) or Kilovolt (kV) level, and this is represented in Figure 1.

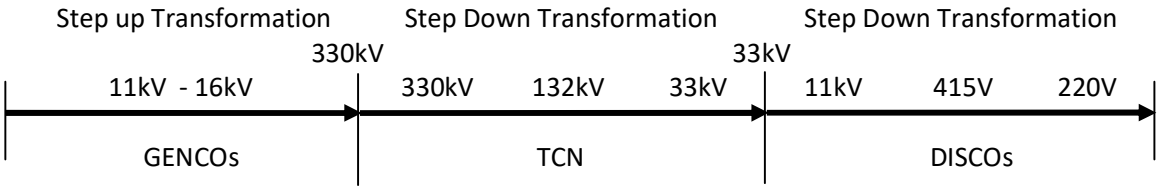

Figure 1: Voltage Levels of Nigeria Electricity Companies

For decades, Nigeria's electricity industry has been challenged with financial and investment deficiency. Other challenges include a shortage of gas supply to generating stations because of vandalization of pipelines; irregular supply of gas, variability in rainfall (for hydro-generating stations); obsolete equipment, poor maintenance, and breakdown of plants and equipment [20]. The system collapses because of over or under frequency (Nigeria uses 50Hz), frequent forced outages, and load management disrupt high voltage (HV) power transmission [21]. Gas supply constraints and overloading of power (HV) lines and transformers are major factors implicated in system collapse. It was projected that electricity demand by Nigerian households will increase between 2005 and 2020 [22]. However, the rate of development in the industry is very poor (45% electrification rate). It is considerably lower compared to many African nations. For example, the growth rate of Ghana and South Africa electricity network is 72% and 85%, respectively [23].

2.1 Electricity Generation and Transmission

Nigeria's electricity industry comprises the generation, transmission, and distribution. In Nigeria, electricity is generated at power stations in 11kV and 33kV. A Step-up transformer steps up these voltages to 330kV for onward transmission to different transmission stations (T/S). As of 2014, there are twenty-three electricity generating (power) stations operating in Nigeria. Their combined installed capacity is 12.5 gigawatts (GW). However, only about 3.9 gigawatts (Power Africa, 2015) of the installed capacity are available [23]. The power stations are mainly thermal, with installed capacity of 8.4gigawatts, while hydro generating stations (Kainji, Shiroro, and Jebba) have an installed capacity of approximately 5 gigawatts[24]**.** Disruption or unavailability of gas supply is one of the major problems of generation companies. For example, in December 2015 and the whole of 2016, 1.5GW and 3.7GW of generation capacities, respectively, were not available because of gas supply constraints. This is not an isolated incidence but a frequent occurrence in the Nigerian electricity generation sector. Furthermore, gas constraint is attributed to underinvestment in technology and infrastructures by Nigerian oil companies and governments [25]. Similarly, the total amount of gas flared in Nigeria annually (almost 80% of the associated gas) is equal to electricity generation capacity for the Sub – Sahara Africa region.

(online) = ISSN 2285 – 3642
ISSN-L = 2285 – 3642
Journal of Economic Development, Environment and People
Volume 9 , Issue 3, 2020

URL: http://jedep.spiruharet.ro
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The amount of gas flared per day is about 56,633m^3 [26], while the quantity of gas used by Nigerian generation companies in 2015 was 12,510,500,300m^3 [19].

At transmission stations, presently managed by Transmission Company of Nigeria (TCN), 330kV is stepped down to 132kV and 33kV and supplied to distribution companies (DISCOs), as shown by Figure 1 above. There are 159 transmission substations in Nigeria, in 2015 [20]. The purpose of transmitting in high voltages (330kV and 132kV) is to reduce losses due to distance. Thus, TCN wheels (transmits) bulk energy from generating stations to transmission substations, and then to distribution injection substations. Transmission lines are a network and traverse all the regions of Nigeria [27]. In 2014, the total transmission network of Nigeria was above 11,000km of high voltage lines; comprising 5000km of 330kV and 6000km of 132kV voltage lines. [28]. Presently, total transmission lines (330, 132 and 33kV) is 20,000km [29]. This shows a 45 percent increase in transmission lines between the periods. However, the Nigerian transmission and distribution sectors of the electricity industry are significantly limited by technical losses.

Between 2000 – 2011, Nigeria's electricity generation increased by 55%, from 14 to 27 billion kilowatt-hours (kWh). Yet, a considerable electricity supply-gap still exists. It is related to Nigeria's high population growth, and substantial technical losses in the transmission and distribution sector [30] as shown in Figure 2.

