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Implication of Poor Energy Supply on the Sustainability of ICT Infrastructure in Nigeria

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ABSTRACT

Information and communication technology (ICT) infrastructures and infrastructure devices require uninterruptible power supply to ensure their availability and usability. Even handheld mobile devices require electricity to get their batteries up and running. This implies that irregular power supply or absence of electricity will render most, if not all these infrastructures and devices inoperable. In this paper we have taken a comprehensive look at the states of both power and ICT infrastructures in the Nigeria and how blackout has increased the cost of operation of providers leading to high Internet access costs. Of particular interest are the power needs of ICT infrastructures, infrastructure devices and end-user devices. Although ICT infrastructure may not be the most energy demanding sector of the economy, it has been shown in this paper that their energy requirement is also significant if account is taken into the power requirement of data centres and all communication devices that are found in our homes and offices today. The power requirement of a typical data centre was examined and it was noted that if such data centre is established in all the six geo-political zones of the country their power demand will be significant in the light of low grid power of less than 5000MW. To remedy these problems some suggestions were provided and include: privatisation of the electricity subsector to its logical conclusion and the Government encourage operators to roll out coverage of advanced wireless technologies beyond urban areas through tax incentives, license conditions and initiatives to promote infrastructure-sharing.

Keywords*: Information and communication technology, Data Centres, Internet exchanges, power supply*

1. INTRODUCTION

The level of economic development of any nation depends to a greater extent on the level of infrastructure provisioning by the current and past governments of that nation. According to Oxford advanced learner's dictionary, infrastructure is the basic systems and services that are necessary for a country or an organisation to run smoothly. Example are buildings, transport and water and power supplies. To this end all the physical facilities and their structural organization that provide the most benefit to the citizens of that country constitute infrastructure. The economic development of contemporary nations has greatly relied on continued supply of energy be it power or fuel. Even though Africa is richly endowed with mineral resources, it belongs to the regions where energy availability is low and this has affected the normal development of African economies. Nigeria's energy future lies in gas. Natural gas reserves in Nigeria are about 5.2 trillion cubic feet, Tcf [4]. Nigeria in particular is endowed with numerous fuel sources for power, including hydro, natural gas, coal, wind, solar and an abundance of waste from biomass, but has failed to provide adequate energy supply to her citizens. Currently, the Nigerian government is focusing on electricity generation in three areas, namely: Hydro, Coal and Natural Gas, of which the latter represents the largest resource for fuel-to-power [33]. It is no longer news that fuel pumps are dry, cooking gas is unavailable and the almighty power supply has gone comatose. All these inadequacies in energy supply have been attributed to the endless drive by those in power to enrich themselves at the expense of other citizens [32], [2]. This has led to the establishment of The Bureau of Public Procurement (BPP), the Independent Corrupt Practices Commission (ICPC) and Economic and Financial Crimes Commission (EFCC). These organisations have not been able to eradicate or reduce corruption to a reasonable level in the affairs of governance in Nigeria [32]. This has virtually affected all sectors of the economy with negative consequences on the utilization of the limited ICT infrastructure [2].

Self-generation of electricity (from diesel and petrol generators) is conservatively estimated at a minimum of 6,000 MW i.e. more than twice the average output from the grid during 2009. Moreover, half the population (and the vast bulk of the country's poor) have no connection whatsoever to the grid [33]. In [33] it was shown that lack of electricity has negative economic consequences on both the poor and the rich and the industry. For instance the poor currently pay more than N80/kWh by burning candles and kerosene while the current regulated (average) tariff is just N8.5kWh. In Nigeria own generation represents more than 20 percent of capacity [11]. The manufacturers pay in excess of N60/kWh on diesel for self provisioning of power whereas everyone else pays around N50-70/kWh on self-generation (diesel or petrol). For example, Nigeria's leading mobile provider, MTN Nigeria, spends in excess of USD 5.55m on diesel to power its 6,000 generator plants across the country monthly [42]. Practically all the telecom companies also run back up power generators in the bulk of their base stations in the country due to continual national electricity supply problems. The result is that Nigerians as a whole spend between 5 and 10 times as much on self-generated light and power as they do on grid-generated electricity. The lack of interest in power generation and supply in Nigeria by the private sector has been attributed to the low tariff, which is lower than the prices in most African

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countries and even lower than most advanced economies like USA and Britain [33].

Various ICT infrastructures require adequate and stable power supply to function optimally. The Internet service providers (ISP) and Web services are the most hit by this irregular supply of electricity as their data centres and their associated redundant equipment require adequate electrical energy to be functional so as to provide the required services to their subscribers. The lack of electricity in both urban and rural areas has further complicated accessibility to Internet. The typical Nigerian firm experiences power failure or voltage fluctuations about seven times per week, each lasting for about two hours or more, without the benefit of prior warning [30]. This causes long ICT equipment down times leading to inaccessibility to Internet by their subscribers. The overall impact of this is increased business uncertainty, huge operational costs, loss of subscriber confidence and lower returns on investment. This high cost of operation is being borne today by Nigerians as a result of high cost of their Internet access and low bandwidth. Due to lack of electricity some of these providers could not embark on expansion of their businesses to most part of the country. This difficulty in accessing electricity by firms in Nigeria is confirmed by the World Bank Enterprise Surveys, which show that Nigeria is among the economies where getting electricity to do business is the most difficult [9]. The objective of this paper therefore, is to x-ray the current state of power and ICT infrastructures in Nigeria and the overall impact of poor electricity supply on the various ICT infrastructures and infrastructure devices, the subscribers and to proffer solutions to the highlighted problems. We further examined the power requirements of both telecommunication and Internet infrastructures, end user devices and infrastructure devices and suggested that more Internet exchanges be established across the country as they provide a platform for information sharing among providers and the expected advantage of reduced price of Internet access.

