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RESEARCH ARTICLE

Energy Efficiency as an Antidote for Economic Growth and Environmental Sustainability in the Telecommunications Sector in Nigeria

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ABSTRACT

Nigeria has been confronted with acute energy challenges highlighted by inadequate electricity generation and increasing energy demand.. Telecommunications is a key sector of the Nigerian economy with high energy intensity. Most telecoms sites in operation in Nigeria are powered using diesel generators resulting in huge operating expenses (OPEX) for operators and enormous emission of Green House Gases (GHGs) to the environment. These challenges have been amplified by soaring population and the need for increased telecoms services nationwide. The work adopted the exploratory research design. It analyzed and appraised existing literature and legislation to determine the potency of energy efficiency in addressing the challenges identified. Case studies were employed to broadly examine telecoms energy efficiency practices in other countries. This helped to identify energy efficiency technologies relevant for adaptation to the Nigerian context. Additional data were obtained from semi-structured interviews conducted with key stakeholders in the telecommunications sector. The study revealed that there exist incoherent and lofty policy statements on energy efficiency in the relevant energy policies in Nigeria and there is no specific legislation on energy efficiency. Furthermore, the adoption of energy efficiency technologies in telecoms network operations can lead to significant reduction in OPEX cost and will contribute to climate change mitigation through energy consumption reduction. This will reduce greenhouse gasses emission and accelerate the nation towards climate change mitigation and sustainable development

Keywords- : Climate Change, Energy Efficiency, Green House Gasses, Telecoms Network, Sustainable Development

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INTRODUCTION

Energy plays a very significant role in any nation with regards to its economic growth and development, including poverty eradication as well as security and this has made uninterrupted energy supply a critical issue in all countries of the world. Future economic growth is a function of the long-term availability of energy from affordable, accessible and environmentally friendly sources. Energy is utilized in the provision of basic needs which include cooking, heating, lighting, the use of home and industrial appliances, provision of pipe-borne water, health care, communication and transportation. In addition, energy supports productive activities such as agriculture, commerce, manufacturing, industry, mining etc. Furthermore, poor or lack of access to energy adds up to poverty and deprivation and can also add to decline in the economy. It is not just that energy and poverty reduction are intertwined but they are also connected with socio-economic development which has to do with productivity, income growth, education and health.[1]One of the most widely used and accepted forms of energy globally is electricity and it is an elementary necessity for economic development as well as for an acceptable standards of living. The increase in the population of a country which is evident on the expansion of its economy also reflects in the multiplication of the demand for electricity. In Nigeria, electricity which is a major prerequisite for operational industrialization and development is insufficient[2].
The experience in Nigeria in the last 20 years is such that electricity demand greatly exceeds its supply. Electricity is a key driver of development of economies of nations all over the world; it is a basic requirement for economic development and for providing the minimum acceptable living condition in any society. The plan for development of any society must necessarily be undergirded by a robust electricity supply base upon which other industrialization initiatives can then thrive. Again, a growth in a country's population and expansion of its economy will result in a geometric increase in electricity demand and if this demand is not adequately met, then a shortage in supply occurs. This shortage can assume crisis proportions[3] and one that is capable of stifling any socio-economic development initiative[4]. A large percentage of business enterprises in Nigeria had to embrace the option of installing electricity generator to power-up and drive their operations.[5] Telecommunications like energy has assumed one of the key drivers of socio-economic development in 21st century Nigeria. Telecommunications operations is technology driven and therefore energy intensive just like every other technology driven process. The growing telecommunications infrastructure requires increasing amount of electricity to function effectively, part of the required electricity comes from power grid and the remaining through

[1] Nnaji C et al 2010, In: Nnaji, C. E., Uzoma, C. C. (eds) *CIA world fact-book, Nigeria.* http://www.cia.gov/library/publications/the-world-factbook/geos/ni.html

[2] Chigbue, N. I. 2006. Reform of electric power sector: journey so far. *A lecture delivered at the US Africa collaboration research sponsored by the national science foundation in Abuja, Nigeria*; pp 3.