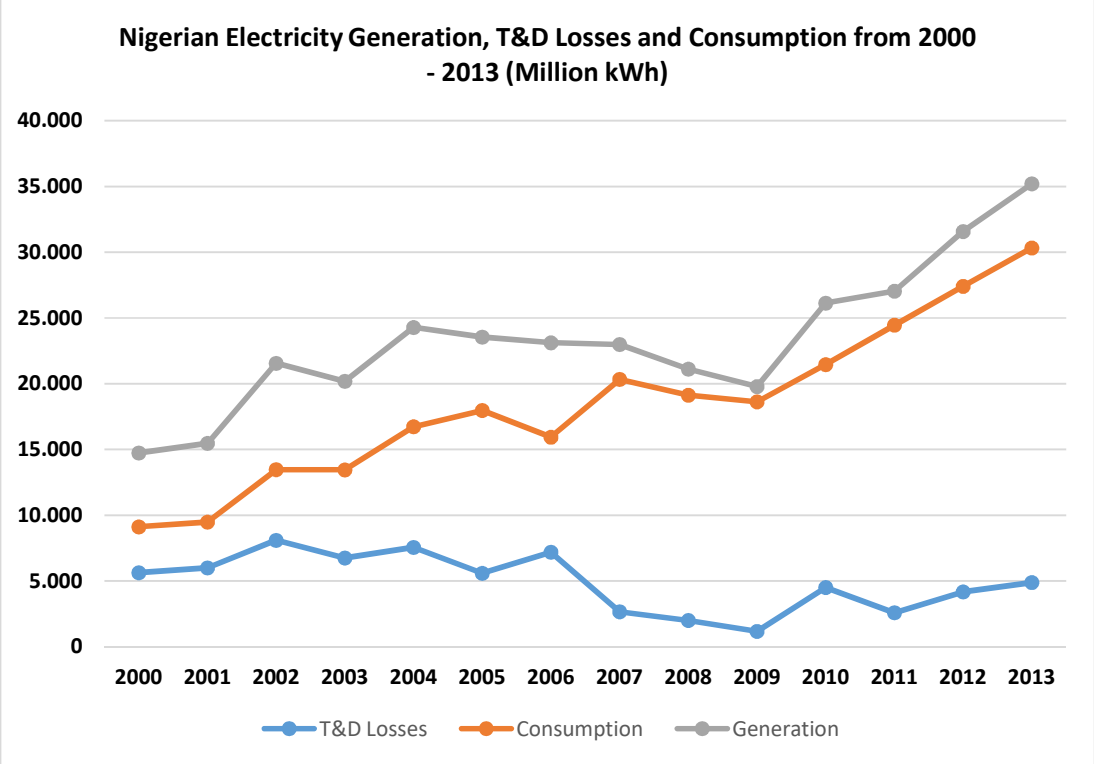

Figure 2: Nigerian Generation, T&D Losses and Consumption from 2000 – 2013
Source: Adapted from CBN (2015)[30]

Figure 2 above shows that as losses in transmission and distribution (T&D) lines decreases (2006 – 2009), consumption increases significantly. Consumption is equal to Generation less T&D losses. Therefore, a substantial reduction in T&D losses will increase the available supply for Nigerians to consume. Averagely, T&D losses over the 14 years was 22.8% of the total generated electricity. [23]. In Mega volt-ampere (MVA), the total capacities of transmission step-down transformers are 6,098MVA (for 330/132kV transformation) and 8,090MVA (132/33kV) [24, 28]. Presently, TCN has installed capacity to wheel 7.5GW; but available wheeling capacity to DISCOs is 5.3GW. This is significantly lower than the total installed capacities of the generating companies (GENCOs) (12.5GW). However, the available transmission capacity (5.3GW) exceeds the functional or available generation capacity of 3.9GW. The difference of 40.84% between the installed generation and transmission capacities, implies an infrastructural gap, which until closed, will keep affecting Nigeria's electricity supply [29]. This poor electricity infrastructure permeates the three sectors of the power industry, in Nigeria, and thus the poor and erratic supply of electricity to Nigerians will adversely impact its economic and industrial development [18]. Nigerian electrification rate increased steadily from 1990 to 1999, and decreased by 2.2% in year 2000. In 2016, Nigerian electrification rate increased by approximately 7% from 2015 level, to 59.3% [31]. The trend was seen throughout the period, as shown in Figure 3 below.