2. THE STATE OF POWER INFRASTRUCTURE IN NIGERIA

It is no longer secret that Nigerian government is going through hard times trying to provide the much needed power to her citizenry. All sorts of measures in the name of reforms have been taken by successive governments to address the abysmal power situation in the country. So far there is nothing to show for it. This leads one to call to question the sincerity of those entrusted with the responsibility to carry out these reforms as billions of Naira have been plunged into this critical sector with practically no results. Power holding company of Nigeria (PHCN) may not have been generating enough power, but the little that is generated may not have been transmitted because of poor transmission infrastructure [33]. The distribution of power to the consumers is one of the greatest challenges being faced by PHCN. Substandard transformers, low gauge cables and vandalism of cables and components of transformers are the key obstacles to proper distribution of electricity to Nigerians. This situation leaves numerous customers in the dark thus denying them the benefits of constant and stable power supply. Without power one cannot have access to internet. Low power generators that have become popular among Nigerians are highly unreliable. The cost of access and poor access to electricity are the bane of growth of Internet activities in Nigeria.

2.1 Generation of Power

The Nigerian overall electricity consumption per capita is about 100kwh [29]. Contrary to the Nigerian government plan in 2003 to expand electricity access to 85% of the population by 2010 only 40 percent of Nigerians have been able to access electricity [29]. The Nigerian electric networks operate below its capacity of 5,900 MW and power outages remain unabated. Nigeria needs at least 20,000 MW but less than 6000 MW has been generated [29]. In 2005, the government launched an ambitious capital investment programme under the title of the National Integrated Power Project (NIPP). The NIPP projects comprise both gas fired power plants and transmission lines. It was expected that when NIPP projects fully come on stream, they would add nearly 5,000 MW to the country's generating capacity within 3 years (see Table 1). However, the NIPP's contribution became a drop in the ocean compared to the investments that will be required for the country to meet the generating target which it has set for 2020, namely 40,000 MW [33]. Moreover, if this target of 40,000 MW were to be met, Nigeria's power capacity per head of population in 2020 would still be less than a quarter of what South Africa currently enjoys.

Table 1: Planned NIPP Power Stations

S/No.	Power Station	Location	State	Capacity (MW)	Type	Year of establishment /completed	Current Status
1	Ihovbor	Benin City	Edo	125	Gas Turbine	2007 – 2013	Under Construction
2	Calabar	Calabar	Cross River	561	Gas Turbine	2007 – 2014	Under Construction
3	Egbema	Egbema	Imo	338	Gas Turbine	2007 – 2013	Under Construction
4	Gbarain	Yenagoa	Bayelsa	125	Gas Turbine	2007	
5	Sapele	Sapele	Delta	450	Gas Turbine	2007 – 2015	Operational

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6	Omoku	Omoku	Rivers	225	Gas Turbine	2007 – 2013	Under Construction
7	Ibom	Ikot Abasi	Akwa Ibom	190	Gas Turbine	2007 – 2009	Partially Operational (60MW)
8	Alaoji		Abia	1074	Gas Turbine	2012 - 2015	Partially Operational (225MW)
9	Geregu II		Kogi	434	Gas Turbine	2012	Taking off (I quarter 2013)
10	Omotosho II		Ondo	450	Gas Turbine	2012	Partially Operational (375 MW)
11	Olorunsogo II			675	Gas Turbine	2012	Partially Operational
Total Planned Capacity				**4,647**			

Source: [33]

As the government pursues vigorously the privatisation of the nation's power sector, the PHCN has been unbundled into11 distribution companies (Discos), 7 generating companies (Gencos) and the transmission company of Nigeria (TCN) [37]. Ibom power plant's overall generating capacity has been technically constrained by existing transmission and distribution facilities of PHCN and TCN, to only 60MW [39], [37]. Other plants are also suffering from one problem or the other. For instance Olorunshogo II is working below capacity due to gas supply issues; Alaoji is delayed due to evacuation capacity; Calabar Gas supply is not available; Egbema plant is waiting for evacuation infrastructure. The older power stations listed in Table 2 are producing power below their total installed capacity of 6,250MW.

Table 2: Overall Installed Capacities of Older Power Stations

S/No.	Power Station	Location	State	Installed Capacity (MW)	Type	Year of establishment /completed	Current Status
1.	Kainji		Niger	800	Hydroelectric Niger River	1968	Operational
2.	Afam IV – V	Afam	Rivers	726	Gas	1982 Afam IV 2002 Afam V	Partially Operational
3.	Jebba		Niger	540	Hydroelectric	1985	Operational
4.	Egbin thermal	Egbin		1320	Gas turbine	1985 – 1986	Operational
5.	Shiroro		Niger	600	Hydroelectric		Operational
6.	AES Barges	Egbin		270	Gas Turbine	2001	Operational
7.	Okpai	Okpai		480	Gas turbine	2005	Operational (IPP)
8.	Geregu I	Geregu	Kogi	414	Gas turbine	2007	
9.	Olorunsogo I	Olorunsogo		336	Gas turbine	2007	Partially operational
10.	Afam VI			624	Gas and Steam Turbines	2009 Gas 2010 Steam	Operational
11.	Aba	Aba	Abia	140	Gas Turbine (IPP)	2012	Gas supply problems
Total Installed Capacity				**6,250**			

Adopted from [33]

Shown in Figures 1 and 2 are the expected combined generation capacities by December 2012 – 11,879MW and December 2013 – 14,218MW. By December 2012 target was not met. For instance in December 2012 the peak generation stood at 4,000MW [27] which, was far less than the targeted generation. With the peak demand forecast of 10,200MW in July 2013 the peak generation was 3714.8MW and the lowest generation was 3118MW [27].

