The economic cost of unreliable grid power in Nigeria

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Abstract

The ever increasing demand for electrical power in Nigeria, coupled with a limited supply, have restricted the nation's socioeconomic development.The country's policy makers, aware of this, have formulated and enacted energy development policies in recent years targeted at diversifying the current electricity mix and increasing electrification to rural settlements.

Despite these efforts, electricity infrastructure projects have been sidelined, power outages are common and grid unreliability is costing industry significant amounts to secure the electricity supply necessary for business sustainability and profitability.

This paper presents the current state of the electricity industry in Nigeria and argues the case for integration of renewable energy technologies. A case study is presented based on electricity cost information collected from a survey of Nigerian industry. Three future electricity supply scenarios are presented: a do-nothing or business-as-usual scenario; a scenario of increased reliance on grid power due to improvements in reliability; and a scenario involving shifting some of the current diesel on-site generation to solar photovoltaics. It is shown that increasing the utilization of renewable sources could significantly reduce the costs and CO_2 emissions incurred due to the current reliance on self-generation, primarily using diesel generators, amidst grid unreliability.

Keywords: Diesel Generators; Electricity Sector; Nigeria; Power Generation; Power Supply; Renewable Energy

1. Introduction

It is essential that Nigeria's electricity mix of natural gas and hydropower be expanded for power generation sustainability. With a growing population and forecast of just over 262 million people by the year 2030 (Worldometers 2016) connection of the entire country to the national grid is fading especially considering the practical difficulties and expense of constructing new transmission lines. The federal government aware of this have started evaluating more sources for diversified electricity production and in April 2015 supporting this cause, the Federal Executive Council (FEC) approved the National Renewable Energy and Energy Efficiency Policy (NREEEP) (NREEEP 2015).

The NREEEP document addresses key areas such as renewable energy supply & utilisation, renewable energy pricing and financing; legislation; regulation and standards; energy efficiency and conservation; renewable energy project implementation issues; research and development; capacity building and training; gender and environmental issues and planning and policy implementation (NREEEP 2015). In summary, the policy's thrust is the optimal utilisation of Nigeria's energy resources for sustainable development.

The current situation of epileptic power supply and incessant power outages nationwide, has left industries, corporations, households and businesses with no other option than to find alternative means of generating their own electricity (Akpan, Essien and Isihak 2013), (Oseni 2016). This is mainly to ensure security of supply and more so cushion the unfavourable effect of power outage on operations (which usually translates as monetary losses for the industrial sector).

The industrial sector, for example, relies heavily on the use of diesel electric power generators in ensuring continued work operations. The use of these generators has resulted in the high cost of energy as it constitutes 40% of the country's production cost (Aliyu, Ramli and Saleh 2013). According to the Manufacturers Association of Nigeria (MAN), more than ₦ 1.8 billion (US$ 11.340 million) is spent weekly on the operation and maintenance of these generators industry-wide (Aliyu, Ramli and Saleh 2013). Furthermore, with the removal of subsidy on diesel, pump diesel fuel retails at ₦ 158 (US$ 0.80) per litre, a similar price to that of China (Nigeria Diesel Prices 2016), although the cost of production is nine times higher than in China. In a survey reported by (Oseni 2016), improvements in grid reliability were found to increase respondents' willingness to dispose of their generators, particularly in the case of small business owners.

Practical solutions are required to reduce the dependency on diesel generators while maintaining the connectivity and reliability of supply to the majority of the country not served by a reliable connection. At the forefront should be the implementation of off grid and mini/micro grid solutions especially for rural communities, settlements and the industrial sector. Previous studies have shown that some regions of the country possess considerable exploitable resources in wind and, in particular, solar energy (Ayodele, Ogunjuyigbe, and Amusan 2016), (Ikejemba, and Schuur 2016) and have demonstrated the cost competitiveness of electricity from hybrid renewable systems with grid-supplied electricity (Ajayi and Ohijeagbon 2015).

Therefore, discussions in this paper are broken down into sections with the objective of eliciting the cost incurred by the industrial sector in sustaining operations as a result of grid unreliability and interrupted power supply. Section 2 gives a background on Nigeria's electricity sector, section 3 discusses the methodology adopted, and section 4 analyses the results of the case study carried out on the industrial sector, with section 5 covering the discussions and the conclusion in section 6.

2. Nigeria's Electricity Sector

The promulgation of the Electricity Power Sector Reform (EPSR) Act in 2005, led to the unbundling of the wholly government owned National Electric Power Authority (NEPA) into eighteen "successor" companies i.e. six generation companies (GenCos), one transmission company (Transmission Company of Nigeria (TCN)) and eleven distribution companies (DisCos). These companies remained under a holding company – Power Holding Company of

Nigeria, (PHCN) until September 2013 when they were conceded and subsequently handed over to investors (November, 2013) in line with the power sector reform objectives (PTFP 2015). The Nigerian Electricity Supply Industry (NESI), like many other electricity markets, delivers the electricity supply value chain starting from generation, through transmission and ending with the distribution of electricity to consumers.

2.1. ***Generation Subsector***

Nigeria's energy mix of natural gas (combined & simple cycle) and hydro-power plants at 84% and 16 % respectively, is integrated for central systems operation at the National Control Centre (NCC), Oshogbo in Osun State (PTFP 2015). For stability and system reliability, regional control centres (RCCs) are also located in three other areas of the country (Shiroro - Niger State, Ikeja West - Lagos State and Benin City - Edo State). With total dependence on two sources of electricity generation and approximately 82% of generating plants in the southern region of the country, the nation's electricity security, stability and reliability continues to be at risk. Figure 1 shows Nigeria's population and power plant distribution.