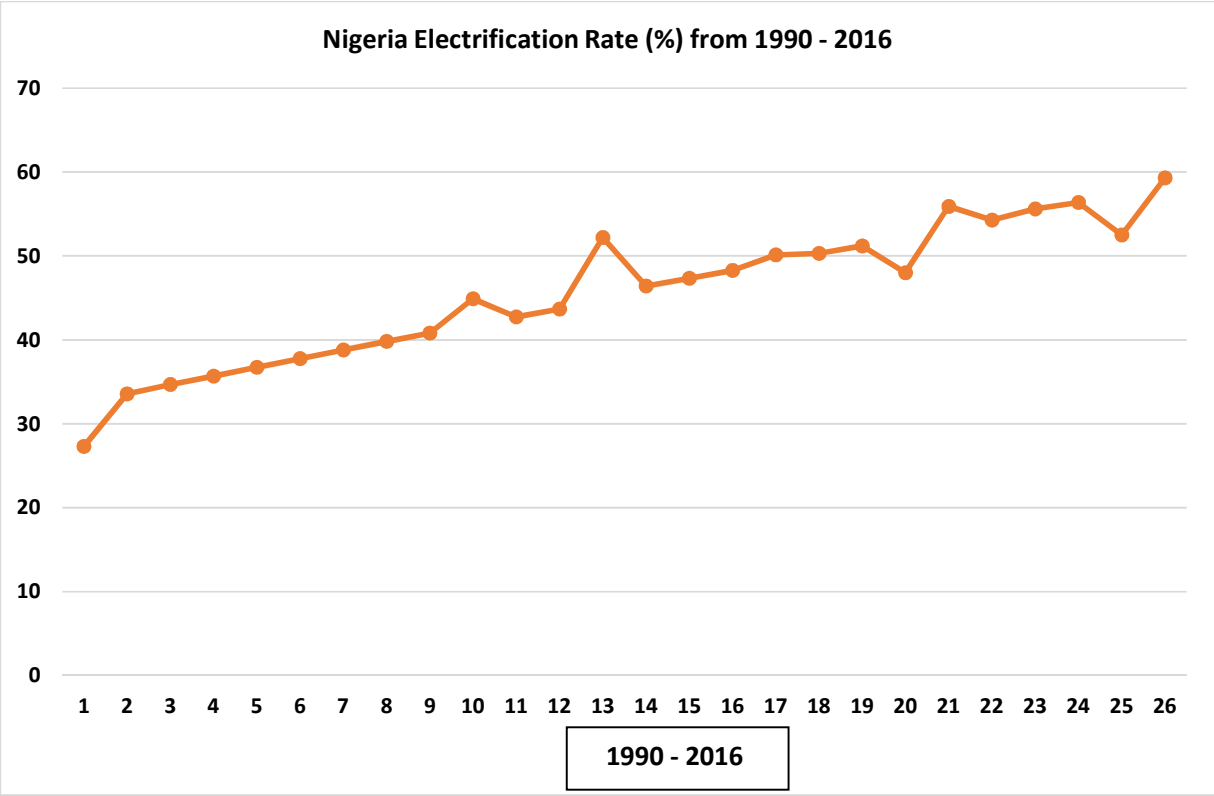

Fig 3: Nigerian Electrification Rate from 1990 – 2016
Source: Adapted from World Bank (2019)[46]

2.2 Electricity Distribution

The distribution sector of Nigeria's electricity industry starts at 33kV, then 11kV, 415V, and 220V. The distribution network comprises of approximately 24,000km (33kV) and 19,000km (11kV) [24, 28].

(online) = ISSN 2285 – 3642
ISSN-L = 2285 – 3642
Journal of Economic Development, Environment and People
Volume 9 , Issue 3, 2020

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The loading of distribution transformers (mostly rated in KVA) beyond their allowable capacity has adversely affected their performance. Thereby disrupting supply to the end-users. In the United States, the average number of end-users per distribution transformer is ten (10); whereas, in Nigeria, it exceeds 200 [18, 32]. Since the privatization of the Nigerian electricity industry in 2008, there has not been a meaningful increase in the capacity and operations of the distribution sector. The distribution companies (DISCOs) incur heavy losses because of the non-collection of electric bills from customers [21]. 80.2% of Nigerian urban households are connected to the national grid (electricity distribution companies - DISCOs). However, only 29.8% of rural area households are connected to DISCOs. In total, 54.9% of Nigerian households do not have access to the national grid [33]. In 2014, the Nigerian household electrification rate was 55.6% [34], implying poor electricity infrastructure and supply from the national grid, especially to rural Nigerians. The regional distribution is shown in Table 1 below.

Table 1: Nigerian Household Electrification by Regions (in percentage)

Region	Access to Electricity	No Access to Electricity	Unaccounted
North Central	48.7	51.2	0.1
North East	29.3	70.4	0.3
North West	42.2	57.7	0.1
SouthEast	66.4	33.6	0.0
South-South	68.3	31.3	0.4
South West	81.1	18.8	0.1

Sources: [33], [35]

Major challenges confronting the distribution companies (DISCOs) are the metering of customers and the poor rate of bill collection. Nigerian Electricity Regulatory Commission (NERC) reported that only 45% of Nigerian electricity customers are metered. Un-metering of customers has resulted in DISCOs applying estimated billings (mostly over- billed above-average metered customers). Many customers refuse to pay estimated bills. Similarly, energy thefts (unmetered, unpaid, and unaccounted for use of energy by consumers) increases the losses of DISCOs. This has resulted in capital constraints for electricity providers [36]. Improper zoning of residential and industrial consumption affects system balance and operation. Industrial outlets (mostly uses 3 phase motors) consumes more electricity than residential sectors on a unit basis. Often, they are mistakenly loaded as residences on transformers. This results in an explosion and severe disruption of power supply, and even low voltages [37].

Technical losses incurred by Nigeria's transmission and distribution (T&D) network is significantly higher (500 – 600%) than that obtained in an efficient electricity network of developed countries [38]. For example, in 2004, almost 320 outages were experienced. In 2005 and 2007, it was 399 and 452, respectively. Table 2 below shows the frequency and hours of electricity supply per week.

Table 2: Frequency of Outages and Weekly Supply of Electricity (in Hours)

Region	Daily Outage Frequency	Weekly Supply of Electricity (Hours)
South East	61.5	31.8

South-South	49.5	41.0
South West	55.5	37.1
North East	54.6	25.1
North Central	57.4	34.1
North West	55.5	29.1

Source: [39]

Despite the effort of the Nigerian government to improve the electricity supply, it has not produced any meaningful results. The failure of government interventions is generally categorized into three. First, the rate of Nigeria's electricity infrastructural development (electrification) does not correspond (increase) with population growth. It implies poor financial investment. Secondly, industrial financial mismanagement, corruption, and embezzlement reduce capital available for infrastructural development. Thirdly, inconsistencies in the implementation of the Electric Power Sector Reform Act of 2005 - privatization of the defunct Power Holding Company of Nigeria (PHCN) [36, 38]. Therefore, it is important to tackle electricity infrastructural development, fiscal mismanagement, and sectoral reform, if Nigeria is to achieve significant electricity supply, for socio-economic and national development.

Gas supply constraints to generation, technical losses in transmission and distribution, energy-inefficient consumption and appliances, population growth – electricity infrastructure development, billing system, and corruption are the challenges encountered by the Nigerian electricity industry. The paper conceptualized challenges limiting the sustainable development of Nigeria's electricity industry in Figure 4 below.

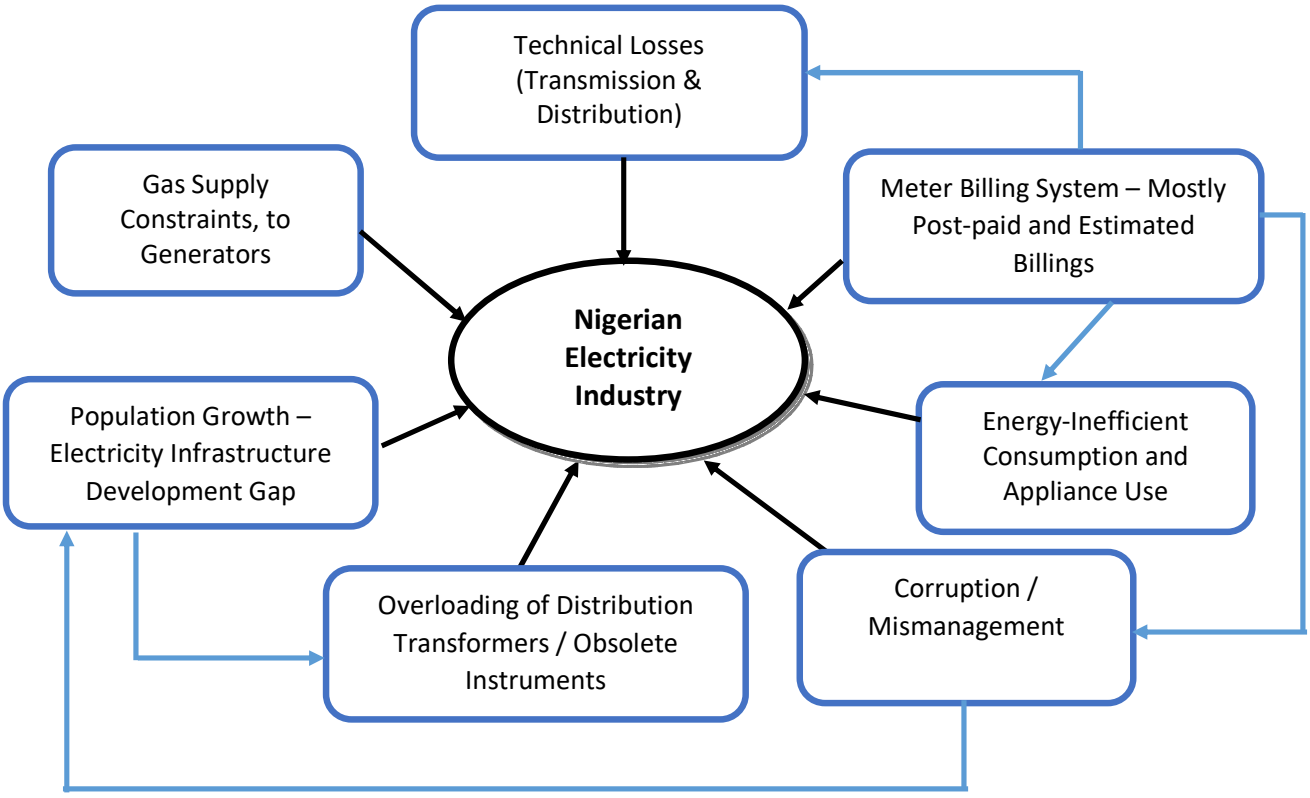

Figure 4: Factors Challenging Nigerian Electricity Industry

(online) = ISSN 2285 – 3642
ISSN-L = 2285 – 3642
Journal of Economic Development, Environment and People
Volume 9 , Issue 3, 2020

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3. Nigeria Electricity Billing / Metering Method

Pre-paid electricity billing was introduced in Nigeria in 2006. Post-2006, Nigerian electricity consumers can be grouped into unmetered, pre-paid, and post-paid metered consumers. Un-metered consumers generally consume energy unsustainably. For example, they do not switch off electrical appliances and lightings when not in use, because of the practice of estimated billings. Their monthly consumption bill is estimated, and not based on actual consumption. For metered (pre-paid and post-paid) consumers, consumer behavior is different. However, pre-paid metered consumers consume electricity efficiently than post-paid. This is because most often electricity distribution companies don't take readings of post-paid meters regularly, and have to rely on past month consumptions to produce bills. There is a lack of transparency and methodology in the assessment and estimation of the bills by DISCOs [40, 41]. The introduction of pre-paid meters increased revenue collection of DISCOs. However, it reduced revenue generation (amount of money). Pre-paid meter reflects actual energy consumption, unlike the estimated billing. In response to complaints of customers towards estimated billings, NERC directed the DISCOs to distribute prepaid meters to electricity consumers under the Meter Assets Providers (MAPs), effective from 1st May 2019 [42].

The post-paid metering system is energy-wasting and results in unpaid debts, which accumulate over a long period. It affects revenue collection and the fiscal status of DISCOs. It is a common practice for unmetered Nigerian households to use electricity cookers for cooking instead of common liquefied petroleum gas (LPG), kerosene, or firewood. Also, lightings (most times, incandescent bulbs) are not switched off even during the day. The practice is attributed to the fact that the monthly electricity bill is not based on actual energy consumption (kWh). Estimated billing is usually higher than customers with similar characteristics, but have pre-paid meters [42, 43]. Unfortunately, the 2018 fourth quarter-power sector report of the National Bureau of Statistics (NBS), show that only 36.3% (1.67 million) Nigerian households use pre-paid meters. It clearly suggests that most Nigerian electricity consumers don't have prepaid meters. Prepaid billing system changes and induces conservation behavior of consumers, compared to post-paid metering [44]. It shows the unsustainable and inefficient development of the Nigerian electricity industry, and thus, the need for deployment of prepaid meters to all Nigerian electricity consumers. Unless there is a massive mobilization by the federal government, regulators (Nigerian Electricity Regulatory Commission), and DISCOs, the pre-paid meter gap will persist for a long while. For an effective and sustainable electricity industry (distribution), electricity bills should be based on actual consumption, and customers must pay for consumed energy. This can only be achieved by the deployment of pre-paid meters, which enables actual revenue determination and collection. For example, most of the post-paid meters, installed decades ago have been tampered with to slow their reading, or not to read at all (energy theft) [41].

Pre-paid metering enables monthly electricity budgeting, depending on household income. Thus, energy-saving measures such as switching off lighting and appliances, use of energy-efficient appliances, and consumption behaviors, are adapted to. In Lagos State, 80% of pre-paid customers, reported that it enables monthly budgeting for electricity, as consumption is targeted (tailored) to fit the budget limit.

This is attributed to monitoring in real-time, energy consumption as shown by 94.5% of the customers [45]. In southwest Nigeria, [46] reveals that use of pre-paid metering system resulted to 39% and 24% reduction in energy consumption for low-income and high-income earners, respectively. Similar findings have been reported in other countries. For example, in Ghana, the transition to or use of a pre-paid billing system resulted in savings in energy consumption. Consequently, 91% switch off lightings when leaving their houses, while 88% turns the light off when leaving a room. The conservation behavior was informed by real-time disclosure of energy consumption by prepaid meters [47]. In the U.S. and Canada, the transition to a prepaid (Pay-as-You-Go) billing system gives consumers inducements to reduce consumption. Electricity industry-sponsored research found that consumers that transitioned from post-paid to the pre-paid billing system reduced consumption by 9%. Similarly, a study in Ontario, Canada, found that ¼th of pre-paid metered electricity consumers spend 20% less than when they were using post-paid meters. It was attributed to viewing in real-time energy consumption, which prompted users to adopt energy conservation, and the use of energy-efficient appliances [48, 49]. Pre-paid metering reduces energy demand, consumption, and expenditure.

The Way Forward

4. Sustainable Consumption: Energy-Efficiency and Conservation

Globally, 40% of total energy consumption is related to buildings. Energy consumption will greatly decrease if energy conservation and efficiency are strongly implemented. Sustainable change in consumption patterns and technologies (appliances) that decreases available energy supplied to provide services, is termed Energy-Efficiency. Energy-efficient appliances minimize energy consumption while increasing output. The services include refrigeration, lighting, industrial applications, transportation, and others [50]. Therefore, adaptation to energy efficiency is sustainable and offers socio-economic and environmental benefits. More monetary value is saved per unit product and services supplied; preservation of natural resource use and consequent abatement of pollution are achieved. A typical example of an energy-efficient appliance is Compact Fluorescent Lamps (CFL). It supplies 400% lumens per watt (lm/w), which is higher than that of incandescent lightings. It also saves energy consumption by a factor of 4 [51]. Furthermore, energy-efficiency in thermal consideration of buildings will save 65% in energy consumption and expenditure [52]. Hence, the need to retrofit already constructed buildings, and integrate energy-efficiency in the design of new buildings. Energy-efficiency is a cost-effective measure for developing an economy, without the additional cost of producing or increasing energy production. In 2013, a study of the Economic Community of West African State (ECOWAS) shows that 30% savings of electricity consumption are possible in the region [53].

Energy conservation attempts to decrease energy use, and it involves a change in behavior, introduction of better technology, and efficient management. It attempts to optimize energy using processes and products, to minimize per unit energy needed for output, and also reduce the monetary costs [54]. The two terms (energy-efficiency and energy conservation) are most often used interchangeably. Change in consumption pattern (energy conservation) and use of energy-efficient appliances reduces the amount of energy that would otherwise have been consumed, conserving it for others connected to the grid, thus improving supply to other electricity consumers. It increases supply to more consumers. However, there is very low awareness (acuity) of energy-efficiency and conservation among Nigerian electricity consumers. For example, 60% of electricity consumers in Rivers State don't know the implications (social, economic, and environmental costs) of using energy-efficient appliances. Similar trends were observed across Nigeria [54, 55]. In Europe, the use of energy-efficient appliances and technologies resulted in a 40% and 35% decrease in energy consumption and greenhouse gas emissions, respectively [56].

(online) = ISSN 2285 – 3642
ISSN-L = 2285 – 3642
Journal of Economic Development, Environment and People
Volume 9 , Issue 3, 2020

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Nigeria needs to focus on energy conservation and efficiency so that the present inadequate generated electricity will serve more consumers. A study of halls of residences at the University of Lagos, Nigeria, found that retrofitting with energy-efficient lightings, decreased energy consumption by 45% [57]. Conversely, many Nigerian homes (58%) use incandescent bulbs. 41% uses compact fluorescent light (CFL), while only 1% uses light-emitting diode (LED) bulbs. It is estimated that the use of CFL and LED bulbs are 500% and 1000% more energy-efficient than luminescent bulbs, respectively. An average Nigerian household consumes about 450kWh for lightings, and a significant number of them are incandescent bulbs [58]. [59] estimated that Nigerian electricity generation will reach 6000MW (6GW) by 2022. This will supply 60 million 100Watts incandescent lamps. However, for the candescent fluorescent lamp (CFL), the projected 6000MW will supply a 300 million point source. This suggests energy will be conserved by a factor of 20, using energy-efficient lightings. Hence, the need for total transition of Nigerian electricity consumers from luminescent lamps to CFL. Therefore, it should be a national policy to phase out incandescent bulbs, through fiscal and regulatory instruments.

Incandescent bulbs produce 75% more heat than candescent (CFLs and LEDs) lightings and consume more energy per kWh, thus increasing household emissions of CO_2 per kWh of consumed energy. Incandescent lightings convert only 5% of supplied electrical energy to light, and 95% to heat [54]. Lightings account for 35% of total electricity supplied to Nigerian urban households [60]. Monetary cost was implicated in the prevalence of incandescent bulbs more than candescent lightings in Nigeria. The average price of an incandescent bulb is ₦100 ($0.277) for 60 watts and ₦250 ($0.694) for 200Watts bulbs. The price of CFL however, averages ₦600 ($1.66). CFL bulbs have an average efficiency of 60 luminescent per watt (lm/w), 1000% more lamp life, high illumination (white light), and saves energy compared to incandescent lightings [54]. Thus, in the long run, candescent bulbs are more cost-effective both in life–span and energy consumption (kWh).

Energy consumption (in kWh) will be highly reduced if Nigerian electricity consumers fully retrofit with CFL and LED bulbs. Per capita/ household energy consumption will decrease, and thus more consumers will be supplied electricity, given Nigeria's limited generation capacity of only 3.9GW [16]. Therefore, the need to strongly pursue and implement energy efficiency and conservation is a matter of national policy. It is more pertinent for Nigeria, an emerging economy where the general populace is indifferent to conservation. This suggests that optimizing Nigeria's power supply can be achieved either, through increased generation or decreased energy demand (conservation and energy-efficiency). Increasing generation capacity requires extensive and consistent infrastructural and capital investment, which has been lacking in Nigeria's power industry over the decades. However, reducing energy consumption requires only a change in consumers' behavior and appliances. [58] estimates that if Energy Policy settings (EPO) of National Renewable Energy and Efficiency Policy (NREEEP) framework are fully implemented by Nigeria electricity consumers in 2030 and 2050, demand for energy will decrease by 61% and 58%, respectively. The EPO framework includes - the introduction of energy-label for household appliances, use of only CFL and LED lightings, deployment of pre-paid meters to all Nigerian households by 2025, the introduction of energy-efficiency in Nigerian building code standards, and reduction in energy intensity.

Energy intensity is a measure of the energy efficiency of a country’s economy, computed as units of energy per unit of GDP. High energy intensity implies a high cost of energy conversion into GDP, while

low energy intensity means a lower cost of converting energy into GDP. The energy intensity of a country is determined by the energy-efficiency of consumers' appliances, conservation behavior, off-grid (self-generation) supply, energy subsidies, etc [61]. The energy intensities of Nigerian households' use of some electrical appliances are - lighting (455kWh), refrigerator (496kWh), air conditioners (828kWh), and DVD / television (122kWh) [58].

4.2 Policy Innovation

Considering a steady population increase, economic growth, and rising per capita GDP of Nigeria, electricity demand will increase by half in the middle of the 21st century. Solar (renewable) energy source for both the grid and domestic supply, offers huge advantageous opportunities for the country. For example, Nigeria has sunshine for $6^1/_2$ hours per day; and the average Nigerian daily solar radiation is 5.3 x 10^3 Watt-hour/m^2/day (Wh/m^2/day) (5.3kWh/m^2 daily). This is equivalent to 1.20 x 10^5 times the amount of electricity generated by Nigerian electricity generating companies (GENCOs) [54, 62]. Similarly, the estimated Nigerian hydropower generation potential is 36x10^6 MWh per annum, or 8,900MW. However, the hydroelectric power generation potential of Nigeria is presently underutilized. The development of these renewable energy sources will offer great socio-economic and environmental benefits to Nigeria [54].

Presently, global state-of-the-art electricity production is dependent on both renewable and non-renewable energy sources. Therefore, the adequacy of supply is a product of a good energy mix. Currently, significant electricity generation in Nigeria comes from gas (thermal) power plants. Therefore, reliable electricity production can only be achieved by solving the problems related to the gas supply, and bulk power evacuation (transmission and distribution losses). Also, efforts should be strengthened to renewable electricity production (hydro and solar). Renewable electricity production and energy-efficient consumption are options capable of improving the supply, and viability of the country's electricity industry. It is therefore important that adequate measures should be designed and implemented to address these obstacles. To this purpose, our paper suggests a number of recommendations.

Firstly, Nigeria, a tropical region has sufficient solar radiation throughout the year almost across the country. However, the grid system (network) as is presently in Nigeria, is not suitable for evacuation of bulk power from these renewable energy sources (especially solar). Thus, we advocate for an embedded generation–distribution model. For this model to succeed and thrive in Nigeria, special provisions through the legislative act should mandate the government to subsidize such ventures through a tax break, lower forex rate for solar panels, and other required materials importation. State governments and local governments can venture into such enterprise, or a regional coalition can be formed, so as to defray costs. Similarly, it can be publicly traded on the Nigeria Stock Exchange, to generate capital. Presently, this is not the situation in Nigeria.

Secondly, important attention should be paid to sustainable electricity consumption as a measure to ensure efficient and adequate supply. One way to tackle it is the enforcement of Nigeria's National Renewable Energy and Energy Efficiency Policy (NREEP). In addition to hydro and solar electricity production, it includes energy-efficiency and conservation. energy [58]. However, incentives ("stick and carrot approach"), should be employed to achieve the expected changes and should include deadlines (targeted period of achieving each of the strategies). It should apply to both economic and residential consumers. Similarly, strong emphasis and legislation should be geared towards the eco-labeling of energy-consuming products. Products that do not meet the energy-saving requirement should be restricted or imposed with higher import duty. For example, is the major use of incandescent lightings by Nigerians, because it is relatively cheaper than candescent lightings [54], even though the candescent bulbs save energy and therefore ensure sustainable electricity consumption. Consequently, the Standard Organization of Nigeria (SON) and Nigerian Customs Service, should work in tandem to achieve this sustainable measure(s). Evidence-based policy and effective institutional framework drive economic

(online) = ISSN 2285 – 3642
ISSN-L = 2285 – 3642
Journal of Economic Development, Environment and People
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growth, sustainable consumption, and conservation of resources. Adopting energy-efficiency and conservation will maximize energy supply to other consumers, considering the high use of energy-inefficient appliances and equipment which consumes more energy [55]. Thus, as a matter of policy, the Standard Organization of Nigeria (SON) and other relevant government agencies should strongly regulate the import and manufacture of electricity–consuming appliances, to ensure compliance to energy-savings.

Financing is critical if Nigeria's electricity sector is to improve supply. Electricity production and supply chain is capital–intensive [21]. Consequently, government and private sector should be involved in financing the electricity industry. The present federal government stakes (40%) in each of the eleven (11) distribution companies (DISCOs) [63] should be reviewed, to enable further investments and capital generation from the financial market. The federal government should therefore divest its interests in DISCOs, and competent partners with technical expertise sourced for, by respective DISCOs. Furthermore, the current DISCOs settings are monopolistic and do not support competitiveness, competence, and innovation, as consumers are simply delineated according to location. A consumer location determines its DISCO supplier. Consumers do not have options. This suggests that DISCOs do not have to be competitive and innovative to make profits, considering the practice of estimated billings and non-deployment of pre-paid meters [26]. Therefore, the paper advocate review and amendment, through effective legislation of the current status of the DISCOs, as informed by the Electric Power Sector Reform Act of 2005. This is informed by the present monopoly in the system (distribution). Competitiveness drives innovation and productivity.

Conclusion

Electricity is necessary for economic and non-economic sustenance, and national development. Its generation, supply, and consumption deserve careful analysis to ensure sustainability. Poor electricity supply and consumption are associated with several economic, social, and environmental issues. Currently, our paper shows that the status of the Nigerian electricity industry is unacceptable. There is a high and growing demand for electricity, and it is related to the increasing population and urbanization. There exists a supply-demand gap, which has limited industrialization, resulted in poor GDP, a lower standard of living, heavy hydrocarbon powered self–generation. However, the situation can be firmly tackled with capital investment, appropriate fiscal management, and deployment of pre-paid meters to consumers nationally. Similarly, investment in renewable energy sources (hydro and solar), will significantly improve supply. Present emphasis is on thermal (gas) generation, but Nigeria, a tropical country can fully develop its solar energy industry. Accordingly, national, state and local governments should properly implement a holistic evidence-based policy. The policy should be synergistic (including generation, transmission, and distribution). The current study also makes a case for energy-efficiency and conservation in electricity use, as one among several good alternatives for sustainable electricity consumption. Thus, revisiting to reposition Nigeria's electricity industry and consumption policies and practices, to be in tune with international best practices, will significantly contribute to ensuring optimal supply and consumption of power (electricity).

Acknowledgment: We acknowledge the academic staff of SHELL-Center for Environmental Management and Control, UNEC, for their support.

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Volume 9 , Issue 3, 2020

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ISSN-L = 2285 – 3642
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Volume 9 , Issue 3, 2020

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