It is unlikely that the targeted generation of 14218MW will be met by the end of 2013 if none or all of the independent power projects (IPP) or NIPP stations under construction is completed.

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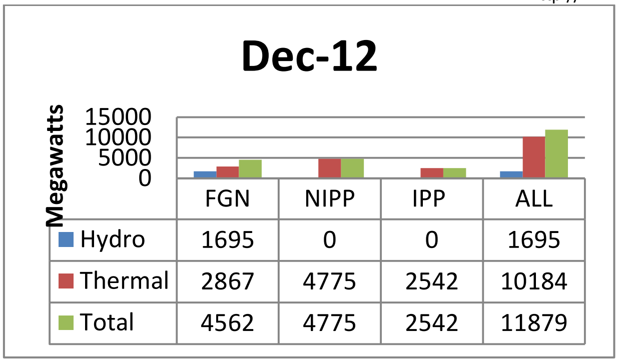

Fig 1: Targeted Increase in Generation Capacity by December 2012 [33].

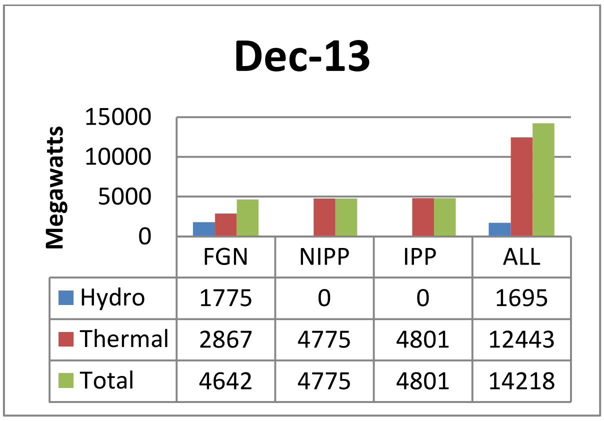

Fig 2: Targeted Increase in Generation Capacity by December 2013 [33]

Figure 3 shows that currently the Federal Government owned power stations are contributing more to the national grid followed by NIPP and IPP. It is hoped that both NIPP and IPP will be the driving force in power generation in future when all their plants currently under construction come on stream. Figures 1 and 2 also show that the NIPP and IPP are focussing more on thermal plants while the Government control all the hydro stations in the country. Some of the problems that have hindered optimal operation of these stations include: inadequate funding,

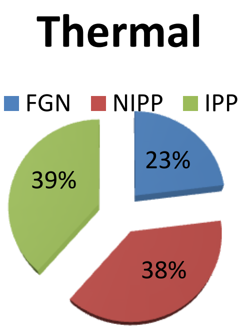

Fig 3: Disaggregation of Generated Power by Percentage of Contributors [33]

Poor maintenance planning; Monopoly; Vandalism of Generation facilities, and lack of interest on the part of private investors because of low tariff [31], [33], [32].

2.2 Transmission infrastructure

Power transmission lines carry grid power across vast distances at variously graded extra high voltages. The state of these lines is very vital for efficient evacuation of generated power for onward transmission to consumers. High voltage transformer substations and switching stations are where the power lines connect with other lines from other parts of the grid to form the power pool. The enormous amount of money spent on transmission lines could be reduced if gas-fired power stations are sited close to load centres, while the oil or gas is piped long distances from the source [30].

In Nigeria we have the sub transmission and transmission lines at their different voltage levels of 11/33kV, 132kV and 330kV lines respectively. There are three important substations- Ikot Ekpene, Ugwuaji and Erukan 330kV that serve as hubs of switching station where many IPPs intend coming into the grid are still under construction. The right of way issue is one of the daunting problems that hinders the expansion and construction of new grids. In most cases compensation is yet to be paid to those whose properties are affected by the planned expansion or construction [33].

2.3 Distribution Infrastructure

Distribution is the process of stepping the high voltage from the transmission stations to voltages suitable for use at homes and factories. These voltages are delivered to homes using four wires (three line voltages and one neutral) – three phase mains supply. For instance, a typical three-phase mains supply delivers 240V to our homes. At the distribution level electrical energy consumed by individual homes or factory is metered and paid for. Nigeria has a very high level of distribution inefficiency, which is attributable to distribution losses and under collected revenues [4].

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Distribution is messier than the other components of electricity provision since its infrastructures are closer to the consumers and hence they are more susceptible to abuse and vandalism. The total peak load on the entire distribution network is currently just over 9,057 MW, while the current total capability is 5,758 MW, giving a total distribution gap of about 3,000 MW [33]. Transformers which are the major component of the electricity distribution network are one of the major reasons why many homes suffer power outages than the industrial sectors and the homes of the rich. Distribution cables are criss-crossing overhead further subjecting them to abuse by overloaded vehicles whose loads usually shoot into the sky. Because these cables are exposed and accessible to all and sundry vandals find it easy to remove these cables to further resell it to willing buyers. These issues have further aggravated the problem of blackouts despite the fact that there might be power but those households whose cables have been vandalised will remain without power.

