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Power Inadequacy, the Thorn in Economic Growth of Nigeria

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Abstract

Adequate access to reliable, quality and affordable power is crucial to national economic growth. The Nigerian power industry performance track records and statistics are dismal and appalling. The power supply is characterized by low accessibility, epileptic and poor transmission. The socioeconomic activities in Nigeria have been grossly impacted negatively by insufficient power supply. Yet the huge energy potential available in the country are insignificantly tapped. Therefore, this study x-rays the past and present power situation in Nigeria; the determinants of the amount of power demanded; and the several interventions in the Nigerian power supply. The study reported that population, industry, transportation, agriculture, and commercial services are the main determinants of energy demand in Nigeria. The study reveals that population interconnects all other factors. Industrial, transportation and residential sectors consume the most energy in Nigeria. Industrialization, urbanization and the general economic wellbeing of Nigeria depend largely on effective power supply. This study concludes that effective power supply relies on careful and logical handling of these critical power technical activities – power generation; efficient power transmission to users; efficient power distribution to the users; reasonable level of domestic power equipment manufacturing infrastructure; management of population growth; and national power infrastructural development planning and enabling policy for power sector investments.

Keywords: Power in Nigeria; electricity in Nigeria; Energy trilemma; Nigerian Energy potential; effect of power on manufacturing; Nigeria power consumption and generation

INTRODUCTION

In 2016, it was reported that only about 58% of Nigeria's population have access to the national electricity grid and in this percentage, only about 30% of its current requirements are met [1]. The power sector in sub-Saharan Africa (SSA), is in a pathetic state, despite several interventions [2]. The most populous country in the region, Nigeria, is severely affected. The challenges that trail the power sector in Nigeria, seem as they were two decades ago and have deepened in some areas. Before divestiture of Power Holding Company of Nigeria (PHCN) by the federal government in 2013, PHCN was solely mandated to construct and engineer power generating units; maintain and service power grids; operate dams and manage water for power generation, flood control and navigations; resettle; maintain control, protections and communications equipment; maintain scheduling; and analyse security and post contingency. The Power Holding Company of Nigeria (PHCN) started in 1950 as the Electricity Corporation of Nigeria (ECN) and later became the National Electric Power Authority. The running of the PHCN has been lacking in professionalism since inception in 1950 and today, the national grid system is characterised by poor workmanship; poor quality materials; poor standards by foreign and local contractors; cable theft; power theft by consumers; vandalization of pipelines and transformers; court disputes and protests; and much more.

Power is needed to drive industrial machines for the manufacturing of different products, as a result, it contributes, significantly, to national economic growth. The power required to stimulate socioeconomic activity in Nigeria, is grossly inadequate, consequently, there is high rate of unemployment, poverty, high cost of production and services, etc. According to Ebhota and Inambao, power consumption per capita, is a yardstick for measuring the quality of life and development of a country or region [3]. However, there is an addition to this benchmark in the contemporary energy world, prompted by attributes of modern energy supply [4]. In the contemporary world, the consumption per capita of clean, adequate, affordable and sustainable power is a yardstick for measuring the quality of life and development of a country or region. Electrical energy production and consumption per capita of selected world countries are shown in Fig. 1. Therefore, access to adequate, reliable, affordable and quality energy, especially electricity, is a panacea to the socioeconomic development of a country. The aim of this study is to identify the relationship between the development of the power sector in Nigeria and its impact on the socioeconomic development of the country. To do this, we analyse government policies for management of the most significant energy consuming sectors in the country and six critical activities for achieving an effective power supply.

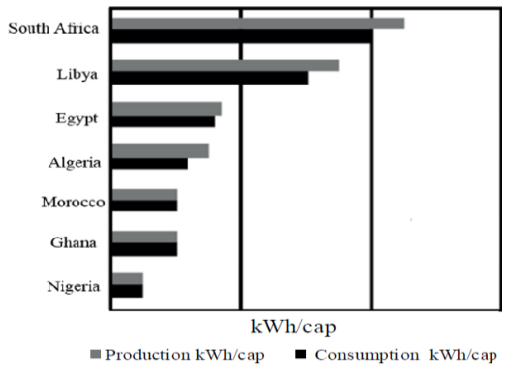

Figure 1. Electrical energy production and consumption per capita of selected world countries [5]

Energy Potential of Nigeria

Nigeria is richly blessed with primary energy resources and is ranked the world's tenth country with the largest crude oil reserves. The oil and gas reserves were estimated in 2006 to be about 36 billion barrels and 166 trillion standard cubic feet, respectively. Nigeria is endowed with significant primary energy sources as presented in Table 1.