[3] Anon., 2016. The power sector suffered a system collapse, which resulted in a national grid output of zero megawatts of power for more than four (4) hours. *Thisday Newspaper*. Retrieved Oct. 12, 2016, from http://www.thisdaylive.com/index.php/2016/04/10/when-power-supply-crashed-to-zero/

[4] Ojobo, T. 2016. Investment in Telecoms Hits $68bn in Nigeria. *IT & Telecom Digest.* 197 Nov: 34. See also Tarpael, F. Nov. 28, 2016. Telecoms Sector Soars, Adds N1.398Trillion to GDP in Q3 2016.

[5] Punch Newspaper Dec. 28, 2017. In heavy use of generators put Nigeria's climate plans in jeopardy. *Punch Newspaper*. Retrieved April 27, 2019, from https://punchng.com/heavy-use-of-generators-puts-nigerias-climate-plans-in-jeopardy/

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burning of fossil fuel like diesel. Both of these sources contribute to emission of Green House Gases (GHGs) with the attendant negative environmental effects. Improving the energy efficiency of telecommunication networks is not just a necessary contribution towards the fight against global warming, but with the rapidly rising prices of energy, it is becoming also a financial opportunity[6].

Background of the Study

There is abundance of fossil fuels in Nigeria yet the energy situation in the country cannot be said to be structured and managed in a way as to ensure sustainable energy development. As a nation with limited technical capacity but which also sees industrialization as constituting a crucial leverage and precondition for meaningful development, it is essential that the country manages its scarce energy resources judiciously.[7] Consequently, it is important that all stakeholders in the built environment begin to seek the adoption of low risk but high worth energy-efficient measures that will contribute significantly to the viability of the various sectors of the economy. Despite enormous coal, oil, and natural gas reserves in the country, at the present rate of extraction, it has been estimated that these reserves, by the next 40 years, will be depleted to the point where it would be uneconomical to continue exploration. Thus it has become imperative for the country to implement energy conservation and efficiency measures in conversion systems while seeking alternative energy sources.[8]

In a developing country like Nigeria, population grows at an alarming geometrical progression without a corresponding growth in social infrastructure. In addition, the requisite economic structures required to cater for the citizenry and ensure the provision of basic social amenities aimed at guaranteeing quality of life and human well-being are grossly inadequate. The implication therefore is that a huge population size places enormous pressure on the very limited available resources within the economy and these to a large extent include energy and power supply. According to Enweze[9], small firms invest about 25% of their overall investments on power infrastructure while large firms on the other hand invest about 10% of their total investments for the same purpose. For instance MTN, a South African Telecommunication company operating in Nigeria with the widest coverage in the country is projected to have installed about 6,000 generators for the supply of power to its base stations with an average run-time of about 19hours daily. The company expends about $5.5 million annually on diesel fuel in other to generate electricity via generators[10].It is against this background that the concept of energy efficiency becomes relevant as a viable tool for socio-economic development.

[6]Čorbadžić, M. 2013. Energy efficiency in telecommunication network: energy consupmtion, saving and renewable sources. 1. Retereived on Oct. 22, 2016 from https://www.scribd.com/document/170838200/Energy-Efficiency-in-Telecommunication-Network-Energy-Consuption-Saving-and-Renewable-Sources.

[7]Oyedepo. S.O., 2012Energy Efficiency and Conservation Measures: Tools for Sustainable Energy Development in Nigeria, *International Journal of Energy Engineering* Vol. 2, Issue 3 86. Aug.22: 86-98.

[8]Energy Commission of Nigeria and United Nations Development Programme Report, 2005.Renewable Energy Master Plan Final Draft Report., Retrieved April 22, 2016, from http://www.iceednigeria.org/REMP%20Final%20Report.pdf.