3. THE STATE OF ICT INFRASTRUCTURE IN NIGERIA

The liberalisation of the communication sector in 2000 has led to wide spread deployment of telecommunication infrastructure in the country. Hitherto, Nigerian telecommunication Limited (NITEL) was the sole provider of telecommunication services in the country. NITEL at the time and for a long time provided only land lines throughout the country. The liberalisation of the telecommunication sector in 2001 led to the emergence in the Nigerian such companies that offers global standard for Mobile Communication (GSM). A good progress has been made in expanding the GSM signal coverage [12]. These companies include MTN Limited, GLOBACOM, ZAIN (formerly Econet Wireless Limited), Etisalat. Prior to 2001 it was very difficult to acquire a telephone line in cities and towns where the services were available. Scalability of telephone lines was not in tandem with the growth of population thus leaving many Nigerians who can afford the lines stranded and without access to telephone services

2.4 Telecommunication Infrastructure

The Nigeria telecommunication sector has witnessed a dramatic change with the commercialisation of NITEL and the establishment of Nigerian Communication Commission (NCC) in 1992. The NCC is the regulatory body that was charged with the deregulation of the telecommunication industry in Nigeria. Since the auctioning of 2G by NCC, the emergence of the first GSM companies brought a great relief to Nigerians in terms of lowered prices for acquiring lines and air time [35]. After the initial hiccup of right of way for the erection of their communication masts these companies increased the number of telephone lines (both mobile and fixed) from a mere 450,000 subscribers in 1999 to 4,700,093 subscribers in 2004 [35]. As at December 2012 (Table 3) the total number of connected lines for GSM, CDMA and fixed wired/wireless stood at 151, 714,650 lines with a total installed capacity of 211,808,092 lines [25]

Table 3: Subscriber Data for December 2012

Nature of Connectivity	Operator			Total
	GSM	CDMA	Fixed Wired/Wireless	
Connected lines	135,253,599	14,041,464	2,419,587	151,714,650
Active lines	109,829,223	2,948,562	418,166	113,195,951
Installed Capacity	182,065,415	18,400,000	11,342,677	211,808,092

Adopted from [25]

There are about sixteen fixed wired/wireless telecom companies but only six were indicated in Table 4 for simplicity. In addition, the total number of subscribers on fixed wired/wireless was shown for all the fixed wired/wireless companies including those companies not reflected in Table 4. As it were, the GSM companies have the largest share of the telecom industry in Nigeria [26]. It is important to note that increase in the number of subscribers is directly proportional to improved infrastructure provisioning. The mobile cellular market has grown because landline telephones require much more maintenance and continued expansion, which has been unsustainable. Cellular phones have been easier to incorporate, also providing useful services in a number of ways. Strict competition among the providers has helped in driving the prices down. For instance in 2009 prices of a monthly fixed-line subscription stood at $9 and prepaid mobile subscription at $11 [12]. The enforcement of lower interconnection rates by NCC in 2010 saw tremendous reductions in tariff.

2.5 Internet Infrastructure

Currently, the classical telecommunication networks and the Internet have converged towards an integrated infrastructure, merging voice and data transmissions. This convergence has led to the emergence of new services, mixing different media on top of the Internet,

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Table 4: Market Share of Subscribers by Telecom Companies

	Operator	Subscriber base	Total As at Dec, 2012
GSM	MTN Nigeria Communication	47,440,991	
	Globacom Limited	24,124,716	
	Celtel Nigeria Limited	23,092,195	
	M-Tel Limited	258,520	
	EMTS Limited	14,912,801	108,829,223
CDMA	Starcomms Limited	307,844	2,948,562
	Visafone Limited	2,265,874	
	Multilinks Telkom	263,767	
	Reliance Telecoms (Reltel)	111,077	
Fixed Wired/ Wireless	NITEL	58,750	418,166
	Starcomms Limited	109,918	
	Visafone Limited	28,552	
	Multilinks Telkom	44,868	
	Reliance Telecoms (Reltel)	10,849	
	Intercellullar Nig. Limited	1,053	
Grand Total			113,195,951

Adopted from [26]

and leading to the explosion of the traffic to be transmitted over the networks and the number of applications and services carried over these networks. The tremendous development of telecommunication infrastructure championed by the GSM operators in the country has direct impact on the growth of internet infrastructure. Before the entry of GSM and CDMA operators into the Nigerian market most of the Internet service providers depended mostly on international satellite services (Intelsat, Eutelsat, SES and SkyVision) for bandwidth [1]. All the ISPs at the time were offering services through the Virtual Small Aperture Terminal (VSAT) with its inherent high cost of bandwidth. With the launch of 2.5GHz and subsequently 3G networks customers were availed the opportunity to have access to the Internet via their handsets and personal digital assistants.

In addition to microwave networks some of the GSM companies have been laying fibre optic cables throughout the country. MTN for example, has massively provided a fibre-optics super highway covering more than 8,900 kilometres across Nigeria [1]; this covers about 87.96 per cent of Nigeria's landmass and more than 85 per cent of the population. This massive investment by the private sector in fibre-optic deployment in the country was made possible by the liberalisation of the fibre-optic infrastructure by the Nigerian government [12]. This extensive deployment of fibre optic cable by MTN and GLO networks throughout Nigeria is aimed at improving mobile broadband penetration in the country which is hoped will improve bandwidth and reduce costs of Internet access. These internal fibre optic networks are currently complementing international fibre optic cable networks such as Main One covering 7000 km fibre cable, Glo 1's covering 9800 km and SAT 3 cables, which deliver international bandwidth into Nigeria. Much is still expected of the GSM and CDMA companies especially investment in stations where the subscribers are connected using cables formerly known as the last mile.