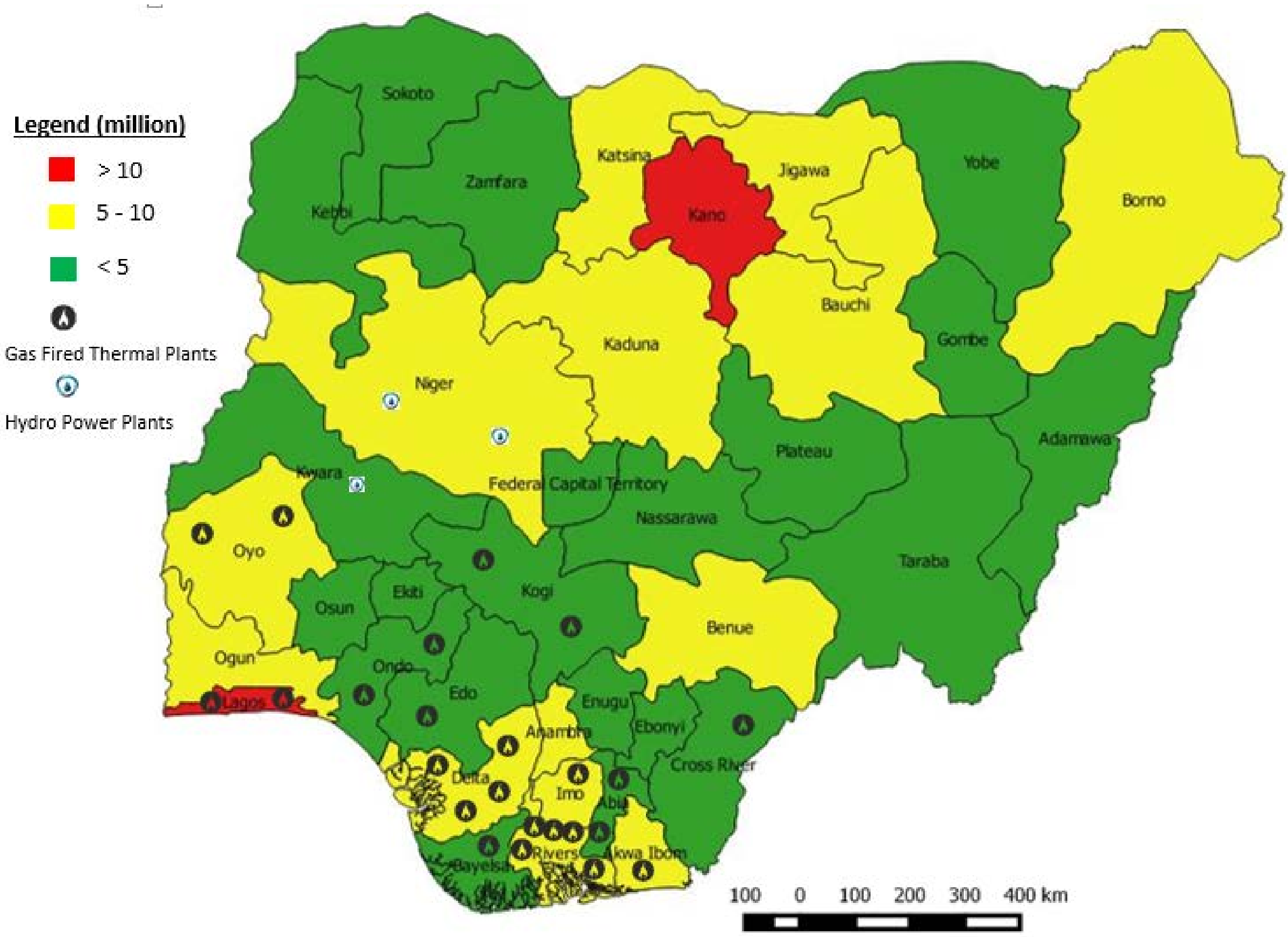

Figure 1 – Map of Nigeria showing population and power plant distribution

As of 2015, the nation's generation capacity was approximately 12.5 GW, with average available capacity of 7.14 GW and operational capacity of 3.9 GW (APT 2015). That being said, Nigeria achieved a milestone peak generation of 5.1 GW on 2nd February, 2016 with maximum wheeled energy of 109 GWh recorded on the 26th January, 2016 (Nigerian Electricity System Operator 2016). Table 1 shows Nigeria's electricity generation profile from 2010 to 2015.

Table 1 – Nigeria's electricity generation profile – Adapted (GIZ-NESP 2015)

Year	Av. Gen Availability (MW)	Max Peak Gen (MW)	Max daily energy Gen (MWh)	Total energy Gen (MWh)	Total energy sent out (MWh)	Per Capita energy supplied (kWh)
2010	4,030.5	4,333.0	85,457.5	24,556,331.5	23,939,898.9	153.5
2011	4,435.8	4,089.3	90,315.3	27,521,772.5	26,766,992.0	165.8
2012	5,251.6	4517.6	97,718.0	29,240,239.2	28,699,300.8	176.4
2013	5,150.6	4458.2	98,619.0	29,537,539.4	28,837,199.8	181.4
2014	6,158.4	4395.2	98,893.8	29,697,360.1	29,013,501.0	167.6
2015	7,141.2	4883.9	106,288.0	33,980,040.8	31,465,920.3	170.1

Maintenance and repair works constrain available generation capacity whilst operational capacity is constrained by (APT 2015):

i. Insufficient gas supply due to low production;
ii. Infrastructure deficit and vandalism;
iii. Poor water management;
iv. High frequency due to demand imbalances;
v. Line constraints also bordering on inadequate grid infrastructure.

2.2. ***Transmission Subsector***

The transmission subsector is charged with bulk wheeling the generated power through high voltage transmission lines and sub-stations to deliver electricity at lower voltage levels for onward supply to the consumer by the distribution companies (PTFP 2015).

The transmission network consists of 159 sub-stations with a total transformation capacity of 19,000 MW spanning 15,022 km in total length (APT 2015). The national grid has a maximum wheeling capacity of 5,300 MW, which is currently above the operational generation capacity but still substantially below the installed capacity.

The grid is plagued by partial and full system collapses and forced outages owing to a poor voltage profile, limited control infrastructure, ineffective maintenance and poor system management (APT 2015). Figure 2 shows a decline in the number of system collapse over the years (2009 – 2015) but this remains slightly above the benchmark range of 2 to 6 per annum for emerging countries (APT 2015).

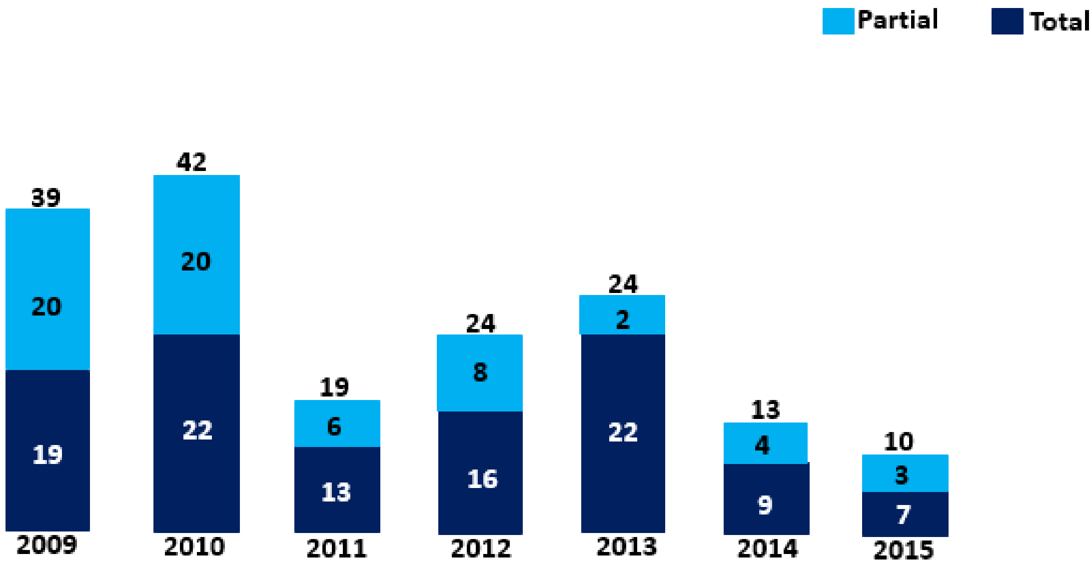

Figure 2 – Number of system collapses over the years – Adapted (APT 2015)

2.3. ***Distribution Subsector***

This serves as the customer interface platform of the value chain with the distribution companies responsible for retailing electricity to the end user. Nigeria's peak demand as of 2015 was estimated at 12,800 MW, whilst her electrification rate at 45% with urban and rural electrification rates at 55% and 35% respectively (translating to approximately 95 million people without access to grid power supply) (GIZ-NESP 2015).

In 2014, approximately 46% of energy was lost through technical (12%), commercial (6%) and collection (28%) losses (APT 2015). The distribution system constitutes a problem, primarily because of the poor condition of the networks and a large number of unmetered consumers (APT 2015). These issues contribute to electricity distribution losses countrywide.

Eleven distribution companies (DisCos) with regional coverage areas, collectively cover the entire country as indicated in Table 2.

Table 2 – Distribution companies and their coverage areas

S/N	DisCos	Coverage Areas (States)
1	Abuja Electricity Distribution Company	F.C.T, Niger, Kogi and Nasarawa
2	Benin Electricity Distribution Company	Edo, Delta, Ondo and part of Ekiti
3	Eko Electricity Distribution Company	Lagos
4	Enugu Electricity Distribution Company	Enugu, Abia, Anambra, Imo and Ebonyi
5	Ibadan Electricity Distribution Company	Oyo, Ogun, Osun, Kwara and part of Ekiti
6	Ikeja Electricity Distribution Company	Lagos
7	Jos Electricity Distribution Company	Plateau, Bauchi, Benue and Gombe
8	Kaduna Electricity Distribution Company	Kaduna, Sokoto, Kebbi and Zamfara
9	Kano Electricity Distribution Company	Kano, Jigawa and Katsina
10	Port Harcourt Electricity Distribution Company	Rivers, Cross-River, Bayelsa and Akwa-Ibom
11	Yola Electricity Distribution Company	Adamawa, Yobe, Borno and Taraba

3. Methodology

To further elicit the problem of electricity supply country-wide, a case study on the industrial sector was presented with a cost benefit analysis carried out on the data supplied by industries. Three future scenarios were created to guide our analysis and enable us quantify the unreliability of electricity supply as well as determine its economic impact on Nigeria's industrial sector in particular.

3.1. A Case Study – The cost of unreliable grid power on manufacturing in Nigeria

This case study consolidates earlier discussions in this paper on the current state of electricity supply in Nigeria. It analyses the manufacturing industry in Nigeria, by examining the added costs to their operations as a result of unreliable grid power. The manufacturing sector is selected for analysis due to its significant contribution to the nation's GDP (GIZ-NESP 2015). Furthermore this sector, in the wake of falling oil prices, could be critical to the government's intensified efforts of diversifying the economy and reducing its overdependence on crude oil export earnings.

3.2. Data Presentation

The industrial sector in Nigeria is made up of factories producing everything from food, beverages, tobacco, textiles, footwear, wood, plastic, rubber and paper to paint, cement, electrical materials and iron/steel. Pharmaceuticals and motor vehicle assembling are also industrial activities in Nigeria. Therefore, data presented in this section (particularly the ones included in Tables 3-8) have been collated from questionnaires circulated by Nigerian Electricity Management Services Agency (NEMSA) to individual manufacturing industries. Other data presented and assumptions made within this section have been generated directly or indirectly through contact with industries.

Although, the list of manufacturing industries surveyed is not exhaustive, it accounts for industries in all but one geo-political zone of the country and is representative of industry-wide electricity consumption patterns. Tables 3-8 show the industry types by region and their electricity consumption patterns in monetary terms (electricity and generator fuel costs) for the years 2014 and 2015. A total of 20 respondents' data were released by NEMSA of which only 14 could be used for this analysis (due to incompleteness and illegibility). All costs are represented in million Naira (₦ - million) with the formula - ($\overline{X}= \frac{(\sum X)}{N}$) used in deriving the average electricity cost.

Table 3 – Cost of electricity to factories in the North-West region

Region 1 – North West					
Year		**2014**		**2015**	
Name	**Type**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**
Factory A	Beverages	51.2	15.8	53.6	15.8
Factory B	Beverages	923.7	557.6	752.3	422.8
Factory C	Textile	70	40	90	36
Factory D	Electrical (Cables)	34	23.9	47.7	22.4
Total		**1,078.9**	**637.3**	**943.6**	**497**

Table 4 – Cost of electricity to factories in the North-Central region

Region 2 – North Central					
Year		**2014**		**2015**	
Name	**Type**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**
Factory E	Food (Flour)	12	71.3	14.4	82.4
Factory F	Food (Cereal)	170	177	128	260
Factory G	Food (Cereal)	19.5	21	20.1	26
Total		**201.5**	**269.3**	**162.5**	**368.4**

Table 5 – Cost of electricity to factories in the North-East region

Region 3 – North East					
Year		**2014**		**2015**	
Name	**Type**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**
Factory H	Electrical (Cables)	2.8	5.2	3.3	4.7
Factory I	Beverages	38.4	274.2	45.6	274.8
Total		**41.2**	**279.4**	**48.9**	**279.5**

Table 6 – Cost of electricity to factories in the South-West region

Region 4 – South West					
Year		**2014**		**2015**	
Name	**Type**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**
Factory J	Food(Processed Meat)	235.7	53	285.2	61.7
Factory K	Iron/Steel	42.9	49.3	44.7	22.9
Factory L	Iron/Steel	364.9	2.2	350	0.7
Factory M	Iron/Steel	0.9	17.3	0.6	14.4
Total		**644.4**	**121.8**	**680.5**	**99.7**

Table 7 – Cost of electricity to factories in the South-East region

Region 5 – South East					
Year		**2014**		**2015**	
Name	**Type**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**
Factory N	Beverages	7.1	8.6	7.7	9.1
Total		**7.1**	**8.6**	**7.7**	**9.1**

Table 8 – Total and average costs of electricity to the factories in 2014 and 2015

Year	**2014**		**2015**	
Source of Supply	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**	**Grid Supply Costs (₦ - million)**	**Self-Generation (Fuel) Costs (₦ - million)**
Grand Total (₦)	**1,973.1**	**1,316.3**	**1,843.1**	**1,253.7**
Average (₦)	**140.9**	**94**	**131.7**	**89.6**
Average cost implication of electricity supply in percentage (%)	**60**	**40**	**59.5**	**40.5**

4. Analysis

In this section, a cost benefit analysis of the data presented is carried out to determine the enormity of the costs incurred by factories in order to sustain their operations. For broader understanding use US$1 = ₦180 (Central Bank of Nigeria (CBN) exchange rate in 2014/2015) (CBN 2016).This exchange rate holds for the period of data collected (2014 and 2015).