[9]Enweze, C. 2000. Restructuring the Nigeria economy: the role of privatization.*In: Proceedings, CBN annual monetary policy* conference held at NICON hotel.

[10] Uduma, K and Arciszewski, T. 2010. Sustainable Energy Development: The Key to a Stable Nigeria, Sustainability, 2, pp. 1558 – 1570

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This paper therefore investigates the role of energy efficiency as an enabler of business growth and key driver for climate change mitigation within the context of telecommunications operations. The work will also provide some energy efficiency mechanism for telecoms servicing companies in terms of optimizing their operations and help lower their operating cost and as well as serve as a viable tool for contributing to carbon emission reduction target of the Nigerian government under the Paris Agreement on Climate Change.[11] Under the Nationally Determined Contribution (NDC), Nigeria committed to reduce Greenhouse Gas (GHG) emissions unconditionally by 20% below Business As Usual (BAU) projections by 2030, and a conditional contribution of 45% reduction, based on commitment with international support.[12]

MATERIALS AND METHODS

The study adopted the doctrinal research approach. It utilized literature search, appraisals of existing literature, reviewed case studies and conducted semi-structured interviews to address the research questions. The study examined the existing legal, policy and institutional framework for energy efficiency standards in Nigeria by reviewing relevant statute books, legislations and government policy documents. Of particular importance and focus here are enabling laws and regulations of key regulatory institutions of government whose statutory functions have a direct bearing on the study. A comprehensive review of other extant policies and institutional frameworks for energy efficiency and standardization was conducted to determine their adequacy or otherwise using selected indicators such as level of clarity and practicability of policies, handshake and inter-agency cooperation between relevant government agencies and the distinctness of relevant legal framework for energy efficiency. Specifically, this helped in understanding the extent of effectiveness of this framework and the reforms options that may be considered to remedy the situation. Due to the technical nature of the study, technical terminologies were explained and diagrams were provided in some instances to provide a pictorial analysis of concepts especially in explaining telecoms network architecture and operations.

Understanding Energy Efficiency

Energy Efficiency often bears different meaning to different people across various disciplines and scientific purposes. Simply put, the concept means using less energy to produce more economic output[13]. In relation to systems, this can be expressed as the ratio of outputs to the corresponding energy inputs. The concept is further made clearer from the understanding of the

[11] Nigeria Signed the Paris Climate Change Agreement on September 21, 2016 through President Muhammadu Buhari. See Channels Television online report of September 22, 2016.Retrieved Oct. 12, 2016, from https://www.channelstv.com/2016/09/22/buhari-signs-paris-agreement-says-nigeria-will-reverse-effects-of-climate-change/.
[12] Idowu, O. 2018. Nigeria Develops Third Paris Agreement National Communication. Retrieved Feb. 12, 2019, from https://www.climatescorecard.org/2018/09/nigeria-develops-third-paris-agreement-national-communication/
[13] Lovins, A. 1976.The road not taken?energy strategy: friends of the earth's not man apart. Spec reprint issue 6.20: 19 - 77

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key word "efficiency". Irrek et al[14]attempt to situate the meaning and understanding of energy efficiency by distinguishing the word efficiency from effectiveness. They contended that while effectiveness refers to the degree to which an activity achieves its objectives, efficiency on the other hand, relates to the degree or level of benefits derived vis-à-vis the expenses incurred in deriving that benefit. Simply put efficiency is measured in terms of ratio of benefits to expenses.
Energy efficiency therefore is concerned with the ratio of the benefits gained or derived from an energy related operation or activity in comparison to the actual energy utilized in deriving that benefit. For example, a compact fluorescent bulb is more efficient than a traditional incandescent bulb as it uses less electrical energy to produce the same amount of light. In the same vein, an efficient boiler makes use of less electricity to heat up a home to a given temperature compared to a less efficient model. From a demand-side perspective, the term energy efficiency majorly refers to energy end-use efficiency and this refers to the proportion of the amount of energy used to achieve a particular purpose which is directly beneficial either to the individual personally or for other non-personal purposes which is tangible and measureable. Thus at this level, efficiency is measured from the physical benefit derived from the energy application, appliance, or system put in place to deliver energy services e. g. heat degree of heat required for cooking, energy for cooling of a refrigerator or cooling of a data centre, energy required to manufacture goods from the production line etc. Consequently, when energy end-use efficiency increases, it means a reduction in the consumption of end-use energy for the same amount of energy services output. In other words, it connotes delivering the same energy services output with less input of energy or delivering more output with the same value of input.[15] It is in this sense of end-use efficiency that the term energy efficiency will be used in this paper. In the context of sustainability and economic development, energy efficiency has been described as possessing inherent potential to deliver broader benefits that support economic growth, enhance social development, advance environmental sustainability, ensure energy security and help advance social prosperity.[16]