As it is now, the full benefit of this massive investment in fibre optic cables will be a mirage if nothing is done in the area of the last mile. It is important to note that for now mobile broadband is dominating the Nigerian market and will continue for a long time to come. The fixed broadband which provides more reliable and faster access to Internet is yet to be developed in Nigeria and indeed in most African countries. This can be attributed to comparatively non-existence of fixed telephone lines in the country. In addition to the three submarine cables already landed in Nigeria MTN's West African Cable System (WACS) commenced operation in 2011 and is delivered to Nigeria by MTN with bandwidth capacity of over 5.12 Terabytes and spanning a distance of 14,530km [24]. This cable links South Africa with the United Kingdom along the West Coast of Africa, landing in South Africa, Namibia, Angola, the Democratic Republic of the Congo, the Republic of Congo, Cameroon, Nigeria, Togo, Ghana, Côte d'Ivoire, Cape Verde as well as the Canary Islands, Portugal and the United Kingdom. This is expected to open Africa's access to faster connectivity to support innovative IP-based services such as video applications for e-education and healthcare. It was expected that the Main One cable introduced in 2010 will reduce the wholesale prices by almost 50% [40] but that was not achieved because of poor patronage by service providers. With increase in the number of international fibre-optic cables that has landed in Nigeria it is expected that the costs of Internet access will fall and Nigeria could emerge as a leading regional bandwidth supplier [8].

Having considered the various infrastructures that enhance fast access to the Internet it is important to look at the devices that utilise these infrastructures. These devices include: routers, LAN devices, cellular and telecom

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infrastructure. In [5] these devices were weighted with the highest assigned to routers and router-like devices and LAN devices. LAN devices encompass a range from cable modems to hubs and switches to WiFi access points—all of the devices in this category operate at the edges of the Internet at a smaller scale than routers. Low weights are assigned to Cell towers and telecom switches. Cell towers provide service to smartphones and telecom switches provide some service for modem users. Fiber optic and copper are less responsible for carrying Internet traffic [5].

3.3 Internet Exchanges

An Internet exchange point (IXP) is a physical infrastructure that allows several Internet Service Providers (ISPs) and network operators to exchange traffic between their networks, generally referred to as autonomous systems, by means of mutual peering agreements, which allow traffic to be exchanged at no cost [18], and [19]. IXP keeps local signal (signal originating from Nigeria) local without having to route the signal to international exchange point and back to Nigeria. The benefits derived from IXP include amongst others; reduction in latency of local traffic, thus speeding up local data exchange, encouraging the development of locally hosted contents and saving local ISPs millions of US Dollars per year on international connectivity charges with the multiplier effect of reducing the cost of Internet access to Nigerians.

The internet Exchange Point of Nigeria (IXPN), which operates from the 8th floor of NCR building on broad street Lagos (its main location), was commissioned on the 14th of January 2011. Other substations or branches are located at Victoria Island, Ikeja, Ibadan, Port Harcourt, Abuja, Enugu, Kano and Maiduguri. Port-Harcourt IXP was commissioned on 17th May, 2012 by the Director General of the National Information and Technology Development Agency (NITDA), Prof. Cleopas Angaye (NITDA, 2013). The IXPN Port Harcourt branch which is the third of the branches meant to be established in the six geo-political zones is already up and running. The major components of IXP include: route servers, switches, 100M FastEthernet with 100Base TX interface, UTP CAT-5 cable and RJ-45 connecter; 1000M GigabitEthernet with1000BaseSX, MM cable and SC connector. The IXPN network is a layer-2 infrastructure on two separate switch fabric across IXPN locations. Currently operating locations are: Nitel Colo (NET House), Lagos Island and Medallion Colo, Victoria Island. Each location has two foundry switches connecting separate peering LANs [18]. The primary peering LAN is interconnected on a 1 gigabit circuit (fibre), while the secondary peering LAN is interconnected on a 450 megabit wireless backhaul. Two of the three operating locations have route servers in place. All the IXPN switches provide 10/100BaseTX switched Ethernet and 1000BaseSX gigabit Ethernet over multimode fibre connections

3.4 Internet Data Centres

Data centre is an important component of the Internet as it is a point (building) where most online service or products providers keep all necessary information that may be required by anybody that needs it on the Internet. They are buildings where multiple servers and communication gear are co-located because of their common environmental requirements and physical security needs, and for ease of maintenance ([5]). Traditional data centres, typically host a large number of relatively small- or medium-sized applications, each running on a dedicated hardware infrastructure that is de-coupled and protected from other systems in the same facility. Those data centres host hardware and software for multiple organizational units or even different companies. Different computing systems within such a data centre often have little in common in terms of hardware, software, or maintenance infrastructure, and tend not to communicate with each other at all. Data centres currently power the services offered by companies such as Google, Amazon, Yahoo and Microsoft’s online services division. The data centres run by Google and others belong to a single organization, use a relatively homogeneous hardware and system software platform and share a common systems management layer [7]. The system software is usually built in-house. When one uses Amazon or Google products for example, their data centres do the work 24/7 and 365 days in any part of world. The computers that hold this enormous amount of data are usually called Servers. Servers are high performance computer system that has the capability of attending to numerous requests in a network. A server consists of a number of processor sockets, each with a multi-core CPU and its internal cache hierarchy, locally shared and coherent DRAM, and a number of directly attached disk drives (Figure 4). The typical building blocks of a large-scale data centre are server racks with 10-80 nodes, with 20-60 such racks per power distribution unit [22]. In addition to the servers, other elements of the data centre include: DRAM, Disks, networking devices, power supply systems and cooling systems. Nigeria has no large scale data centre at the moment but it appears that this is about to change with the planned establishment of one that will accommodate up to 600 server racks by Main One Cable company of Nigeria ([38]; [23]). At the moment all ISPs and telecom companies are hosting their data from outside the country.