4.1. *Assumptions*

- We created a single industrial electricity consumer, “Company X”, which is based on the average load of the survey respondents, reflective of a typical industrial user in Nigeria. The following values were assumed in formulating the plant size, costs, demand profile and potential supply options for Company X.
- Industries having at least two operational generators with capacities and costs in the range of 150 kVA – 1250 kVA and ₦50 - ₦150 million respectively;
- Daily energy demand is 600 kWh, industries operate for 23 hours a day and demand is uniformly distributed throughout these hours i.e. 26.1 kW for each hour
- Scheduled maintenance of machineries and equipment occurring at least once every three months;
- With average cost of ₦50,000 for both generators maintenance i.e. ₦200,000 per year;
- Average monthly maintenance of 30 hours and grid power outage of 30 days per year;
- Increased number of outages as some residential consumers are served by sub-transmission lines;
- An 80% improvement in grid power (with good power quality) will bring about a reduction in self-generation and this will be reflected in the electricity and fuel costs - scenario 2;
- 220 kW is the amount of power required to sustain the industry’s operation - scenario 3;

- $1500m^2$ is the estimated land space needed to generate this amount of power - scenario 3;
- Cost of the required land space using one of the industrial states in Nigeria (Ogun state) would be ₦ 25 million - scenario 3;
- System was sized with solar generation for 5 hrs a day and battery storage utilised for the remaining 18 hrs - scenario 3;
- Deep cycle batteries connected in an array with 50% depth of discharge were considered - scenario 3;
- Inverter and charge controllers having 10 year lifetime were considered – scenario 3;
- Renewable Energy System (RES) installation is 20% of capital cost - scenario 3;
- Batteries replacement every 5 years - scenario 3;
- Batteries re-installation cost in the 8th year is 10% of total purchase costs - scenario 3;
- Balance of System components (wires, switchgears, circuit breakers, connectors etc.) is 15% of capital cost - scenario 3;
- Annual maintenance of the RES is 3% of installation cost - scenario 3;

Table 9, 10 and 11 show Cost Benefit Analysis calculations for Company X over a 10 year period

Table 9 – Scenario 1 of company X's cost-benefit analysis of operating a manufacturing plant in Nigeria

Data Required				**Costs (₦ - million)**			
Generator costs (immediate payment)				50 x 2 = 100			
Year 1 Electricity costs				140.9			
Year 1 Fuel costs				94			
Year 2 Electricity costs				131.7			
Year 2 Fuel costs				89.6			
Years 1 – 10 O&M costs				0.2/Year			
Scenario 1 – Business as Usual (Maintain the current system of operation)							
Year	**Costs (₦ - million)**						**Benefits (₦ - million)**
	Immediate Payment	Electricity	Fuel	O&M	Total Costs	PV of Total Costs	PV of Benefits
1	100	140.9	94	0.2	335.2	319.2	0
2	0	131.7	89.6	0.2	221.4	200.8	0
3	0	141	94	0.2	235.2	203.2	0
4	0	141	94	0.2	235.2	193.5	0
5	0	141	94	0.2	235.2	184.3	0
6	0	141	94	0.2	235.2	175.5	0
7	0	141	94	0.2	235.2	167.2	0
8	0	141	94	0.2	235.2	159.2	0
9	0	141	94	0.2	235.2	151.6	0
10	0	141	94	0.2	235.2	144.4	0
Grand -Total of Costs and Benefits (₦ - million)					**2,438.2**	**1,898.9**	**0**
As no benefits are recorded for the 10 year period, the present value (PV) of benefits would be zero for the duration considered. **Therefore, the net PV (NPV) in Naira (₦ - million) = - 1,898.9**							
Calculating discount rate taking into account inflation: Where discount rate = 14% and inflation = 8.8% Therefore; Real discount rate = (1 + discount rate)/(1 + inflation rate) – 1 = (1+14%)/(1+8.8%) – 1 **~ 5%**							

Other considerations for this analysis:	
No Benefits	
Year(s)	Costs (₦ - million)
1	Generators cost (Immediate payment), Electricity costs, Fuel costs and O&M costs
2 - 10	Electricity costs, Fuel costs and O&M costs

Table 10 – Scenario 2 of company X's cost-benefit analysis of operating a manufacturing plant in Nigeria

Data Required	**Costs (₦ - million)**
Generator costs (immediate payment)	50 x 2 = 100
Year 1 Electricity costs	140.9
Year 1 Fuel costs	94
Year 2 Electricity costs	131.7
Year 2 Fuel costs	89.6
Years 1 & 2 O&M costs	0.2/Year
Years 3 – 10 O&M costs	0.1/Year

Scenario 2 – Improvement in Grid Power

Year	**Costs (₦ - million)**					
	Immediate Payment	Electricity	Fuel	O&M	Total Costs	PV of Total Costs
1	100	140.9	94	0.2	335.2	319.2
2	0	131.7	89.6	0.2	221.4	200.8
3	0	141	18	0.1	159.1	137.4
4	0	141	18	0.1	159.1	130.9
5	0	141	18	0.1	159.1	124.7
6	0	141	18	0.1	159.1	118.7
7	0	141	18	0.1	159.1	113.1
8	0	141	18	0.1	159.1	107.7
9	0	141	18	0.1	159.1	102.6
10	0	141	18	0.1	159.1	97.7
Grand -Total of Costs (₦ - million)					**1,829.4**	**1,452.7**

Year	**Benefits (₦ - million)**				
	Sale of Generator	Fuel Savings	O&M Savings	Total Benefits	PV of Total Benefits
1	0	0	0	0	0
2	0	0	0	0	0
3	41.6	72	0.1	113.8	98.3
4	0	72	0.1	72.1	59.3
5	0	72	0.1	72.1	56.5
6	0	72	0.1	72.1	53.8
7	0	72	0.1	72.1	51.2
8	0	72	0.1	72.1	48.8
9	0	72	0.1	72.1	46.5
10	0	72	0.1	72.1	44.3
Grand -Total of Benefits (₦ - million)				**618.4**	**458.6**

With the same discount rate i.e. 5% used in scenario 1 still valid, **we calculate the NPV in Naira (₦ - million)as:**
458.6 – 1,452.7 = - 994.1

Other considerations pertinent to this analysis:

Generator cost depreciation over 2 years in Naira (₦ - million):
Using sum of the year digits method and assuming that the residual/salvage value is 10% of initial purchase price;
Therefore residual salvage value is 10% of 50 million = 5 million
Depreciation in first year of operation = (50 - 5) x 20/210 = 4.3
Depreciation in second year of operation = (50 - 5) x 19/210 = 4.1
Total Depreciation over the two year period = 8.4
Value of Asset – Depreciation (50 – 8.4) = ₦ 41.6 million

Other considerations pertinent to this analysis cont'd

Year(s)	Costs (₦ - million)	Benefits (₦ - million)
1	Generators cost (Immediate payment), Electricity costs, Fuel costs and O&M costs	No benefits recorded
2	Electricity costs, Fuel costs and O&M costs	No benefits recorded
3	Electricity costs	Money recouped from selling ½ diesel/petrol generators, savings on O&M and average savings on fuel costs
4 - 10	Electricity costs	Savings on O&M and average savings on fuel costs

Table 11 – Scenario 3 of company X's cost-benefit analysis of operating a manufacturing plant in Nigeria

Data Required	**Costs (₦ - million)**
Generator costs (immediate payment)	50 x 2 = 100
Year 1 Electricity costs	140.9
Year 1 Fuel costs	94
Year 2 Electricity costs	131.7
Year 2 Fuel costs	89.6
Year 1 – 2 O&M costs	0.2/Year
Year 3 – 10 O&M costs	0.1/Year
Year 3 Land costs (immediate payment)	25
Year 3 Charge controllers (immediate payment)	0.24 x 5 = 1.2
Year 3 Batteries (immediate payment)	0.044 x 320 = 14.3
Year 3 Inverters (immediate payment)	4.6
Year 3 Installation costs (immediate payment)	14.1
Year 8 Batteries replacement (immediate payment)	0.044 x 320 = 14.3
Year 8 Re-installation costs (immediate payment)	1.4
Years 3 – 10 Annual O&M of RES	0.424/Year

Scenario 3 – Complementing RES with Diesel Generation						
Year	**Costs (₦ - million)**					
	Immediate Payment	Electricity	Fuel	O&M	Total Costs	PV of Total Costs
1	100	140.9	94	0.2	335.2	319.2
2	0	131.7	89.6	0.2	221.4	200.8
3	59.2	0	18	0.524	77.8	67.2
4	0	0	18	0.524	18.5	15.2
5	0	0	18	0.524	18.5	14.5
6	0	0	18	0.524	18.5	13.8
7	0	0	18	0.524	18.5	13.2
8	15.7	0	18	0.524	18.5	23.2
9	0	0	18	0.524	18.5	11.9
10	0	0	18	0.524	18.5	11.4
Grand -Total of Costs (₦ - million)					**779.7**	**690.4**
Year	**Benefits (₦ - million)**					
	Sale of Generator	Electricity and Fuel Savings	O&M Savings		Total Benefits	PV of Total Benefits
1	0	0	0		0	0
2	0	0	0		0	0
3	41.6	213	0.1		254.7	220.1
4	0	213	0.1		213.1	175.3
5	0	213	0.1		213.1	167
6	0	213	0.1		213.1	159
7	0	213	0.1		213.1	151.4
8	0	213	0.1		213.1	144.2
9	0	213	0.1		213.1	137.4
10	0	213	0.1		213.1	130.8
Grand -Total of Benefits (₦ - million)					**1,746.4**	**1,285.2**
With the same discount rate still valid, **we calculate the NPV in Naira (₦ - million) as: 1,285.2 – 690.4 = 594.8**						
Other considerations pertinent to this analysis:						

<u>Generator cost depreciation over 2 years in Naira (₦ - million):</u> Using sum of the year digits method and assuming that the residual/salvage value is 10% of initial purchase price; Therefore residual salvage value is 10% of 50 million = 5 million Depreciation in first year of operation = (50 - 5) x 20/210 = 4.3 Depreciation in second year of operation = (50 - 5) x 19/210 = 4.1 Total Depreciation over the two year period = 8.4 **Value of Asset – Depreciation (50 – 8.4) = ₦ 41.6 million**		
Other considerations pertinent to this analysis cont'd		
Year(s)	Costs (₦ - million)	Benefits (₦ - million)
1	Generators cost (Immediate payment), Electricity costs, Fuel costs and O&M costs	No benefits recorded
2	Electricity costs, Fuel costs and O&M costs	No benefits recorded
3	RES costs, Fuel costs and O&M costs	Money recouped from selling ½ diesel/petrol generators, savings on O&M, average savings on electricity and fuel costs
4 - 10	Electricity costs	Savings on O&M and average savings on electricity and fuel costs
8	RES component part re-installation	Savings on O&M and average savings on electricity and fuel costs

4.2. ***<u>Scenario Development</u>***

Scenario 1: Represents a continuation of the current situation vis-à-vis grid connection, self-generation

Scenario 2: It is assumed that improvements in grid reliability will allow for reduced reliance on self-generation with diesel

Scenario 3: Complementing RES with diesel generation

5. <u>Discussions</u>

The cost benefit analysis of operating a manufacturing plant in Nigeria from the perspective of electrical power availability/unavailability has been undertaken to support earlier discussions in this paper. Average costs of fuel supply to diesel/petrol generators and grid power supply for the years 2014 and 2015 were calculated with the numbers derived forming an integral part of the calculations for all scenarios.

The inflation rate for this purpose was set at 8.8% (Nigeria Inflation Rate 2016) with the discount rate at 14% (Nigeria Interest Rate 2016). The real discount rate taking into account inflation was calculated with a resulting value of 5% as shown in Table 9. The real discount rate was then employed in calculations to determine the present value of costs and benefits in the 10 year period.

Certain costs due to their nature could not be determined and were not taken into account for these calculations. These costs, unlike the ones employed in calculations, vary per industry type, location, requirements, regulations and trade partners. Some of which include:

i. Cost of securing and extending dedicated 33kV sub-transmission lines for factory use (costs determined by distance in kilometres);

ii. Cost of building an injection sub-station in cases where the factory is not located in an industrial area;
iii. Cost of procuring associated safety equipment – isolators and circuit breakers;
iv. Shipping and import duties on RES components
v. Cost of transporting RES components to site

Scenario 1

For this analysis, years 2014 and 2015 were considered the 1st and 2nd years of the 10 year period. The total costs incurred in the first year was the sum of purchasing; (2 x electric power generators), electricity costs, fuel costs and operation & maintenance (O&M) costs for the generators. The same costs were incurred in the second year with the exception of purchasing costs for the electric power generators (which was an immediate payment and only a factor for the 1st year). The 3rd – 10th year costs were constant and included electricity costs, fuel costs and O&M costs. Electricity costs and fuel costs for this period were chosen as the higher values of costs obtained for years 2014 and 2015 respectively, with O&M costs already defined in Table 9.

As this represents the current system of operations scenario, no benefits were recorded for the entire period.

$$\frac{C}{(1+i)^t} \quad \ldots\ldots (1)$$

$$\frac{B}{(1+i)^t} \quad \ldots\ldots (2)$$

Once the total costs were derived and populated in the table, equation (1) was used to determine the present value of the costs over the 10 year period as shown in Table 9. Where;
C = Costs; *B* = Benefits; *i* = discount/interest rate; *t* = years
Thereafter, the total present values of costs were realised (as in Table 9) from the summation of present values of costs for the 10 year period considered. Therefore, the Net Present Value (NPV) for this scenario was a deficit of ₦ 1.898 billion.

Scenario 2

Years 1 and 2 are the same as in Scenario 1. The 3rd – 10th year costs assumed that electricity power supply would have become 80% more reliable and generator need was surplus to requirement or only available as security in the infrequent case of total grid system collapse. It is also assumed that an 80% improvement in grid power would bring the grid power outage days down to six. Thus the value for the 3rd to 10th year for both electricity and fuel costs were constant and was derived by calculating the total cost of electricity for 359 days and the cost of fuel for the remaining six days in the year (working with year 2 values). Therefore this study set the cost of 80% improvement in grid power supply per year to factories' operations at ₦ 141 million and fuel costs at ₦ 18 million.

In the case of benefits, no benefits were recorded in the 1st and 2nd year. Although as power became 80% more reliable in the 3rd year, cost savings from generator fuel costs, O&M costs of generators and monetary value realised from the sale of half of the electric power generator were recorded as benefits for the 3rd to 10th year. The 3rd year recorded the most benefits of the seven years due to the sale of one of the electric power generators.

All other years only took into account the average cost savings realised from fuelling the generators and their maintenance. The calculated cost savings for factories were ₦ 72 million (to the nearest million). Also, in order to maintain security of supply in an extreme situation, only one of the generating sets was sold. To determine the asset's sale price, a two year depreciation value was calculated and deducted from the original asset purchase price as shown in Table 10. The drop in average electricity costs in 2015 from 2014 can be attributed to increased hours of electric power unavailability to factories in 2015, whilst the drop in average fuel costs within the same period can be attributed to improved customer-supplier relationship and/or varying price of fuel i.e. petrol being cheaper than diesel in Nigeria.

The total costs and benefits were derived and populated in the table as per scenario 1 using equations (1) and (2). Thereafter, the total present values of costs and benefits were realised from the summation of present values of costs and benefits for the 10 year period considered. The NPV for this scenario was a deficit of ₦ 994.1 million as calculated in Table 10.

Scenario 3

Years 1 and 2 remained the same as in previous scenarios. The 3rd year costs comprised mainly of the purchase and installation of the RES. O&M of the RES, maintenance and fuelling of half of the generators accounted for the rest of the costs in that year. The 4th to 10th years with the exception of the 8th year, incurred costs from the O&M of the RES and maintenance and fuelling of half of the generators. The 8th year in addition to these costs, incurred costs from the purchase and re-installation of new batteries for the RES.

Similar to the previous scenarios, no benefits were recorded in the 1st and 2nd years. The 3rd year brought in the most benefits as a result of the sale of half of the generators. Total benefits for that year came to the tune of ₦ 254.7 million (savings realised from sale of half of the generators combined with savings on electricity consumption and savings on fuel purchase and savings on O&M). The 4th to 10th year recorded the same benefits as the 3rd year (₦ 213.1 million) excluding money realised from the sale of half of the generators (₦ 41.6 million). Savings on electricity consumption were set at ₦ 141 million which was the constant cost for grid consumption (years 3 – 10) in scenario 1. Savings on fuel purchase were set at ₦ 72 million which were same as the constant savings realised for this commodity in scenario 2 (improvement in grid power).

The total costs and benefits were derived and populated in the table as per scenarios 1 and 2 using equations (1) and (2). Thereafter, the total present values of costs and benefits were realised from the summation of present values of costs and benefits for the 10 year period considered. The NPV for this scenario was savings to the tune of ₦ 594.8 million as calculated in Table 11. It is also important to note that this scenario was the only business viable scenario going by the numbers derived post analysis.

Going by results derived from the analysis in Scenario 1, it is evident that factories are incurring significant costs to guarantee their power supply towards sustained operations. In Scenario 2, the situation improves with stable grid power supply and reduced dependency on electric power generators. These improvements in comparison to Scenario 1 (base scenario) led to significant savings to the tune of ₦ 905 million.

Furthermore, the following points are elicited to summarise the analysis carried out in this section:

i. The current cost incurred by industries in the country due to lack of reliable grid power is significant and would unavoidably be transferred to the consumers in the sale price of commodities produced;
ii. Industries already incur various costs (safety equipment procurement, erecting substations, extending sub-transmission lines etc.) from liaising with TCN and DisCos in their coverage areas towards securing the longest possible hours of uninterrupted power supply;
iii. They also incur added costs from operating petrol/diesel generators towards securing their electricity supply as grid power failure is inevitably expected;
iv. On average, the reliance on diesel/petrol generators to industries' operations account for 40% of the total costs incurred in securing their electricity supply;
v. Savings of approximately ₦ 905 million per annum would be made if diesel/generators were less utilised and only available in cases of emergency power outage;
vi. From this study it is also questionable that total grid power with little or no dependency on the use of generators would be the best solution for reduced operations/production costs;
vii. Scenario 3 buttresses the latter point as company X recorded savings to the tune of ₦ 601 million per annum and further savings of ₦ 2.5 billion in comparison to base scenario;
viii. A situation where industries' are in full control of their source of power generation (complementing a RES with diesel generator backup) seems the most plausible for increased profitability, sustainability for their business and favourable commodity prices for the consumers;
ix. Also, knowing that diesel fuel emits 2.68 kg of CO_2 per litre consumption (Energy Conversion 2005) with the cost of diesel per litre at ₦ 158 (Nigeria Diesel Prices 2016) and approximately ₦ 90 million is spent by industries on fuel per annum, 600,000 litres of diesel (1.61 kilo-tonnes of CO_2 gas) would be required to power generators and sustain operations in base scenario for company X.
x. Working with the best available data, the 126 industries we have on record in Ogun State (South-West) Nigeria, will emit 202.6 kilo-tonnes of CO_2 gas on average per annum into the atmosphere, thus contributing to human-induced climate change.

6. <u>Conclusion</u>

Post-privatisation Nigeria is still facing challenges that were existing prior to the electricity sector privatisation. The unbundling of NEPA although necessary, has not brought about the desired effects many expected. As the core departments of TCN (Transmission Service Provider (TSP), System Operator (SO) and Market Operator (MO)) strive to ensure improved service delivery to stakeholders and the wider nation, the Federal Government for its part must secure funding to accelerate the completion of integral on-going projects countrywide.

With the nation's operational generation capacity at approximately 3.9GW and peak demand estimated at 12.8GW (a shortfall of 70%), these roll out plans must be focused and expedited to bridge the widening generation-demand gap, as well as meet electrification rate projection targets**.** It is critical that with the impending generation increase, there is measurable expansion in grid capacity to avoid the bottle neck that could present itself in operational generation capacity substantially exceeding the maximum wheeling capacity.

The case study in this paper revealed that a more cost effective arrangement for the industrial sector is a hybrid system involving off-grid solar and diesel generation, as grid reliance complemented with diesel generation is cost-intensive and posed a problem to industry, sustainability and the respective cost of commodity and services to the consumers. Our results clearly show the huge cost incurred by Nigerian industry as a result of reliance on diesel generation. A typical industrial user would save ₦ 905 million per annum if grid reliability is greatly improved. However, distributed renewables may offer even greater cost savings of about ₦ 2.5 billion per annum, when adopted. Furthermore, this study found the last scenario the most affordable, reliable and sustainable of the three considered options. Cost savings of 132 % over base case scenario were recorded, with industries' ultimately becoming prosumers and securing their power supply as well as potentially decimating the 1.61 kilo-tonnes of greenhouse gas (GHG) emitted into the environment on average per year.

These results present a strong case for integrating renewable energy technologies for rural electrification, ensuring cost savings for industry, reducing countrywide GHG emissions, reduced reliance on imported hydrocarbons etc. On-going research on our part will focus on exploring and proposing appropriate methods for integrating renewable technology through software modelling and analysis with country-specific technical and resource data. Our research work will shift towards presenting the case for total to partial grid defection for the commercial sector in Nigeria. As solar photovoltaic offers the greatest potential to achieve these goals due to the abundant resource and excellent geographic distribution throughout the country, we will focus primarily on this renewable technology. Its integration into a hybrid mix similar to the case presented in this paper will be optimised for servicing variable load applications, especially those of commercial centres popularly referred to as plazas in Nigeria.

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