Energy Efficiency and Environmental Sustainability

Energy use has a major impact on the environment and its inadequate supply is a major barrier to development of society as it limits economic growth and also adversely affects the general quality of life. The improvements in standards of living as shown in increased food production, increased industrial output, the provision of efficient transportation, adequate shelter, healthcare and other human services which are all directly and indirectly determined by consumption of energy. There is no single definition for sustainable development but the key idea common to all definitions concerns resource exploitation at a rate that would not prove detrimental to future

[14]Irrek, W., Thomas, S., Bohler, S., Spitzner, M., 2008.Defining Energy Efficiency. Wuppertal Institut fur Klima, Umwelt, Energie GmbH. Retreived Dec. 27, 2016 from http://wupperinst.org/uploads/tx_wupperinst/energy_efficiency_definition.pdf

[15]Tromo, R. Campbell, N. Cleere, Maryrose. 2013. Introduction to Energy Efficiency. *International Energy Agency Energy Training and Capacity Building Week* 3.Retreived Dec. 27, 2016, from http://www.iea.org/media/training/presentations/day_1_session_2_energy_efficiency_intro.pdf; See also, Irrek, W. Thomas, S. Bohler, S. Spitzner, M. 2008. Defining Energy Efficiency. Wuppertal Institut fur Klima, Umwelt, Energie GmbH. Retreived Dec. 27, 2016, from http://wupperinst.org/uploads/tx_wupperinst/energy_efficiency_definition.pdf.

[16]International Energy Agency. 2014. *Capturing the multiple benefits of energy efficiency*, Page 19. Retrieved on Jan 4, 2017.

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generations. A widely use definition is that of the Brundtland Commission of 1987[17] which defined sustainable development as “development that meets the present needs, without compromising future generations to meet their own needs”.According to Adejumo and Adejumo[18] the environment should be seen as an asset, a stock of available wealth but if the present generation spends this wealth without investment for the future then the world will run out of resources. This includes the preservation of natural resources for the benefits of present and future generations, the exploration of natural resources in a sustainable, prudent and rational manner and the integration of environmental consideration into economic and other development programs of nations. The implication of this is that no meaningful development can be achieved without consideration for environmental protection, as it is the environment that provides the means for human survival and development. Since socio-economic growth and development is a permanent feature in the agenda of governments of nations all over the world, it stands to reason therefore that one of the most daunting challenges faced by Governments all over the world today is the pressure of how to improve energy consumption with very minimal environmental effects which is considered as one of the major components of sustainable development.