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Fig 4: Typical elements of a data centre. Source: [7].

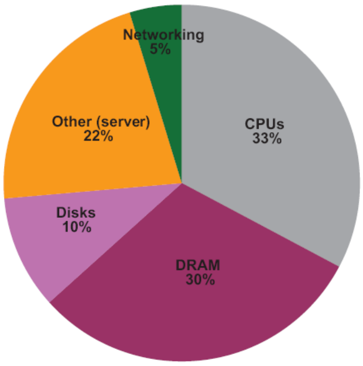

Fig 5: Approximate distribution of peak power usage by hardware subsystem in one of Google's data centres (circa 2007). Source**:** [7].

Internet infrastructure require enormous amount of power to remain operational and provide the required services. Power demanding component of the Internet infrastructure is the data centre, where large numbers of servers/ networking equipment, data centre power systems and data centre cooling systems are installed including redundant equipment for reliable computing. Servers/networking components of the data centre comprise of racks of servers, Ethernet switches and routers at various levels of clusters as well as collection of disks for storage. Modern data centres containing tens of thousands of server consume up to 20MW of power or more [21]. The data centre power system supply distributes power to the other data centre components. Included in the data centre power system are uninterruptible power supply (UPS) systems and Power distribution unit (PDU), switch gear and emergency diesel generators. The data centre cooling systems ensure that appropriate temperature is maintained in the data centre for optimal performance and availability of the computer and networking equipments [13]. The data centre cannot operate without cooling for more than a few minutes before overheating. The data centre cooling systems comprise of computer room air conditioning (CRAC) units, pumps, heat rejection devices, free cooling, Air flow consideration and in-rack cooling. The cooling systems maintain the temperature of the data centre at 16 – 20^o C, though the server cold air-intake is 18 - 22^o C because it heats up slightly on its way to the server [5]. It is normal to oversize the CRAC system up to 30% [34] to overcome the recirculation effects of the higher temperature equipment exhaust air.

4. INTERNET'S INFRASTRUCTURE ENERGY NEEDS

Internet services must achieve high availability, typically aiming for at least 99.99% uptime (about an hour of downtime per year). Achieving fault-free operation on a large collection of hardware and system software is hard and is made more difficult by the large number of servers involved [5].

4.1 Power Utilisation of Internet Infrastructures and Infrastructure Devices

The wall socket power consumption of Internet infrastructure and devices vary in various degrees. For instance Routers consume about 4 kW [20], telecom switches -50 kW [3] and cell towers- 3 kW [16]. A crude estimate has been used assuming the owner of an Internet device uses it 50% (duty cycle) of the time for Internet activities and the other 50% for activities not related to Internet [5]. This situation holds true if Nigerians enjoy regular and adequate power supply. As at 2011, Internet uses 84–143 GW (Table 5) of wall-socket power –3.6–6.2% of the 2.3 TW of electricity produced globally [5], [17].

Table 5: Power Utilisation by Internet Infrastructure and Devices

Categories		Global Device Count	Wall socket power	Wall-socket Duty cycle	Total Power (min)	Total Power (max)
End User Devices:	Desktops	750 x 10^6	150 W	0.5	28.1GW	53.4 GW
	Laptops	750 x 10^6	40 W	0.5	11.3GW	15.0 GW
	Cloud	50 x 10^6	450 W	1.0	18.0 GW	22.5 GW
	Smartphones	1,000 x 10^6	1 W	0.5	0.13 GW	0.45 GW
	Servers	100 x 10^6	375 W	1.0	18.8 GW	35.6 GW
Infrastructure Devices	Routers	1 x 10^6	5 W	1.0	4.5 GW	5.0 GW
	Wi-Fi/LAN	100 x 10^6	20 W	1.0	1.5 GW	2.0 GW
	Cell Towers	5 x 10^6	3 KW	1.0	1.5 GW	7.5 GW
	Telecom Switches	0.075 x 10^6	75 kW	1.0	0 GW	1.4 GW

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	Fibre Optics	1,500 x 10^6 km	0 W	0	0 GW	0 GW
	Copper	3,500 x 10^6 km	0 W	0	0 GW	0 GW
Global Total for Internet					84 GW	143 GW

Adopted from [5].

Assuming this same percentage is used by Internet infrastructure and devices for the 4000MW currently generated in Nigeria; this translates to about 144 – 248MW of electricity. With this crude estimate Nigeria's highest share of global power utilisation by the Internet is about 0.017%. This low figure is as a result of poor electricity supply to the citizenry and the poverty level in the country. Desktops and laptops actually comprise the largest fraction, approximately half of the Internet's total power consumption, due to their large number.

