A SUSTAINABILITY ASSESSMENT OF ELECTRICITY PRODUCTION AND CONSUMPTION IN NIGERIA

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Abstract
Electricity is a secondary form of energy, which defines social development and is a major driver of world urbanization. Electricity is produced, transmitted and distributed for use with a range of resources and technologies which results in a process that has impact on sustainability. Generally, electricity production sector is a significant polluter in societies around the world.This paper is an exploratory sustainability assessment of the electricity system in Nigeria considering the interconnectedness among production, regulation and consumption of electricity in Nigeria. The Sustainability Assessment of the electricity production and consumption system in Nigeria is based on the adaptation of the seven basic general principles postulated by Robert B. Gibson. These sustainability principles provided the framework for considering the electricity system in a broad and coordinated format and provided the basic guidelines for assessing the sustainability of electricity supply options and consumption patterns. The paper utilizes three sustainability assessment procedures for the study, these are: Electricity Infrastructure, System regulation and attitude of local residence. These three indicators represent the life cycle of electricity from production to transmission through distribution to consumers and it ensures that the supply management and demand factors of the electricity system are taken into consideration for each individual sustainability principle and extensively influence electricity production and consumption.

Keywords: *Sustainability assessment, Electricity production and Consumption, Nigeria*

Introduction

Electricity is a fundamental physical phenomenon and a convenient intermediary form of energy that is transformed from a source to an application point over a large distance. It is created through the conversion of naturally occurring energy sources such as petroleum, coal, water and natural gas into an intangible, yet organized flow of electrons. It arrives in the homes and businesses of consumers through transmission lines, transformer stations and distribution wires. Electricity is a secondary form of energy and is the most favoured means of supplying lighting, cooling of buildings and running of various equipments and appliances, tools and various computer technologies. It is essential for information and communication technologies, education, and monetary transactions, including other important functions of the modern society.

The electricity system is defined as the process of producing, transmitting, distributing and consuming electricity. The first step of the system is the harvesting of the natural resources required to convert energy into electricity. This process may involve coal mining, oil or natural gas extraction, water diversions or simply catching the power of the winds. In the second stage, power plants using various technologies convert this natural energy into electricity. Transmission and distribution of the electricity generated from these sources requires the building and maintenance of infrastructure to ensure that a steady supply is available for residents, industries and commercial activities alike. These processes of the electricity system have varying impacts, some of which are more or less sustainable.

This study is an exploratory inquiry into the essential aspects of a sustainable electricity system by taking both the producers and consumers of electricity into consideration. For this study, sustainability of the electricity system is defined as a critical concept which analysis the interdependencies of the social and physical realities of the electricity system through the development of an analytical framework with the objective of suggesting alternative development paths to the development of electricity infrastructure using established and existing principles.

The study is divided into five sections. The first section includes the introduction, section two discuses the electricity system in Nigeria, while the sustainable indicators for assessing the electrical system in Nigeria is discussed in section three. Section four uses the sustainable index of the previous section to analyze the electrical system in Nigeria. Section five concludes.

2.0 The Nigerian Electricity System

Electricity production in Nigeria dates back to 1896 when electricity was first produced in Lagos, fifteen years after its introduction in England (Niger Power Review, 1985). The total capacity of generation was then 60kW. In 1946, the Nigerian government electricity undertaking was established under the jurisdiction of the Public Works Department (PWD) to take over the responsibility of electricity supply in Lagos State. In 1950, by an ordinance act, the Electricity Corporation of Nigeria (ECN) was created, as the central electricity supply and development agency in Nigeria.

In 1962, the Niger Dam Authority was established, and was responsible for the construction and maintenance of hydro dams and other works on the river Niger including improving navigation and promoting fish brines and irrigation (Manafa, 1995). The energy produced by NDA was sold to ECN for distribution and sales at utility voltages.By 1st April 1972, the operation of ECN and NDA were merged in a new organization known as National Electric Power Authority (NEPA) by FGN decree 24 of 1972 (Agunwamba, 1994). The decree that created NEPA mandated the agency to maintain and co – ordinate an efficient and economic system of electricity supply for all parts of the federation.

The inability of NEPA to meet its statutory objective of providing adequate and efficient electricity; led to the FGN approving in March 2001, a National Electric Power Policy (NEPP). The major fall out of the policy was the vertically unbundling of NEPA – National Electric Power Authority - into generation, transmission and distribution in 2004 and the passage into law of the Electric Power Sector Reform Act (EPSRA) in March 2005. The EPSRA became the legal and regulatory framework for driving the power sector reforms.

The EPSRA set in motion the necessary legal framework for the unbundling of NEPA into 18 autonomous companies – 11 distribution companies, one generation company, and one transmission company; the establishment of the Nigerian Electricity Regulatory Commission (NERC) and the creation of the Power Holding Company of Nigeria (PHCN) which came into effect in June 2005.

Electricity generation

Currently, the Nigerian electricity power generation sector can be sub – divided into three Sub – sectors, namely: Existing FGN power generation facilities, Independent Power Projects (IPPs) and National Integrated Power Projects (NIPPs). The total installed generating capacity of the FGN power generating units are 1,900MW of hydro and 5,004.6MWof thermal; while the available capacity for the hydro plants is 1,380MW and 1,978MW of thermal power. The IPPs, which

are all thermal plants, are the non – FGN funded investment in the Nigerian power sector and their current installed and available capacities are respectively 1,759MW and 1,484MW. The NIPPs, which are also thermal plants are power projects funded by the three tiers of government in Nigeria (Federal, State and Local government). These facilities are currently being constructed and the total designed generating capacity of the NIPPs is currently 4,775MW (BPE, 2010).

Thus currently the total installed generating capacity of the electricity system in Nigeria is about 8,663MW (excluding about 4,775MW under construction), as at December 2010 (Onaguruwa, 2011); however available capacity is about 4,842MW.

Electricity transmission

The National grid; the network of transmission lines that transverse the country is now owned and managed by the Transmission Company of Nigeria (TCN). The TCN was created as a result of the unbundling of NEPA in 2005. It is owned by the FGN and has responsibility of undertaking the system operation and market settlement functions. The TCN is currently divided into two departments namely: the Transmission Service Provider (TSP) and the System Operator (SO).

The TSP develops the transmission grid to new areas and maintains the infrastructure in the Grid while the SO operates the whole system which includes the Generation Companies (GENCOs) and the Distribution Companies (DISCOs). It does this by deciding which power station comes on and when and by how many Megawatts (MW) and decides which transmission line or transmission station should be supplied what quantity of MW i.e. load shedding. The SO also enforces grid discipline. The TCN operation covers the 36 states of Nigeria and administratively is divided into 8 transmission regions and 35 work centers.

The total transformation capacity of the transmission network currently stands at a capacity of 16,818 MVA (14,295.3MW) (Akarakiri, 1999&Labo, 2010); while the current average available transmission capacity on the 330/132 KV and 132/33KV transformers are respectively 7,364MVA and 8,448MVA, representing 95.8% and 94.1% of installed capacity respectively. Also the current average transmission loss is 8.5% (Labo, 2010). There are also various on-going transmission projects which are financed both by the Federal Government of Nigeria and the NIPPs, with the objective of improving the transmission capacity of the Nigerian power sector.

Electricity distribution

The EPSRA in sections 8, 67 and 68 empowered the Distribution Companies (DISCOs) to perform the functions of distributing electricity in apportion authorized areas on 240V up to 33KV networks of the Nigerian electricity Industry. In addition, Discos are expected to have the responsibility of overseeing retail operations to end users of electricity. Currently the Nigerian power sector has 11 Discos and span across the country.

The current distributive capacity of the Nigerian power sector stands at: 50,179km of total installed 33KKVA line; 34,868km of total installed 11KVA line; 10,506 MVA – total installed injector substation capacity; 17,899 MVA – total installed distributive substation capacity; 1,078 No. of 33/11KV transformers and 41,477 No. of 33/0.415/11KV transformers (FGN, 2010). Also, In order to improve the distributive capacity of the power sector, the FGN invested $0.5225 billion (N81billion) in various distributive projects in the country. These projects are on – going and consist of 1,707km of new 33KV lines, 2,666Km of new 11KV lines, additional 3540MVA sub – station capacity and 22, 598 transformers (Labo, 2010).

Sustainability assessment of the electricity system

The World Commission on Environment and Development (WCED), defined sustainability as a process in which the exploitation of resources, the direction of investments, the orientation of technology development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspiration (WCED, 1987). However for the purpose of this study, sustainability is defined as a critical concept describing the interdependence of social and physical realities and challenging current structural assumptions and practices, in order to suggest alternative development paths. The operationalization of sustainability is Sustainability Assessment (SA) which is an evaluation of social and physical reality.

Generally, electricity production sector is a significant polluter in societies around the world (Nielson and McEloy, 1998; Elliot, 2000; Jacobsson and Johnson, 2000; Lu and Ma, 2004). The sustainability problem of electricity production and consumption may be summarized from three perspectives as:

1. The intangible nature of electricity creates the perception of a seemingly impact less consumption process.
2. Alienation from the centralized electricity production process disconnects individuals and societies from understanding resource requirements and energy transformation processes, and
3. Current electricity generation paradigm encourages centralization of production and undervalues the contribution of small – scale generation options.

In this study, the seven sustainability principles postulated by Gibson (2002) forms the conceptual framework for the SA of the Nigerian electricity system. The sustainability principle has been used as the basis for developing the SA criterion specifically relevant to the electricity system. Each of the sustainability principle has been analyzed in relation to the life cycle of electricity, which are: the infrastructure, system regulation and the attitude of consumers.

The Gibson's principles of sustainability

Gibson (2002) describes the concept of sustainability in terms of seven principles. Six are contextual principles: Integrity, sufficiency and opportunity, equity, efficiency, democracy and civility, precaution and adaptation. The seventh principle is conceived as the integration of all principles and is described as a necessity for creating a broad and holistic interpretation of sustainability. Gibson's general sustainability principles are stated in Table 1.

Table1: Gibson's general sustainability principle

S/N	Sustainability Principles	Explanation
1.	Integrity	Build human ecological relations to maintain the integrity of biophysical systems in order to maintain the irreplaceable life support functions upon which human well being depends.
2.	Sufficiency & Opportunity	Ensure that everyone has enough for a decent life and that everyone has opportunity to seek improvements in ways that do not compromise future generations' possibilities for sufficiency and opportunity.
3.	Equity	Ensure that sufficiency and effective choices for al are pursued in ways that reduce dangerous gaps in sufficiency and opportunity (and health, security, social recognition, political influence, etc) between the rich and the poor.
4.	Efficiency	Reduce overall material and energy demands and other stresses on socio – ecological systems.
5.	Democracy and Civility	Build our capacity to apply sustainability principles through a better informed and better integrated package of administrative, market, custom ary and personal decision making practices.
6.	Precaution and Adaptation	Respect uncertainty, avoid even poorly understood risks of serious or irreversible damage to the foundations for sustainability, design for surprise, and manage for adaptation.
7.	Immediate and Long term Integration	Apply all principles of sustainability at once, seeking mutually supportive benefits.

Gibson's initial set of seven sustainability principles have been adapted to fit the context of this study. The adaptation process has been based on available literature that discusses the electricity sector in sustainability terms and renamed as electricity assessment indices. The principles provide a framework for considering the system of electricity production and consumption in a broad and coordinated format. The themes presented in the adaptation serve as basic guidelines for investigating sustainability within the context of electricity supply options, along with the resultant impacts of consumption patterns. The adapted Gibson's principle of sustainability in relations to the electricity sector is shown in Table 2.

In order to further refine the principles for this study, the principles have been refined under specific operational headings, which reflect the life – cycle of electricity from production to consumption under the headings of infrastructure, system regulation and attitude of local residents. The sustainable assessment framework is shown in Figure 1.

Table 2: Gibson's Adaptation of Sustainability Principles for the Electricity Sector

S/N	Sustainability Principles	**Electricity Assessment indices**	**Explanation**
1.	Integrity	**Impact**	*impact* assessment of electricity supply and demand on local and regionalbiophysical systems (Finamore, 2000; Che at el., 2002; He et al., 2002; Aunan et al., 2003; Chang et al., 2003; Ni &Johansson, 2004; Smil, 2004;)
2.	Sufficiency & Opportunity	**Availability**	Sufficient supply of electricity to meet residential andindustrial demand and the opportunity to seek improvements in the production ofelec tricity; *availability* of electricity in a broad sense (Weber, 1999; Martinot, 2001;Short, 2002; Wang &Feng, 2003).
3.	Equity	**Access**	Emphasis on equal *access* to the electricity system and reduction of gaps insufficiency and opportunity based on socio -economic status and geographic location(Meadows, 1998; GNSED, 2004; Lam, 2004; Yeoh&Rajaraman, 2004).
4.	Efficiency	**Performance**	assessment of efficient electricity sources and efficiency levels ofelectricity consumption; emphasis on *performance* of the electric ity system andenergy requirements (Sinton et al., 1998; Wortmann& Schuster, 1999; Chen &Porter, 2000; Martinot, 2001; Lu & Ma, 2004; Ni & Johansson, 2004; Shiu& Lam,2004).
5.	Democracy and Civility	**Policy innovation**	capacity and motivation of decision -making bodies toimplement *innovative policies* related to the electricity system; level of opendeliberations, community awareness campaigns, and integrated decision processes areconsidered (Elliott, 2000; Lew, 2000; Martinot, 2001; Che et al., 2002; Chang et a l.,2003; Lu & Ma, 2004; Ni & Johansson, 2004;)
6.	Precaution and Adaptation	**Future**	understanding and respecting the concept of risk -basedmanagement and planning with respect to the *future* of the electricity system;anticipating unknown effects of electric ity production techniques (Streets, 2003; Lu &Ma, 2004; Ni & Johansson, 2004)
7.	Immediate and Long term Integration	**Integration**	emphasis on links between the principles and integrated consideration of sustainability components.

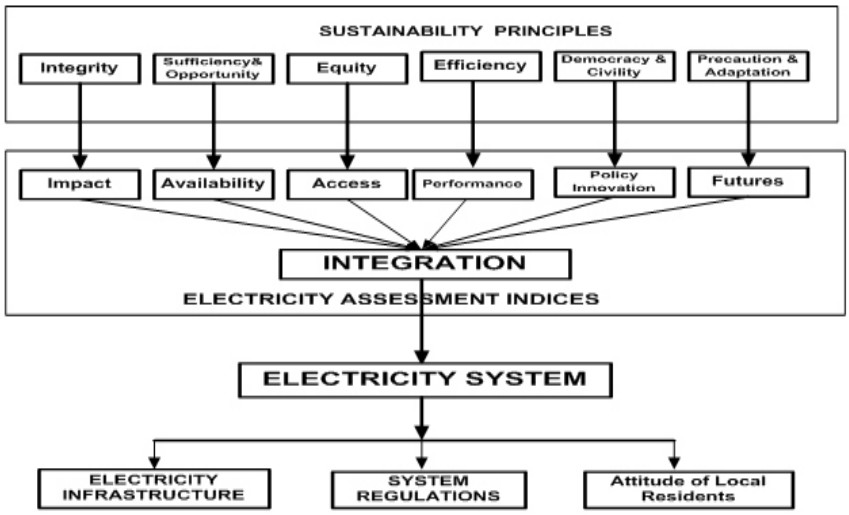

Figure 1: Sustainability Assessment Framework

Electricity infrastructure

Electrical infrastructures are the basic physical, organizational and technical structures needed for the operation of the power industry and facilitate the provision of electricity to the end user. Thus substantial expansion in quality, quantity and access to electricity infrastructures is fundamental to rapid and substantial growth and poverty alleviation; and has imperatives for development from an economic, social and environmental viewpoint. It also presents sustainable issues which tend to undermine conflict with the development needs it aims to address.

Systems regulations

System regulations refer to the policy, rules and regulations that govern the operations of the power sector. These have far reaching consequences on the sustainability of the electricity industry in any nation. The System regulation stipulates the pattern of ownership, the tariff structure of the industry and specifies the relationship between generation, transmission and distribution of electricity to the end users.

Attitude of local residents

Electricity production and regulation are not the only factors affecting the electricity system. Attitudes and social norms are also important considerations because they influence individual and group consumption behaviour (Weber, 1999). Without the consideration of the social aspects, namely the consumer in the electricity sector, it is difficult to assess the actual progress towards a sustainable electricity future.

Table 3 summarizes the relationship between the sustainability principles, electricity assessment indices and the sustainability assessment factors for the electricity system from the perspectives of electricity infrastructure, systems regulation and attitude of local residence.

Table 3: Summary of relationship between Sustainability Principles,Electricity Assessment Indices and Sustainability factors of the Electricity System.

S/N	Sustainability Principles	**Electricity Assessment indices**	Electricity infrastructure	Systems Regulation	Attitude of Local Residence
1.	Integrity	**Impact**	Infrastructure Impact	Environmental Studies & Assessment; Air Pollution index	Air quality & standards. Health impact of electricity production
2.	Sufficiency & Opportunity	**Availability**	Infrastructure Demands	Residential/industrial electricity demand. Production regulation	Sufficient supply of electricity and consumption awareness.
3.	Equity	**Access**	Infrastructure Limitation	Pricing of electricity; construction and location of plants	Cost of electricity and perceived barriers; location of power plants
4.	Efficiency	**Performance**	Infrastructure Performance	Energy conservation for industry and residents. Industrial efficiency	Efficiency awareness
5.	Democracy and Civility	**Policy innovation**	Infrastructure Changes	Local and national planning objectives. Sustainable development considerations. public participation and consultation	Perception of renewable energies, importance of public consultation and participation.
6.	Precaution and Adaptation	**Future**	Infrastructure Planning	Short and long term planning for electricity provision. Anticipated drawbacks of conventional supply scenarios.	Primary resources for electricity production. Present and futures.
7.	Immediate and Long term Integration	**Integration**			

Sustainability Assessment Analysis of the Electricity System in Nigeria

Impact

Electricity infrastructures have been located near the source of energy resources used for the energy transformation process. Apart from the hydroelectric facilities in Shiroroand Jebba that have resulted in flooding of lands around their host communities, there are no reported adverse airs, water or soil impacts in the other thermal plants scattered across the nation. Infact, the location of the new thermal plants which use gas are expected to help solve a major environmental problem of gas flaring in the Niger delta region. With regards to system regulations, the NERC and the Nigerian Standard regulation Agency of Nigeria (NESRA) have established environmental standards for the operations of the power plants that produce electricity. Also, it is a major requirement for establishment of the power plant to conduct Environment Impact Assessment (EIA).Also, with regards to the local residents, most power plants are located in remote areas far from local residents. This

has made it possible not to have any adverse reports of negative impact of power plants on local residence.

Thus, in summary it can be said that in terms of impacts, the Nigerian electricity system has no negative impact on the environment.

Availability

In terms of availability, the Nigerian electricity system continues to grapple with the problem of supply/ demand imbalance. The current infrastructural level whether at generation, transmission and distribution are grossly inadequate and are not able to meet even overall domestic demands. Hence there is inadequate supply of electricity to local residence, while the system regulators continue to grapple with the issues of effectively coordinating and providing electricity at the distribution points. This situation has created a situation where the resort to the use of alternative power sources such as generating sets of varying capacity has led to local emissions of Carbon monoxide (CO) and very high noise level, making most residential areas environmentally unfriendly due to unavailability of the electricity.

Access

The Nigerian electricity system continues to grapple with the problem of provision electricity in rural areas. Currently in Nigeria, it is estimated that over 70% of the population live in rural areas with less than 15% of them having access to electricity. Also efforts geared towards provision of electricity in the rural areas have been stalled by several policy issues and in the location of power plants and pricing of electricity, the rural consumer is hardly considered.

Access is a major environmental issue because the lack of electricity in most of the rural areas in Nigeria has led to the consumption of biomass and other inefficient sources of energy which have created the problems of deforestation and health issues.

Performance

The performance of power plants in the country is dependent of several factors including the age of the plant, its carrying capacity, and fuel type and maintenance culture. Most Nigerian power equipment at the three levels of generation, transmission and distribution are quite old. The average age of infrastructure in the Nigerian electricity system is between 25 – 40 years, this has made many of the plants inefficient and in need of overhauling. This age of infrastructure has also affected delivery to local residence and the ability of the system regulator to enforce regulations related to operations of the sector. With respect to transmission facilities, Nigeria has a long transmission system leading to between 20 – 30% transmission losses between power generation and eventually power distribution. Making performance a major environmental challenging issue in the Nigerian electricity system.

policy innovation

The National Energy Policy (NEP) and the Renewable Energy Master Plan (REMP) explicitly spell out regulations for including renewable energy into the Nigerian electricity mix. This policies have not however been concretely implemented due to lack of adequate participation by the private sector in the Nigerian electricity system, another major constraints is the cost of deploying new renewable in the country and the low conversion ratio of renewable systems.

Futures

The Nigerian electricity system is currently under reforms and there are plans to expand the generating, transmitting and distributive capacity of the sector. The success of the reform programme will be based on several factors including: access to finance, mobilization of resources, involvement of the private sector and foreign direct investment

into the sector.Adequate provision of electricity will certainly improve the environment and wellbeing of local residence.

Conclusion

The paper has examined the Nigerian electricity system, and using seven major indices of impact, availability. Access and others as environmental assessment index, the paper examined the environmental impact of the Nigerian electricity system on the local residence, the system operator and electricity infrastructure providers. The paper concluded by asserting that with proper provision of infrastructure and integrating of renewable energy into the electricity mix, the Nigeria electricity industry will be more environmentally friendly and provide more efficient services.

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