A major theme on the discussion of sustainable development in the context of energy production and utilization is that the production and utilization of energy should not in any manner compromise or jeopardize the quality of life of the immediate inhabitants of the environment and those of the generations coming after them and also that the production and use of energy should be conducted within the carrying capacity of the ecosystem. Energy usage is directly proportional to productivity level in the industrial, commercial, and agricultural sectors. Thus, as we strive for socio-economic development; industrialization, urbanization and enhanced standard of living, there will be direct proportional impacts on the environment. The present generation must necessarily see itself as trustees of future generations, thus at the bottom of any activity that would impact the environment ought to be the question whether such activity would leave the environment better or worse than was inherited. An objective response to this question is the responsibility of all actors within the environment as this would determine the legacy that would be bequeathed to future generations. Alanne and Sarri[19] described a sustainable energy system as a cost-efficient, reliable and environment-friendly system which utilizes local resources and networks effectively when compared with the need for efficient use of energy resources. Such system is not slow and inactive like a conventional energy system but it is flexible in relation to advancements in technology as a veritable tool in finding solution to socio-economic challenges as well as the active promotion of the introduction of new solutions. Sustainable energy will require a broad perspective to energy production, utilization and management. It would require a greater focus on renewable energy and the harnessing of the various renewable energy sources and the development of viable renewable energy technologies on the one hand, as well as the application of relevant green and energy efficiency technologies that makes possible the use of fossil fuel in a more environment-friendly manner. Energy-use efficiency is one of the very effective, cheapest, and cleanest ways to address modern energy challenges. The reliable,

[17]United Nations. 1987. Our Common Future: Report of the World Commission on Environment and Development. Retrieved Mar. 26, 2016 from http://www.un-documents.net/our-common-future.pdf

[18] Adejumo, V.A. and Adejumo. O.O. 2014.Prospects for Achieving Sustainable Development through the Millennium Development Goals in Nigeria.European Journal of Sustainable Development3. 1, 33-46.

[19]Alanne, K. and Saari, A., 2006. Distributed Energy Generation and Sustainable Development. Renew. Sustain. Energy Rev. 10(6), 539–558.

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affordable and less-polluting efficient use of energy and supplies are important and essential components of sustainable development thus to use energy more efficiently, there needs to be the adoption of environmentally-friendly practices of energy utilization coupled with the application of new energy efficiency technologies that offer very improved energy utilization vis-à-vis performance of systems[20].

A large chunk of the electricity needed for powering telecoms networks and infrastructure is obtained from grid power and the rest is from diesel powered generating sets. Unfortunately, both sources contribute to the emission of Greenhouse Gases (GHG) with the negative environmental effects associated with it. The framework for the reduction in the level of carbon emission produced or caused to be produced in telecoms operations is what is known as or referred to as *green telecoms*. The rise in the average temperature of the earth is associated with the impacts of global warming which resulted from the accumulation of greenhouse gases (GHG) in the atmosphere. According to Minoli[21]green telecoms deals with minimizing energy consumption, maximizing energy-use efficiency, and using, wherever possible, renewable energy sources. He identified that g*reening* is an off-shoot of the imperatives for reduction in GHGs emission from the perspective of environmental responsibility and the pressing need on the telecoms industry to reduce "run-the-engine" costs and he sought to extend the same principle to the concepts of green networks. He further noted that telecommunications service providers do use relatively large quantities of energy and exert a significant impact on the environment; therefore, the time has come to introduce green technologies and processing into the networking field itself. According to Fall,[22]energy efficiency is an inescapable part of the solution to Africa's sustainable development and its improvements can result in cost-effective ways that can contribute to economic and social development as well as environmental sustainability.

RESULTS AND DISCUSSIONS

It would be useful for the purpose of this study to analyze where and how energy is consumed within a telecoms network, especially in the light of the relevance and growing demand for information and communication services in the 21st century. There is a very strong linkage between energy and telecoms operations. At the base of telecommunications network operations is energy utilization. Power consumption occurs at all levels of the value chain of telecommunication service provisioning: from the operation of the Base Transceiver Station (BTS), to network equipment and data centre operations as well as end-user's consumption of services either by mobile handsets, fixed lines, servers, routers and switches; they are all energy dependent. Increase in demand for telecommunications services will necessarily lead to an increase in the infrastructure required to provide the services coupled with the expansion of the network to cover the country's geography, deliver good network uptime and quality service availability threshold and this will in turn result in increased amount of electricity needed to

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[20]Goldenberg, J. and Johansson, T.B. 1995, Energy as an instrument for socio-economic development. *Energy for Sustainable Development: A Policy Agenda*. T.B. Johansson and J. Goldemberg Eds. New York: United Nations Development Programme. 9-17.