Table 1: Energy potential of Nigeria [6]

Resource Type	Reserves	Reserves (BTOE)
Fossil		
Crude Oil	36.0 billion barrels	4.896
Natural Gas	166 Trillion ft^3	4.465
Coal & Lignite	2.7 billion tonnes	1.882
Tar Sands	31 billion barrel of Oil equivalent	4.216
Hydropower		
Large Hydropower	10,000 MW	
Small Hydropower	734 MW	
Biofuel		
Fuelwood	13,071,464 Hectares	
Animal Waste	61 million tonnes/yr	
Crop Residue	8.3 million tonnes/yr	
Solar Radiation	3.5 – 7.0 KWh/m^2-day	
Wind	2 – 4 m/s (annual average)	

Nigeria and the Energy Trilemma

Apart from satisfying the need for adequate, quality and affordable power supply, the global dynamics in the transformation of the power sector are digitization, de-carbonization and decentralization. Also, there is emergence of accredited energy consumers with new options of utilisation and management of their energy. The control of this complex global energy dynamics is challenging and significant to energy poverty, energy security, and climate change mitigation. The reinforcement of energy security, energy equity and environmental sustainability, as shown in Fig. 2, is termed energy trilemma. Energy sustainability was described by World Energy Council based on energy security, energy equity, and environmental sustainability [7-9]. Balancing these three dimensions constitutes energy trilemma and is the foundation of Nigeria's success and competitiveness [4].

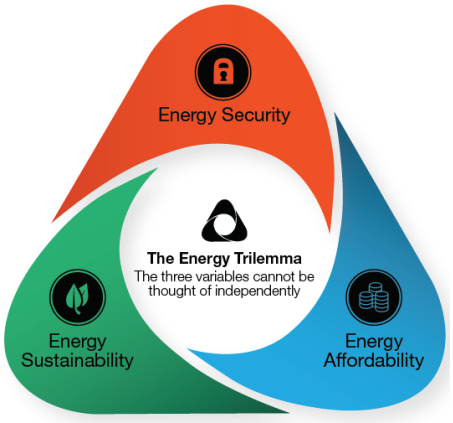

Figure 2. The schematic of energy trilemma [10].

PRESENT STATUS OF POWER SECTOR AND THE EFFECT OF INADEQUATE ELECTRICITY ON MANUFACTURING SECTOR IN NIGERIA

Power inadequacy has been identified as a key factor with regards to the old industries struggling for survival and the slow development pace of new industries in Nigeria [11]. The reality is that manufacturing sector needs adequate, reliable and cost effective power supply to thrive and impact significantly on the commercial sector in Nigeria. From the global perspective, uninterrupted and safe energy supply is needed to fit into the fourth industrial revolution space that is characterised by full automation and digitisation-based operations. Hence, for Nigeria to significantly grow economically, the development of the energy industries is a panacea. The negative impacts of inadequate electricity on the economies of Nigeria and other parts of SSA have been analysed and reported by several studies [12-15]. The present situation negates the several huge interventions in terms of funds and policy framework initiatives by the government, and international community, as presented in Tables 2 and 3.

Table 2: Capital from the Federal Government of Nigeria released to the power sector

Year	₦ (Billion)	US$ (Million)	Average Exchange Rate (₦ per US$)
1999	6.7	72.28	92.6934
2000	49.8	487.73	102.1052
2001	70.9	633.36	111.9433
2002	44.2	394.84	111.9433
2003	5.2	43.00	120.9702
2004	54.5	421.32	129.3565
2005	70.3	531.97	132.1500
2006	72.4	562.77	128.6500
2007	61.1	485.58	125.8300
Total	435.1	3,632.83	

The growth in the power sector is not commensurate to the huge amount of resources that Nigeria's successive government has plunged into it.

Table 3: Several major initiatives taken by Nigerian government to transform power sector

Year	Initiative
2005	Establishment of Electric Power Sector Reform Act; Nigerian Electricity Regulatory Commission (NERC); and Power Holding Company of Nigeria (PHCN)
2006	Launching of rural electrification programmes; unbundling of assets (transmission, distribution and generation); execution of ten National Integrated Power Projects (NIPP); and establishment of market operations department of the Transmission Company of Nigeria (TCN).
2008	The establishment of presidential task force on power Appointment of a body to oversee progress of unbundled generation and distribution companies; and the approval of multi-year tariff order
2010	Introduction and establishment of the national power road map and Nigerian Bulk Electricity Trader (NBET) respectively
2012	The entering of Transmission Company of Nigeria into a management contract with a utility and asset management company; and the signing of Nuclear energy Memorandums of Understanding (MoUs).
2013	Improvement in hydro-electric power stations; and the signing of MoUs for coal power partnerships
2014	Strengthening of renewable energy programme
2015	Establishment of transitional power market.

PHCN Successor Companies

The electricity challenges in Nigeria failed to appropriately respond to the several interventions and reforms. The most recent of the reforms is a shift from centralised monopolies to unbundled structures, which is the unbundling of stakeholders in the power value chain. Power Holding Company of Nigeria was unbundled into eighteen companies that can be classified into three main components – Generation Companies (GENCO); Transmission Company of Nigeria (TCN) and Distribution Companies (DISCO) [16]. Details of the unbundling is presented in Table 4. Many factors are responsible for the power inadequacy in Nigeria, such as, dwindling revenue available to the government, security threats, corruption, inadequate manufacturing infrastructure, and shortage of technical personnel.

Table 4: PHCN Successor Companies [17]

PHCN successor companies		
Generation companies (6)	***Transmission (1)***	***Distribution companies (11)***
1. Afam Power plc 2. Egbin Power plc 3. Kainji Hydro-Electric plc 4. Sapele Power plc 5. Shiroro Hydro-Electric plc 6. Ughelli Power plc	Transmission Company of Nigeria	1. Abuja Electricity Distribution Company plc 2. Benin Electricity Distribution Company plc 3. Eko Electricity Distribution Company plc 4. Enugu Electricity Distribution Company plc 5. Ibadan Electricity Distribution Company plc 6. Ikeja Electricity Distribution Company plc 7. Jos Electricity Distribution Company plc 8. Kano Electricity Distribution Company plc 9. Kaduna Electricity Distribution Company plc 10. Port Harcourt Electricity Distribution Company plc 11. Yola Electricity Distribution Company plc

Nigeria power transmission subsector

The transmission segment of the Nigerian power sector value chain is managed, controlled and maintained by the government through the Transmission Company of Nigeria (TCN). The transmission grid network comprises mostly 300kV circuits and substations covers only 40% of the country – a potential power sector growth drawback in Nigeria. Currently, although the transmission wheeling capacity (5,300 MW) is less than the operational generated capacity (3,879 MW) it is far below the total installed generation capacity (12,522MW). The transmission subsector's critical infrastructure and operational challenges are reflected in the percentage of losses in the transmission. The estimated transmission losses across the network is 7.4% and this is high compared to emerging countries' benchmarks of 2–6% [18]. Going forward, it will be necessary to implement policies that will attract investments to expand the geographic network coverage in power transmission to enable the environment.

The effect of inadequate electricity on manufacturing sector in Nigeria

The damaging effects of poor, inadequate and unsupplied power to manufacturing industries have been estimated in different ways by many studies. These studies evaluated various types of value of unproduced output and outage costs, such as equipment and material losses [19, 20]. Ukong study, revealed that about 130 kWh and 172 kWh were the unsupplied electricity to selected manufacturing firms in 1965 and 1966 respectively [19]. These amounts correspond to N1.68 million and N2.75 million respectively, as the costs of power outage to the manufacturing sector in the two years. The study concluded that it had an adverse effect on manufacturing. A similar research was performed in 1993 in Lagos by Uchendu [20]. The study reported values of unproduced output for 1991, 1992 and mid 1993 were reported, as N1.3 million, N2.01 million and N2.32 million respectively. This development was reported to have caused reduction in economic value to major manufacturing firms in Lagos. In 1992, it was reported that Nigeria's manufacturing sector spends approximately 90% of their variable cost on infrastructure [21] and power accounts for half of this-. To date, erratic, inadequate, poor and expensive power supply to manufacturing sectors and homes continuously dominant Nigeria's energy reports. Frequent power supply cuts is detrimental to equipment and is a major cause of breakdown of production machinery.

It is a common knowledge in Nigeria that industries rely more on private (off-grid) power generation than the national grid. The diesel, and petrol plants are commonly used generators and at times gas turbine plant, with the relative consequence of high cost of fuelling. Studies have shown that the source of energy and technology has a direct impact on cost of production and services. The levelised cost approach, which is the preferred method, was applied in the analysis of cost of electricity generation in Nigeria between the different sources on the basis of equal footing [22]. The levelised cost of electricity (LCOE) described as the ratio of lifetime costs to lifetime electricity production and is mathematically represented as in equation (1):

$$CRF = \frac{r(1+r)^i}{\left(r(1+r)^i - 1\right)} \quad \text{_____} \quad (1)$$

Where *CRF* is the Capital Recovery Factor; *r* is the Weighted Average Cost of Capital (WACC); and *i* is the investment life, which is 11% as defined by Nigerian Electricity Regulatory Commission (NERC).

The results of comparative costs of power generation in Nigeria using LCOE approach were presented in a report produced by the Nigerian Economic Summit Group and Heinrich Böll Stiftung, Nigeria in 2017. According to the report the cost of [22]:

i. Power generation by on-grid systems – large scale hydropower and natural gas, combined cycle turbines is USD 0.05 to 0.07kWh on average

ii. Off-grid generation by solar PV systems on a lifetime basis is an average of USD 0.20/kWh (including storage costs)

iii. Off-grid generation by diesel generators in Nigeria is about USD 0.30/kWh

iv. Off-grid generation by gasoline over USD 0.60/kWh.

The results show that the cost of generating electricity from diesel or petrol is about 5-7 times the cost of generating from on-grid large hydro or gas turbines. It was observed that off-grid solar PV systems are cost competitive in Nigeria on a lifetime basis but PV systems like other renewables are still perceived as high-risk investment technologies. The off-grid diesel and petrol are more expensive compared to other sources but are more attractive to investors because of their lower upfront costs. In another report by IRENA shows that the annualised cost of diesel and petrol systems for home lighting (156-228 USD per year) is significantly lower than the solar PV solar system below 1 kW (55-210 USD per year) [23]. The LCOE of unsubsidised off-grid electricity generation of different sources in Nigeria, is shown in Fig. 3.

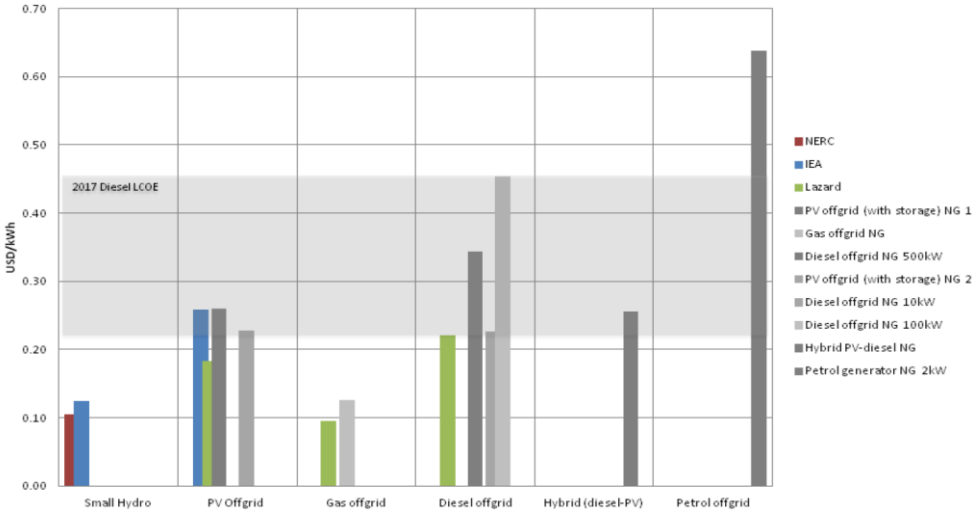

Figure 3: Unsubsidised LCOE for off-grid electricity generation in Nigeria [22]

POWER GENERATION AND CONSUMPTION

On-gird generation and challenges

The level of electrification in Nigeria is quite low and is estimated at about 45% [24] and in 2016 the maximum electricity generated and delivered to the national grid was 5074 MW [25]. Power generation in Nigeria was relatively steady from 2009 to 2013 as shown is Fig. 4.

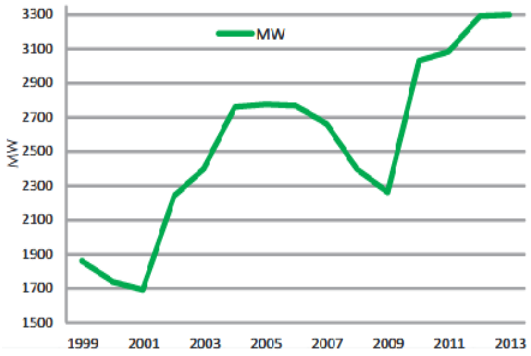

Figure 4: Electricity Generation (MW) [26]

Recently, the Minister of Power, B. Fashola, stated that although substantial fund has been expended in the sector by the government, it is insufficient to satisfactorily address the enormous power challenges [27]. Currently, out of the 12,000 MW power capacity installed, about 6000 MW is deliverable on the national grid. This capacity of electricity supplied on the national grid is grossly inadequate for a country with a population of about 185 million [28]. The power loss in Nigeria is relatively very high, as shown in Fig. 5. There are so many factors responsible for the wide gap between the installed capacity and the supply, such as vandalism of gas pipelines, poor scheduling of gas supply and evacuation, orchestrated by regional resource control agitation and political motives to sabotage the government's performance.

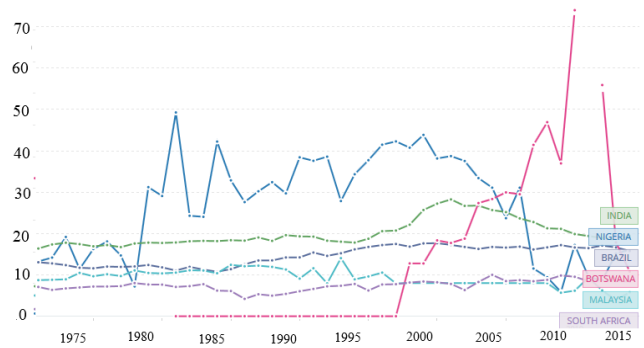

Figure 5: Electricity loss in selected countries (1971-2014) [29]

Other factors that contribute to the power loss are lack of equipment maintenance and the use of substandard, undersized and outdated transmission equipment. Most turbines at the generating stations were designed for 5-6 year overhaul scheduled maintenance and this was only done after 28 years in 2013, as a post privatization activity [25]. The transmission loss is due to voltage drop, a consequence of imbalance between generation and consumption. Nigeria's electricity consumption and loss from 1980-2013 is shown in Fig. 6. The exceeding power supplied by consumption causes the voltage dropping. In addition, energy loss along the transmission lines and lack of transparency in the sector are equally challenging. These drawbacks coupled with insufficient financial investments and human capacity in the power sector are the culpable power issues in Nigeria. The negative impact of insufficient power equipment manufacturing infrastructure in the country on power supply is rarely mentioned [3, 30]. Subsequently, human and infrastructural building capacities to facilitate domestic manufacturing of power equipment and systems has not been given adequate consideration.

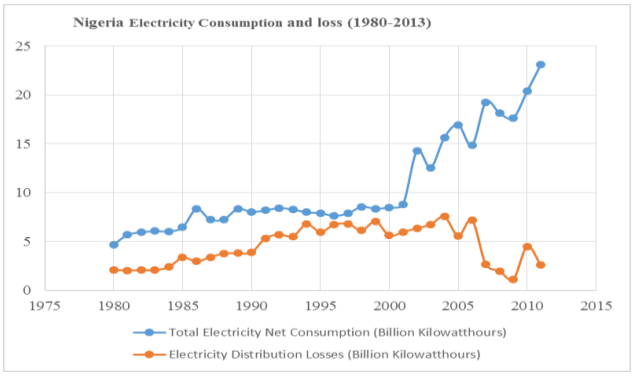

Figure 6: Nigeria Electricity Consumption and loss (1980-2013) [31]

The most significant quantity in the energy balance of Nigeria is the overall consumption of 24.57 billion kWh of electric energy per year. Per capita this is an average of 132 kWh. Nigeria generates completely the consumed electricity from her production facilities of total production capacity of 30 bn kWh [32]. Nigeria Energy Balance is shown Table 5.

Table 5: Nigeria Energy Balance

Electricity	**Total**	**Nigeria per capita**	**Compared to Europe per capita**
Own consumption	24.57 bn kWh	132.10 kWh	5,412.25 kWh
Production	29.83 bn kWh	160.39 kWh	5,831.12 kWh
Crude Oil	**Barrel**	**Nigeria per capita**	**Compared to Europe per capita**
Production	1.87 m bbl	0.010 bbl	0.005 bbl
Export	2.28 m bbl	0.012 bbl	0.004 bbl
Natural Gas	**Cubic meters**	**Nigeria per capita**	**Compared to Europe per capita**
Own consumption	26.86 bn m^3	144.42 m^3	1,164.59 m^3
Production	45.15 bn m^3	242.76 m^3	445.87 m^3
Export	26.33n m^3	141.57^3	388.47^3

Private power generators in Nigeria – off-grid

The inability of the power sector to adequately provide the needed national power grid capacity, forced homes and firms to augment the deficit with privately owned off grid generators. The actual energy generated and consumed in Nigeria is huge but complex to estimate due to the massive use of diesel and petrol generating sets. In 2009, it was estimated that 60 million Nigerians own power generating sets for their individual electricity [33]. It was reported that Nigerians expend over N796 billion annually on fuel for dedicated electric generators, and this was described as the highest in the world. A breakdown of this figure shows that N540.9 billion was spent on diesel, while N255.5 billion goes to petrol for fuelling of generating sets [34]. This has since given rise to a huge market for power generators and today, Nigeria is a haven for the sale of industrial and home power generators. The market is flooded with mostly generators manufactured in China, Germany and United Kingdom. In a study, Nigeria was identified as the largest market for diesel and petrol power generating sets in Africa, with a promising growth rate of 8.7%. Power generators importation to Nigeria has been predicted to grow from N71.55 billion ($450 million) in 2011 to about N151.16 billion ($950.7 million) by 2020 [35].

Nigeria electricity consumption

Despite the limiting power supply issues in the country, the demand for electricity keeps rising and the growth is critical to national economic growth stimulation. The country's electricity consumption increase is about 8% per annum. In 2015, an average of 3.1 GW of power was supplied in Nigeria, as against the country's minimum electricity demand of about 9.3 GW [24]. Considering the electric power consumption (kWh per capita) from 1975–2014 of some developing countries as shown in Fig. 7, it is obvious that available power in Nigeria is grossly inadequate. The growth rate is far below the current power need of consumers.

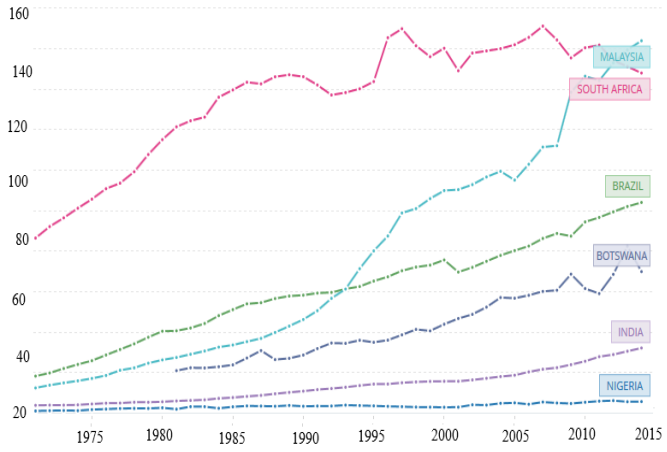

Figure 7: Electric power consumption (kWh per capita) of some developing countries [29]

NATIONAL ENERGY DEMAND AND CONSUMPTION DYNAMICS

The energy demand of a given country is determined by its population, industry, transportation, residential, agricultural, and commercial activities and others. The key sectors that consume the most energy are residential, industrial and transportation. The energy demand in Petajoule (PJ) in key sectors in Nigeria is shown in Fig. 8.

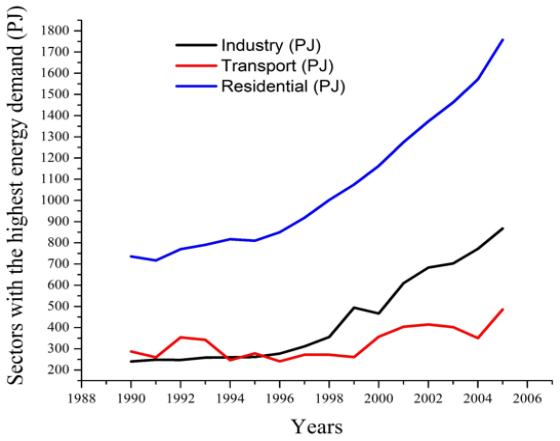

Figure 8: Energy Demand in Petajoule (PJ) in key sectors in Nigeria [5]

Population

The average annual per-capita energy consumption is defined as the total amount of energy consumed by a country in a year divided by the population of that country. Increase in population requires more power and availability of adequate power attracts population growth, which subsequently exerts power demand pressure on energy resources. The ultimate consequent is scarcer energy resources, occurrence of decline of marginal returns of energy resource extraction. This is measured in the nearby forests depletion, level of environmental complexity of oil drill, and coal mines deepness. This expanded the Earth's carrying capacity, resulting from the exploitation of new energy sources.

Several measures have been proposed to tackle the effects of population on power availability. These include family planning and availability of modern contraceptives in developing countries; development of cleaner, more efficient sources of energy; reduction of energy consumption; and introduction of stricter regulations by the governments [36, 37]. Nigeria is the 7th most populous country in the world. The growth rate of Nigeria increased at an amazing rate from 1.5% in 1950 to 3.03% in 1977 and declined to 2.53% in 1983. Since then, the population rate has been relatively stable and a growth rate of 2.63% was recorded in 2015, as shown in Fig. 9. Adequacy of power supply has been linked with population growth, the higher the population, the greater the power demand.

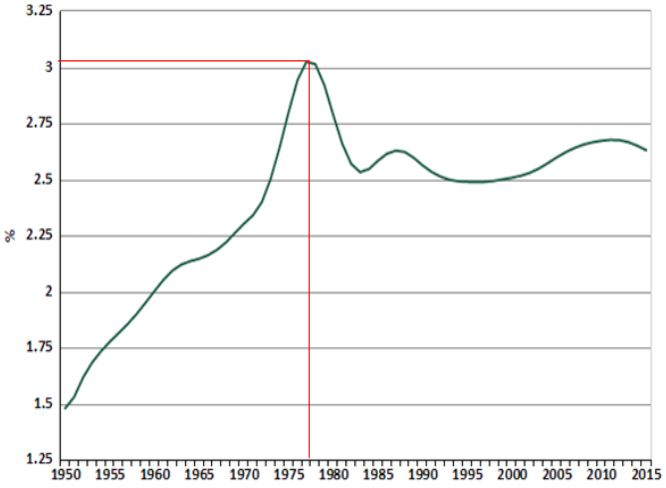

Figure 9: Nigeria - Population - Population growth rate [38]

Nigeria experienced an exponential population increase that almost trebled between 1970 and 1975. The rise in energy prices coupled with the start of gas exportation in the 2000s helped cushion the challenges emanating from this increase and significant GDP growth [39]. Fig. 10 shows Nigeria's population and GDP from 1970-2012.

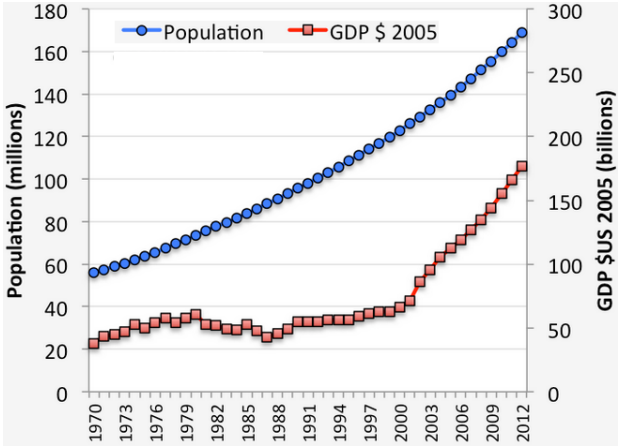

Figure 10: Nigeria's population and GDP from 1970-2012 [39].

Industrialisation

The word industrialization originated in Europe during the industrial revolution in the 18th and 19th centuries. It was a period that witnessed human effort being replaced by machinery in the manufacturing process for the purpose of mass production. This, coupled with urbanisation, have a substantial impact on energy consumption. Urbanization and industrialization are usually co-evolved in the economic development of growing countries. This involves the migration of people from rural to urban areas and from agricultural to industrial engagement. This movement prompts energy consumption increase [40]. The continuing urbanization and industrialization in Nigeria as a developing country further triggers power instability. The industrial sector frequently consumed in excess of 50% of the energy supplied and this generates tension between economic development goals and the limited energy supply. In Nigeria, like other developing countries, electricity supply has not been able to meet the growing demand in the various sectors of the economy. This resulted in the operation of industrial and commercial establishments below their production capability.

Residential

The types of household appliances influence the total power consumed. Frequently, in Nigeria, power is needed for these common household appliances, water heaters, lights, fridges, freezers, air conditioners, televisions, radios or music sets and computers. In 2014, the residential sector consumed over 50% of the country's total supply and is subsequently the largest electricity consumer in Nigeria. In Nigeria around 55% of the population have electricity with an average household consisting of 5 people. This is very low compared to China (99% and 3 respectively) and most wealthy countries with an average household size of 2.5 people [24].

Agricultural sector

Although this study could not find credible data on the actual energy consumed in the agricultural sector, it is logical to conclude that a reasonable amount of energy would be required for production. Agriculture requires fuel or electricity to operate machinery and equipment, for lighting, and to cool or heat buildings. Also, power is required for irrigation, fertilizer production, transportation and the preservation and processing of agricultural produce, etc. As it stands today, a lot of agricultural products spoil because of poor preservation due to inadequate and frequent power outages in Nigeria. This normally causes produce shortages resulting in commodity price hikes. Providing adequate power for socioeconomic wellbeing

Adequate power supply stimulates activities that advance the socioeconomic status of a given country. The proponents of quality, adequate, affordable and sustainable power supply system are sufficient electricity generation, efficient transmission and distribution, and domestic manufacturing of power equipment. Therefore, in the dwindling circumstances in the power sector in Nigeria, creative and innovative ideas that reflect global sustainability trends are needed. Industrialisation, urbanisation and the socioeconomic wellbeing of Nigeria depend largely on effective supply of clean, adequate, affordable and sustainable power. Effective power supply relies on the careful and logical handling of these critical activities – power generation; efficient power transmission and distribution to consumers; an infrastructure for the manufacturing of domestic power equipemnt; management of power supply to meet population, industrialisation, and urbanisation growth; and national power infrastructural development planning and enabling policy for power sector investments.

CONCLUSION

Industrial machines need power to run to provide the needed manufacturing for socioeconomic development. The growth of socioeconomic activities in Nigeria is at a snail's pace as power required to stimulate in the economy, is grossly inadequate and frequently cut. Consequently, there is a high rate of unemployment, poverty, high cost of production and services, etc. Therefore, access to clean, adequate, reliable, affordable and quality energy, especially, electricity, is a fundamental to the socioeconomic development of a country. Therefore, the balancing of energy sustainability components - energy security, energy equity, and environmental sustainability is the foundation of Nigeria's economic success and competitiveness.

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