4.2 Data Centre Power Utilisation

The energy needs of a data centre have been identified as a serious challenge when operating a data centre. All the components of data centre consume energy to varying degrees even the data centre power system is also a source of energy consumption. The US environmental protection agency EPA estimates show that US data centres consumed 61 billion kilowatt-hours in 2006 [10]. An important parameter for analysing power consumption of computing equipment is the Processor Utilisation Efficiency (PUE). This is actually the ratio of total data centre consumption to that consumed by the computing equipment. Recall that the computing equipment is the main hub of the data centre; other components of the data centre are provided to ensure smooth operation of the computing equipment. In a survey of 22 data centres carried out by Greenberg and collaborators, and Tschudi and collaborators as reported in [14] and [41] a PUE of approximately 2.0 was obtained. This shows that the building's mechanical and electrical systems consume twice as much power as the actual computing load. This is the fairest picture painted of data centre power consumption. In most cases the estimated PUEs of most data centres is greater than 3.0. While a PUE of 2 to 3 is considered good, Google has achieved PUEs as low as 1.2 in some of its data centres [13]. Power consumption by information technology equipment is especially important because other elements of data centre energy consumption scales with it, such as air-conditioning and power distribution facilities.

One vital issue to note about PUE is that it fails to recognize that real measure of effectiveness is not the power consumed by the servers, but the work accomplished. Furthermore, engineers at the Google observed that current computer systems are not power proportional [6]. Energy Efficiency was, defined as:

$$EnergyEfficiency = \frac{SystemPower\ Utilisation}{Total\ Power\ Supplied} \quad (1)$$

From equation (1) it can be seen that energy efficiency tends towards 0 as system utilization approaches 0, but does not. Even a relatively energy-efficient server still consumes about half of its peak power when doing virtually no work [22]. In a study of over 5,000 of its servers, Google found that the average CPU utilization of most servers is between 10% and 50% of maximum utilization. This translates to 25% utilisation of servers in data centres.The breakdown of data centre power overhead, which has been adopted from [22] is shown in Figure 6.

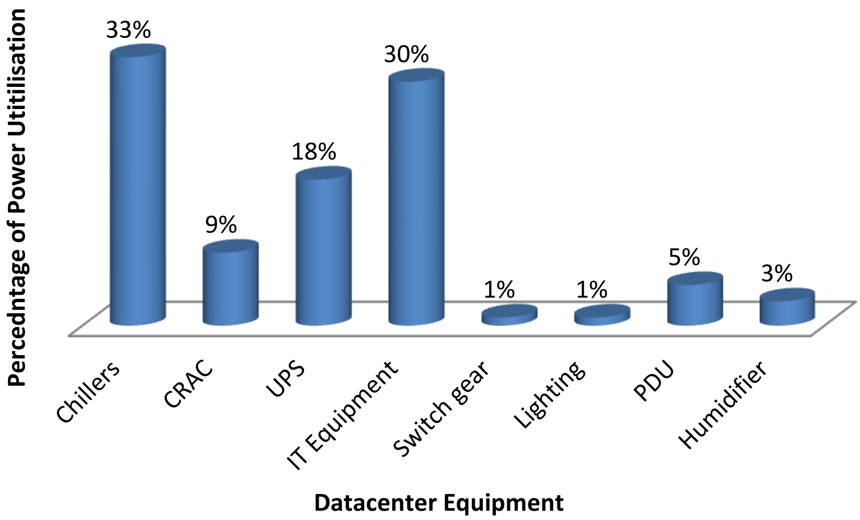

Fig 6: Power Distribution overhead of various Data centre Equipments [22]

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From the above data the physical cooling infrastructure and power equipment constitute 70% of the data centre energy needs (Figure 7). Depicted in Figure 8 is the distribution of the 30% IT load among the various IT devices; 33% can be attributed to the CPU, 30% to DRAM, 10% to disks, 5% to networking equipment, and 22% to other backend servers and appliances [15]

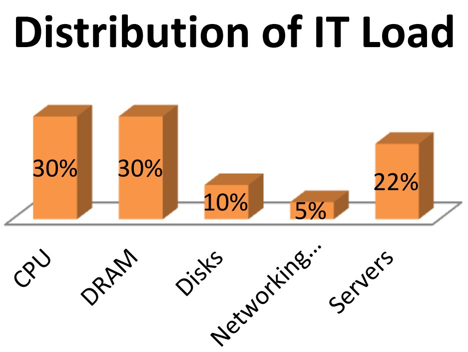

Fig 8: Distribution of various IT Loads

Before estimating the power needs of a data centre, it is important to consider the various topologies of the IT computing equipment as it relates to UPS redundancy. Most critical systems are provided with 2N topology where critical systems would be completely redundant to provide the required availability of 24x7. If one critical system fails another critical system (redundant one) maintains operational load. This also provides for a degree of concurrent maintainability whereby maintenance could be performed on one system while another supplies the load [36]. Other topologies include: N configuration, where no redundancy is provided; N+1 topology provides a degree of redundancy for a key component of a time sensitive system. The UPS system design configuration notwithstanding, power provisioning for critical load and keeping it cool is the same. The critical load is all of the IT hardware components that make up the IT business architecture: servers, routers, computers, storage devices, telecommunications equipment as well as the security systems, fire and monitoring systems that protect them [36]. In order to determine the total electrical power requirements for a data centre, the power rating of all current loads and future loads of the data centre must be calculated in kW and summed up. The following items and their rating (Figure 9) should be used for electrical power calculations in kilowatt [36].

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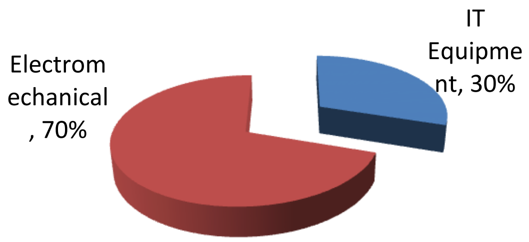

Fig 7: Distribution of Power between IT Equipment and Other Data centre Equipment

a. Critical load – Rating of each IT ((Calculator total in VA x 0.67) / 1000)kW
b. Future loads – ((Total VA of nameplates x 0.67)/1000)kW
c. Peak power draw due to variation in critical loads – Total steady state critical load power draw = (a + b) x 1.05 kW
d. UPS inefficiency and battery charging - Actual Load + Future Loads (in kW) = (a + b + c) x 0.32 kW
e. Lighting - Total floor area associated with the data centre = 0.002 x floor area (sq ft) KW, or 0.0215(m^2) x floor area kW
f. Total power to support electrical demands = (c + d + e) kW
g. Total power to support cooling demands = (f x 1.7) kW
h. Total power requirement for electrical and cooling = (f + g) kW
i. Requirements to meet regulatory bodies =(h x 1.25) kW
j. Three-phase AC voltage from Discos provided at service entrance = 230Volts AC
k. Electrical service required from Discos = (i x 1000)/(j x 1.73) Amps

Fig 9: Data Centre Power Requirement Estimate

In order to estimate the power requirement of a typical data centre, we assume the data centre occupies a floor area of 400 m^2 and has a critical load of 100 kW. We further assume that one quarter of the current critical load (i.e. 25 kW) will be added in future. With the above assumptions we can now use the formulae provided in figure 9 to calculate the power requirements of the proposed data centre (electrical service required from a Disco). The results of these calculations are shown in Table 6. This typical data centre will draw a maximum of 1543 Amperes from mains supply at its peak operation

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Table 6: Computation of Power Requirement for a typical Data Centre

S/No.	Item	Calculation	Subtotal in kW
a	Critical load	-	100
b	Future loads	-	25
c	Peak power draw due to variation in critical loads	(100+25) x 1.05	131
d	UPS inefficiency and battery charging	131.25 x 0.32	42
e	Lighting - Total floor area associated with the data centre	0.0215 x 400	9
f	Total power to support electrical demands	131.25+42+8.6	182
g	Total power to support cooling demands	181.85 x 1.7	309
h	Total power requirement for electrical and cooling	181.85+309.145	491
i	Requirements to meet regulatory bodies	490.995 x 1.25	**614**
j	Three-phase AC voltage from Discos provided at service entrance	-	230
k	**Electrical service required from Discos in Amperes**	**(614 x 1000)/(230 x 1.73)**	**1543Amps**

4.3. Implication of epileptic power supply on Data Centre operations

From the foregoing, it can be observed that Data Centre infrastructure not only consume comparatively minimal amount of energy but also require a continuous or uninterrupted flow of power supply. When this is the case, the system components will operate at optimum efficiency with minimum cost implication. Power outage and epileptic supply could result in the following:

1. Hinders proper planning for the deployment of future infrastructures.
2. High cost of operation with negative consequences of high tariffs.
3. Discourages the providers from expansion and deployment of new infrastructures, this in turn leads to low-speed Internet access.
4. Possibility of damage to equipment as a result of over voltage and spikes.
5. Limited coverage area of provider's services.
6. Poor accessibility to provider's services as subscribers experience long hours of no electricity to power their devices.

5. CONCLUSIONS

In this paper, we have discussed how poor energy availability impacts the sustainability of ICT infrastructures and ICT infrastructure power needs especially the power consumption of data centres. Despite all the efforts by the government in ensuring regular and stable power supply Nigerians are yet to reap the benefits of these efforts. The various states of power and ICT infrastructures in the country were examined. The establishment of Internet exchanges in some parts of the country was a welcome development. Calculations show that the energy requirement of the Internet infrastructure and infrastructure devices is not significant compared to the power consumed in the other areas of human endeavour. We consider this important in the light of low and irregular grid electricity in Nigeria and its implications on expansion of infrastructures. If one of the typical data centre examined in this paper is sited in each of the six geo-political zones of Nigeria, their overall power requirement will be significant with respect to the mere 4000MW currently generated.

Since all the above are adverse effects that would hamper the growth of the ICT industry in Nigeria, it is hereby suggested that (i) More Internet exchanges be established across the country as they provide a platform for information sharing among providers and the expected advantage of reduced price of Internet access; (ii) The government should not relent in carrying out the privatisation exercises of the electricity subsector to its logical conclusion; as Nigerians hungrily waits to enjoy properly priced power consumption and other benefits that will accrue from it; (iii) NCC needs to create a trusting environment among operators and develop policies that promote infrastructure sharing and allow operators to compete on services rather than at infrastructure level [42]. This has been embarked upon in Nigeria with the establishment of Internet exchanges in some of the zones. And we hope that this effort should be intensified to ensure that other planned exchanges are completed and rolled out as early as possible; (iv) Operators should be encouraged to invest in fixed-wired broadband Internet, which offers the most reliable and fast access to Internet compared to the current 3G wireless broadband currently in use. This we hope will reduce prices for telecommunications services, which has direct cost implication on cost of Internet access; (v) Operators should roll out the third-generation mobile networks and WiMAX. They offer promising solutions for increasing broadband access in Nigeria; (vi) The Federal Government of Nigeria should encourage operators to roll out coverage of advanced wireless technologies beyond urban areas through tax incentives, license conditions and initiatives to promote infrastructure-sharing [42].

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