[21]Minoli. D. 2011. *Designing green networks and network operations* CRC press. Boca Raton.

[22] FALL. L. 2010. XXIst World Energy Congress, Montreal, Canada, *Achieving Energy Efficiency in Africa: What are the Priorities, the best Practices and the Policy Measures* 9. Retrieved Dec. 3 2015, from http://www.worldenergy.org/documents/congresspapers/139.pdf

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power these infrastructure. Such is the chain reaction inherent in the life-cycle of telecoms operations.

The challenges associated with the supply of electricity to power telecoms networks are becoming greater due to the ever increasing number of people around the world that are becoming connected by fixed and mobile telecommunications networks. According to the International Telecommunications Union (ITU)[23] the ICT sector alone contributes to around 2 to 2.5 percent of global greenhouse gas (GHG) emissions with about 0.2% attributed to mobile telecom and about 0.3% to fixed telecom (the balance being with PCs, data centers, etc.). Specifically, we see from Fig 1. Below that within the ICT sector, the highest contributing segments include the energy requirements of PCs and monitors (40%), data centres which is about 23% and fixed and mobile telecommunications which contribute about 24%, printing contributes 6% and LAN equipment accounts for the remaining 7% of the total emission[24]. Pursuing growth in telecom networks remains the challenge for the telecom service providers, manufacturers of telecom equipment and the government while they ensure that there is no significant increase in the 2% of global emissions in the years to come[25].

In Nigeria, the inadequacy of grid power supply is a major concern and has affected telecom operations in terms of costs, reliability and quality of service. More than half of telecoms sites in operation today are powered using off-grid sources usually by diesel generators with attendant huge operating expenses (OPEX). The poor quality of power supply and frequent outages lasting long hours has made the remaining grid-connected sites to suffer and has led to a heavy dependence on diesel generators even for the grid-connected sites as well. Nigerian telecom tower operators face other operational hazards apart from the poor grid power supply. Site security, for example, is a major issue as there have been several cases of damage to tower assets across the country and this has discouraged operators and Tower Companies from investing in green power alternatives for the network. Fuel pilferage and thefts of equipment have affected the OPEX of telecom sites. In addition, initiatives reducing the diesel consumption have been contradicting with Operations and Maintenance partners' interests, thereby hindering the successful implementation of these alternatives.

Gross[26] observed that the cost of energy constitutes the largest operating expenses for telecom network operators and consequently, an increasing contributor to global greenhouse gas (GHG) emissions is energy consumption from telecom operations. She opined that electricity consumption of a telecom Base Transceiver Station (BTS) is on average divided as follows: transmitters: 54%, air-conditioning: 35%, other equipment: 11%. Typically, 34 litres of diesel is being consumed daily by a BTS which has a 4.8kW site load. This is equal to more than 12,000

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[23] Energy Efficiency Page of International Telecommunication Union website Retrieved Feb. 22, 2015 from http://www.itu.int/en/action/climate/Pages/energy_efficiency.aspx

[24] International Telecommunications Union (ITU) *ICTs and Climate Change*, Background Paper for the ITU Symposium on ICTs and Climate Change, Quito, Ecuador, 8-10 July 2009. Retrieved on Feb. 22, 2016, from http://www.itu.int/dms_pub/itu-t/oth/06/0F/T060F00600C0004PDFE.pdf

[25] South Asian Telecommunications Regulator's Council (SATRC) Report on Green Telecommunications, adopted by the 13th Meeting of the South Asian Telecommunications Regulator's Council, 18 – 20 April 2012, Kathmandu, Nepal

[26] Gross, I.2012. Mitigating ICT Related Carbon Emissions: Using Renewable Energy to Power Base Stations in Africa's Mobile Telecommunications Sector. *Case Study: ICTs and Climate Change Mitigation, Climate Change, Innovation & ICTs Project, Centre for Development Informatics (CDI)*, University of Manchester, United Kingdom. at p. 2

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litres of diesel with an operating cost that can be double or triple that of an on-grid BTS in accordance to the price of oil. In terms of emissions, this translates into an annual carbon footprint around 33.3 tons of CO_2.According to Minoli,[27] these percentages as well as the absolute values may grow as ICTs become even more widely deployed. He reasoned that in a business-as-usual (BAU) scenario, the ICT sector's own emissions are expected to increase from 0.53 billion tons (Gt) carbon dioxide equivalent (CO_2e) in 2002 to 1.43 $GtCO_2e$ in 2020; bearing in mind that the ICT contributes as much as 7% of global gross domestic product (GDP).

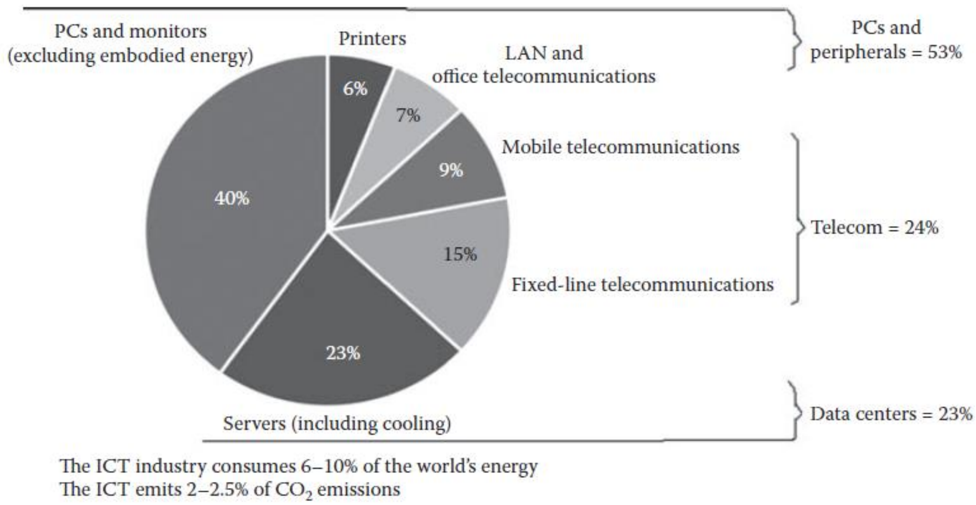

Fig. 1.Distribution of global Co_2 emissions from ICT. Source: Minoli. Daniel 2011. *Designing green networks and network operations* CRC press. Boca Raton.

Minoli[28] therefore emphasized that the need to increase operational efficiencies and reduce cost have become the main drivers for telecom equipment vendors and service providers to seek innovative ways of reducing energy consumption and heat generation of network equipment. Telecom operators are now seeking innovative ways to minimize power, cooling, floor space, and online storage, while at the same time optimizing service performance, capacity, and availability.

Understanding the structure of telecommunication network

It would be useful for the purpose of this study to analyze where and how energy is consumed within a telecoms network, especially in the light of the increased relevance information and communication technology in the 21st century as underscored by the growing demand for ICT services.

[27]Minoli. D. 2011. *Designing green networks and network operations* CRC press. Boca Raton
[28] Ibid

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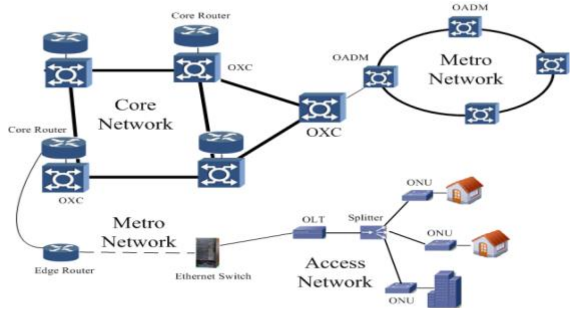

Fig. 2.Telecoms Network Hierarchy.
Source: Zhang, Y., Chowdhury, P., Tornatore, M. and Mukherjee, B. 2010 Energy efficiency in telecom optical networks. *IEEE Communications Surveys & Tutorials Journal*, 12.4: 441 – 458

In Fig 2 above, we see the relationship and interactions between the various components of a typical telecoms network. At the base of the network architecture is the core network which serves as the backbone of the network. The core network is the portion of the network where the network capacity is aggregated and is typically represented by network nodes spanning national and international distances. Next to the core network is the metro network which covers metropolitan areas to deepen the network presence and to serve as a carrier path between the backbone and the access network. According to Mukherjee[29] typically, the metro network spans metropolitan regions which covers distances of a few tens to a few hundreds of kilometers and is dominantly based on a deep-rooted legacy of Synchronous Optical Network (SONET) or Synchronous Digital Hierarchy (SDH) optical ring networks or a wireless architecture feature connected by microwave radios or a mix of both technologies. While at the base of the hierarchy is the access network which is the portion of the network that delivers value to the end-user customer which includes homes, offices and businesses.[30]Also known as the "last mile" of a telecom network, the access network is the portion of the network connecting the telecom provider's Point-of-Presence (PoP) with end users customers. According to Lange et al[31] the access network is the largest portion of the telecom network and it contains a high number of active elements and as a result is major consumer of energy in telecoms network operations.In general, the telecommunication sector accounts for approximately 4% of the global electricity consumption[32].

Today, Nigeria is witnessing the advent of novel concepts and technologies including but not limited to electronic banking (e-banking), electronic commercial transactions (e-commerce), video-conferencing, remote monitoring, Internet of Things (IoT), Machine-to-Machine (M2M), cloud computing, Software Defined Wide Area Network (SD-WAN) etc. All of these communication services only point to one thing – increase in bandwidth capacity. This is

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[29]Mukherjee, B. 2006. *Optical WDM Networks*. 1st ed. New York: Springer Science+Business Media Inc

[30] See footnote 119

[31]Lange, C. and Gladisch, A. 2009. Energy consumption of telecommunication networks - A Network Operator's View. Proceedings of FC/NFOEC'09, Workshop on Energy Footprint of ICT: Forecast and Network Solutions, San Diego, CA.

[32]Gladisch, A, Lange, C. Leppla, R, 2008 Power Efficiency of Optical Versus Electronic Access Networks.*Proc. European Conference and Exhibition on optical communications*, Brussels. Retrieved Dec. 11, 2016 from https://www.researchgate.net/publication/224363603_Power_efficiency_of_optical_versus_electronic_access_networks

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however not without a price because the pervasiveness of Information and Communications Technology (ICT) in daily life raises the fundamental issue of energy consumption of the network equipment utilized in the communication process and this has become a major issue in global energy discourse. Energy is a key driver and a major enabler across every layer of the telecoms network and innovations in science and technology continues to place a huge demand on the telecommunications industry to expand services and meet the ever increasing demands of connectivity from other sectors. We are also confronted with the imperatives of reduced pricing, climate change mitigation and carbon emission reduction. Thus telecoms operators are faced with a major goal of achieving reduced energy consumption and at the same time grow their network footprint, improve service coverage and also remain profitable. The possibility or otherwise of achieving these objectives is hugely dependent on being able to identify the layers and components of the network responsible for huge energy consumption and in some other cases being able to identify areas where potentials for energy savings exists and take adequate measures to turn these potentials to reality.

We shall now examine the potentials for energy saving savings at the different layers of the telecom network. In terms of energy consumption at the level of the core network, Ghani et al[33] in their work observed that energy consumption at this level of the network usually occurs at both network layers i.e. the optical layer and the electronic layer as the core networks exhibit multilayer network architectures. