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Assessment of Nigeria power sub-sector and electricity generation projections

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Abstract – Nigeria is faced with continues electricity problem, which made goods and services to be very costly in the country because industries have to generate their power themselves. Residential homes not left out, since all most all Nigerian homes now has a standby generating set. Although Nigeria has abundant supply of natural resources like coal, hydro, natural gas, crude oil etc. yet cannot harness these resources for power generation, so that the power generated will match the demand which seems to be increasing daily. This problem can only be solved by building more power stations so as to meet the projected power demand by 2030 which is estimated to be 297,900MW and also by using available energy supply more efficiently.

Index Terms – Demand, Energy, Hydro, Power, Projection, Supply, Thermal

1 Introduction

NIGERIA needs to improve efficiency and reduce waste in the public sector, and strengthen the private sector as its engine of growth [1], [2], [3].This can only be achieved by supply of efficient electricity generation. Although the country is richly endowed with gas, coal, hydro resources and solar, yet power generation in Nigeria is mainly from thermal plants which generate 60% and hydro power plants which generate about 30% [4], [5], [6].

Nigeria has an installed generation capacity of 8,644MW of which 6,905MW is government owned. Over the past two decades, population has increased to 150 million, with an average GDP growth rate of 6.66%, over the last five years [7]. Within this period, power generation capacity has stagnated. This factor, combined with inadequate maintenance of existing power generation stations, has given rise to severe generation shortages [8].
It is estimated that 26,561MW will be required in the next nine years to meet demand as envisioned in the vision 20:2020 target.

2 Electricity Generation in Nigeria

Electricity generation in Nigeria began in 1896. The Nigeria electricity supply company (NESCO) commenced operations as an electric utility company in Nigeria in 1929 with the construction of a hydroelectric power station at Kurra near Jos. The electricity corporation of Nigeria (ECN) was established in 1951, while the first 132KV line was constructed in 1962, linking Ijora power station to Ibadan power station.

The Niger Dams Authority (NDA) was established in 1962 with a mandate to develop the hydropower potentials of the country. However, ECN and NDA were merged in 1972 to form the National Electric Power Authority (NEPA). In 1998, NEPA ceased to have exclusive monopoly over electricity generation, transmission, distribution and sales [9]. NEPA was later changed to PHCN (Power Holding Company of Nigeria) on the 15th of April 2005 thinking that a change in name will necessarily mean an improvement in performance.
The Nigerian power generation sector can be detailed into the following sub-sectors:

1. Existing federal government of Nigeria (FGN) power generation facilities.

TABLE 1
Existing Govt. Owned power stations-Hydro

s/ no	Name of generation company	Year of const.	location	Installed capacity (MW)	Available capacity (MW)
1	Kanji hydroelectric plc - kanji power station	1968	Kanji Niger State	760	480
2	Jebba hydroelectric plc. Jebba power station	1985	Jebba Niger State	540	450
3	Shiroro hydroelectric plc	1989	Shiroro Niger state	600	450
			Total	1,900	1,380

2. Independent power projects.
3. National integrated power projects.

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TABLE II
Existing FGN power stations – Thermal

s/no	Name of generation company	Year of const.	location	Installed capacity (MW	Available capacity (MW)
1	Egbin power plc	1986	Egbin, Lagos state	1320	1100
2	Geregu power plc	2007	Geregu, Kogi state	414	276
3	Omotosho power plc	2007	Omotosho, Ondo state	304	76
4	Olorunsogo power plc	2008	Olorunsogo, Ogun state	304	76
5	Delta power plc	1966	Ughelli, Delta state	900	300
6	Sapele power plc	1978	Sapele, Delta state	1020	90
7	Afam(iv-v) power plc	1963/01	Afam, River state	726	60
8	Calabar thermal power station	1934	Calabar, Cross river state.	6.6	Nil
9	Oji river power station	1956	Oji river, Achi, Enugu state	10	Nil
			Total	5,004.6	1,978

TABLE III
Independent power plants

s/n	Name of power plant	location	Installed capacity (MW)	Available capacity (MW)
1	AES power station	Egbin, Lagos state	224	224
2	Shell-Afam vi power station	Afam, Rivers state	650	650
3	AGIP-OKPAI power station	Okpai, Delta state	480	480
4	ASG-IBIOM power station	Akwa ibiom state	155	76
5	RSG-TRANS Amadi power station	Port-Harcourt, rivers state	100	24
6	RSG-omoku power station	Omoku, Rivers state	150	30
		Total	1,759	1,484

The IPP's are the non-FGN funded invested in the Nigerian power generating industry.

3 Descriptions of Some of the Power Plants

3.1 Kanji hydropower station

The first unit of kanji hydropower powerhouse were put into operation in 1968 and other units were added between the period 1969 and 1978. The dam consists of a 2,315 meters (M) long right embankment section separated by a 550m long concrete intake and spillway structure. A navigation lock is situated near the centre of the left embankment section. There is also a 4,115m long embankment saddle dam located approximately 1.6kilometers (km) east of the project. The maximum height of the saddle dam above the foundation is 80m at the right river channel. The facility when it was fully commissioned was equipped with 8 turbines (numbered 5 to 12) with a total installed capacity of 760MW. Units 1-4 were not installed at commissioning but left as open bays with installed penstocks and other structural works [10].

3.2 Jebba hydropower station

This station is located in Kwara state downstream of the kanji hydro power station. It has 6 units which were commissioned thus: 6 x 95MW -------- 1986.

3.3 Shiroro hydropower station

This station uses natural gas and is located in Niger state on the Shiroro Gorge along the Kaduna River. It has four generating units, which were commissioned thus:

1 x 150MW ------------- 1989
3 x 150MW ------------- 1990

There are various distribution companies in Nigeria thus:

1. Abuja Electricity Distribution Plc.
2. Benin Electricity Distribution Plc.
3. Eko Electricity Distribution Plc.
4. Enugu Electricity Distribution Plc.
5. Ibadan Electricity Distribution Plc.
6. Ikeja Electricity Distribution Plc.
7. Jos Electricity Distribution Plc.
8. Kaduna Electricity Distribution Plc.
9. Kano Electricity Distribution Plc.
10. Port-Harcourt Electricity Distribution Plc.
11. Yola Electricity Distribution Plc.

The distribution companies comprising a national grid, in turn, are managed by a separate company, the transmission company of Nigeria (TCN) PLC, from a national control centre at Shiroro. TCN is a subsidiary of the Power Holding Company of Nigeria (PHCN).

4 Energy Demand and Supply in Nigeria

In the development of every nation, electricity plays a very vital role. Nigeria's electricity supply has been on the down side (very poor) making demand for electricity to be greater than supply.

The nation's electricity problems hinder its development notwithstanding the availability of vast natural resources in the country. Only four sources (coal, crude oil, natural gas and hydro) are currently being utilized in processed forms while two others (wood fuel and solar) are used in their crude forms for heating, cooking and lighting. It is widely accepted that there is a strong correlation between socio-economic development and the availability of electricity.

Power supply in Nigeria is not a recent phenomenon judging from the fact that electricity was first generated in Nigeria in 1896, just a decade after its introduction in Europe [14]. In 1952/53 the total electricity consumption was only 77 million kilowatts-hours which grew to 4066 million kilowatts-hours in 1979/80 and became 188340 million kilowatts-hour in 2007/2008 [15]. As at July 12, 2011 the electricity consumption was recorded to be 19.21 billion kilowatts-hours.

TABLE IV
YEARLY ELECTRICITY CONSUMPTION OF NIGERIA

Country	2000	2001	2002	2003	2004	2005
Nigeria	13.72	17.37	14.77	14.55	14.55	18.43

Country	2006	2007	2008	2009	2010	2011
Nigeria	14.46	17.71	15.85	15.85	19.21	19.21

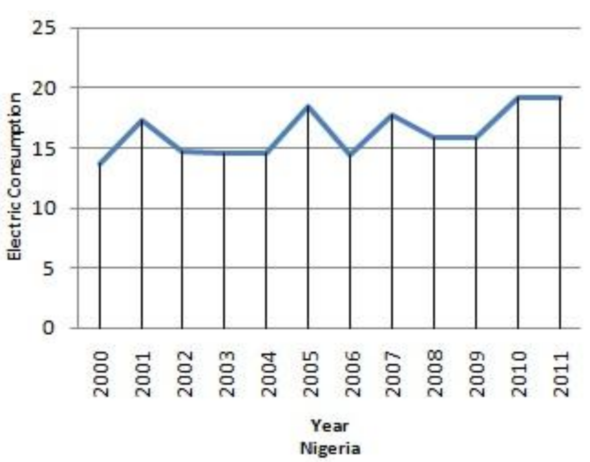

Fig I: graph showing Nigeria's yearly electricity consumption

In order to produce reasonable electricity supply targets and milestones, it is imperative to have energy demand and supply projections for the country using internationally accepted energy modelling techniques. Accordingly the Energy Commission of Nigeria enrolled in the IAEA's project "Sustainable Energy Development in Sub-Saharan Africa" and acquired the competence to use international energy modelling tools.

The Energy Commission of Nigeria (ECN) was established by Act No. 62 of 1979, as amended by Act No. 32 of 1988 and Act No. 19 of 1989, with the statutory mandate for the strategic planning and co-ordination of national policies in the field of energy in all its ramifications. By this mandate, the Commission which is the apex government organ empowered to carry out overall energy sector planning and policy co-ordination. As part of its contribution to their solution of the problems of the electricity sector along the line of its mandate, the ECN has been collaborating with the International Atomic Energy Agency (IAEA) under an IAEA regional project titled "Sustainable Energy Development for Sub-Saharan Africa (RAF/0/016)".

The project entails capacity building for energy planning and the determination of the actual energy demand and the strategies for supply for each participating country over a 30-year time horizon. The implementation of the project requires the establishment of a Working Team (WT) and a Country Study Team (CST) both of which include the major public and private stakeholders in the energy sector of the country. The working team consists of technical experts that directly implement the project and reports to the CST, which serves as the steering committee for the project on a regular basis. Members of the WT were trained on the use of the IAEA models and have computed the Nigeria energy demand and supply projections covering the 2005-2030. The project involves the use of the following IAEA Energy Modelling tools:

- Model for the Analysis of Energy Demand (MAED)
- Model for the Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE).

4.1 Energy Demand Projection

The energy demand projections were computed using MAED with the key drivers of energy demand, namely demography, socio-economy and technology. The application of MAED requires detailed information on demography, economy, energy intensities and energy efficiencies. This information is first assembled for a base year which is used as the reference year for perceiving the evolution of the energy system in the future. Selection of the base year is made on the basis of availability of data, assessment that the data are representative of the economic and energy situation of the country.

MAED allows the breakdown of the country's final energy consumption into various sectors and within a sector into individual categories of end-uses in a consistent manner. The breakdown helps in the identification of the social, economic and technical factors influencing each category of final energy demand. In modelling the Nigeria's energy case, four economic scenarios were developed and used as follows:

Reference Scenario - 7% GDP Growth;

1. The main driver of growth is the manufacturing sector.
2. GDP grows by an average of 7% p.a
3. Manufacturing accounts for 15% of GDP by 2030 from 6% in 2005.
4. Per capita electricity consumption increase to 4,000kWh.
5. Consistent with the MDG objective of reducing poverty by half by 2015.

High Growth Scenario - 10% GDP Growth;

1. GDP grows by an average of 10% p.a
2. Manufacturing contributes 24% of GDP by 2030
3. Per capita electricity increase to 5026kWh by 2030
4. Nigeria is transiting from an agrarian economy to an industrializing nation.

Optimistic Scenario I – 11.5% GDP Growth;

1. GDP grows by an average of 11.5% p.a in line current administration's vision for the economy.
2. Manufacturing contributes 25% to GDP.
3. Per capita electricity increase to 5,450kWh by 2030.

Optimistic Scenario II – 13% GDP Growth (based on Presidential Pronouncement for the desire to be among the first 20 economies by 2020).

1. GDP grows by an average of 13% p.a in line current administration's vision for the economy.
2. Manufacturing contributes 25% to GDP.
3. Per capita electricity increase to 6620kWh by 2030.

Economic growth and structure of the economy are the major driving parameters in the four scenarios. Projected electricity demand has been translated into demand for grid electricity and peak demand on the bases of assumptions made for T&D losses, auxiliary consumption, load factor and declining non-grid generation. Table 1 shows the electricity demand projections for the scenarios. It must be emphasized that the demand indicated for 2005 represents suppressed demand, due to inadequate generation, transmission, distribution and retail facilities. Suppressed demand was expected to be in non-existence in 2010.

For the 13% GDP growth rate, the demand projections rose from 5,746MW in the base year of 2005 to 297,900MW in the year 2030 which translates to construction of 11,686MW every year to meet the demand. The corresponding cumulative investment (investment & operations) cost for the 25-year period is US$ 484.62 billion, which means investing US$ 80.77 billion every five years within the period. In conducting the studies, all the available energy resources in the country were considered in order to broaden the nation's energy supply mix and enhance its energy security.

TABLE V
ELECTRICITY DEMAND PROJECTIONS PER SCENARIO, MW

Scenario	2005	2010	2015	2020	2025	2030
Reference (7%)	5,746	15,730	28,360	50,820	77,450	119,200
High growth (10%)	5,746	15,920	30,210	58,180	107,600	192,000
Optimistic I (11.5%)	5,746	16,000	31,240	70,760	137,370	250,000
Optimistic II (13%) Presidential pronouncement	5,746	33,250	64,200	107,600	172,900	297,900

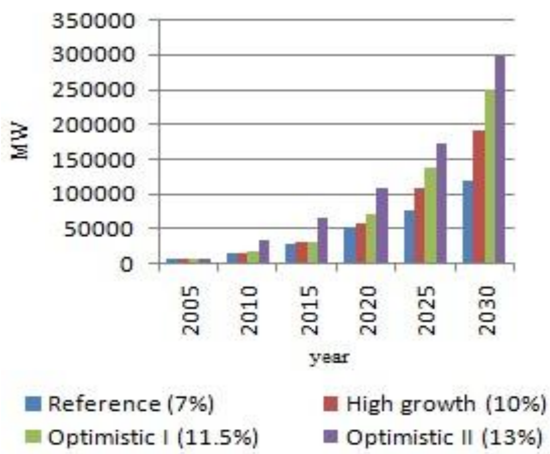

Fig. II: Electricity Demand projection.

TABLE VI
ELECTRICITY SUPPLLY PROJECTION

Scenario	2005	2010	2015	2020	2025	2030
Reference (7%)	6440	15668	28356	50817	77450	136879
High growth (10%)	6440	15861	30531	54275	107217	192079
Optimistic I (11.5%)	6440	15998	31235	71964	177371	276229

The demand projection method of MAED is given by the following equation [13]:

$$E_i = e_i * VD_i = e_o * F_i * VD_i \quad (1)$$

Where E_i = energy demand in year i

e_o = base year energy intensity or energy consumption per unit of VD in base year. (e_i = the value in year i)

F_i = modifier of e_o for year i; it depends on such factors as penetration of technology, energy use efficiency, economy, life style, demography etc, in year i relative to the base year.

VD_i= value of the driver of energy demand in year i.

4.2 Energy supply projection

The total energy supply were computed using MESSAGE and utilizes the projected energy demand as an input to produce a supply strategy. MESSAGE is an energy supply model, representing energy conversion and utilization processes of the energy system (or it's part) and their environmental impacts for an exogenously given demand of final energy. It is used for development of medium-term strategies, the planning horizon being in the order of 30 years. The time scope is limited due to uncertainties associated with future technological development. The energy system dynamics are modelled by a multi -period approach. It is an optimisation model which from the set of existing and possible new technologies selects the optimal in terms of selected criterion mix of technologies able to cover a country's demand for various energy forms during the whole study period.

MESSAGE takes into account demand variations of various final energy forms during the day, week and year, as well as different technological and political constrains of energy supply. It is an energy and environmental impact model, enabling the user to carry out integrated analysis of the energy sector development and its environmental impacts. The application of the MESSAGE model results in a least-cost inter-temporal mix of primary energy, energy conversion and emission control technologies for each scenario. For the computation of Nigeria's Energy Supply the same scenario that was used in MAED are used. The result for the electricity supply projection is shown below:

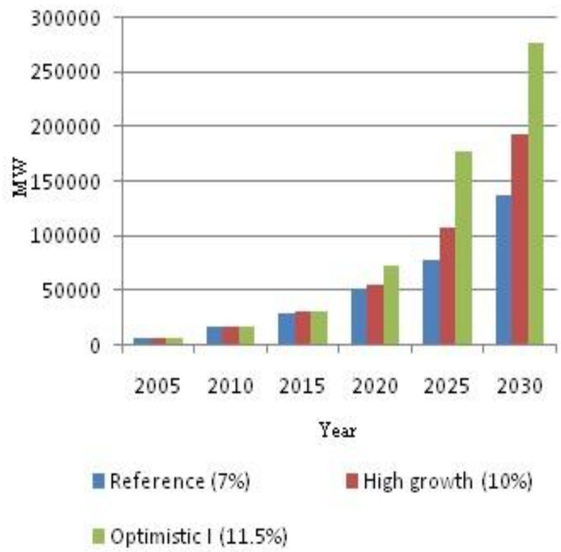

Fig II: Electricity Supply projection

1. Objective of the supply projections was to optimal fuel or source-mix for the diversification of the electricity supply.
2. Supply projections used the model for energy supply strategy alternatives and their general environment (MESSAGE).
3. Scenarios are similar to that used for demand-side analysis, except for non-inclusion of the optimistic scenario II to obtain gross electricity supply projections.
4. Seven fuel or source-options, including coal, gas, hydro, nuclear, wind, solar, were used for optimization. The optimization provided relative or likely contributions of each source-mix in the projected electric supply [16].

5 Energy Efficiency and Conservation

Energy utilization in Nigeria is far from efficient, forest and woodland reserves are being depleted for heating and cooking purposes using stoves of efficiency less than 10%. The results include soil erosion, desertification, micro climate change etc. Oil extraction process includes a lot of waste in the form of spillage resulting in serious environmental problems. Serious pollution due to inefficient use of fossil fuels is affecting our major cities, leading to negative consequences on agriculture, water supply, forest resources, sea level rise, health etc. Continuous flaring of large volumes of natural gas in the oil fields of the Niger Delta is worsening the situation. Emission from inefficient transport vehicles are sources held hazard in major cities. Inefficient electrical appliances (lighting, refrigeration, air conditioning, motors, fans etc), especially in the residential, commercial and industrial sectors in the face of inadequate supply has aggravated the demand-supply imbalance. Energy efficiency regulations are currently absent in the country.

Although energy efficiency and conservation is not a resource per se, it is acknowledged that its adoption in the country can significantly mitigate the supply the supply challenge. It is in recognition of this that the Federal Government of Nigeria approved the establishment of a National centre for energy efficiency and conservation. The centre, which operates under the auspices of the energy commission of Nigeria, is situated at the University of Lagos, in the commercial centre of Nigeria. The centre is charged with the responsibility for organizing and conducting research and development in energy efficiency and conservation. In this regard, the centre carries out the following functions:

1. Develop and execute pilot/demonstration project highlighting energy efficiency concepts.
2. Develop guidelines for energy efficient end-use products and advise on their implementation.
3. Develop energy efficiency codes, standards and specifications for domestic, industrial and commercial facilities.
4. Serve as a centre for training of high level man power in energy efficiency and conservation.
5. Gather, analyze and manage energy supply and consumption data and information.
6. Disseminate information on energy efficiency and conservation concepts through public awareness programmes such as seminars, workshops, publications etc.
7. Perform any other functions, as may be directed by the federal government.

6 Conclusion

Poor electricity supply in Nigeria to match the demand is due to poor generation of electricity from our power plants. Some of these plants are not operational (example: Oji river power station and Calabar thermal power station) due to lack of maintenance, while those in operation, do not work at full capacity thereby generating less than the installed capacity.

An estimated total investment to meet the demand for the optimistic growth scenario is US$484.62 billion. The Federal Government alone cannot provide this level of funding. The state governments, private sector and foreign investors must be involved. Moreover all the country's energy resources need to be deployed in order to achieve matching supply with demand on a continuous base [11].

Also to solve these problems of demand-supply imbalance the following needs to be done [12]:

1. Proper planning using internationally recognised Energy Modelling tools will optimise the Nigeria's Electricity supply as well as promoting Energy mix.
2. Full implementation of the National Energy policy and the National Energy Master plan will prevent the country from shortage of Electricity supply.
3. Coal should contribute 40% to the Electricity generation mix due to its abundance in the country which is estimated to be in excess of 2.5 billion tonnes.
4. Using the result of the projected Electricity Supply will reduce the Electricity under supply in the country.

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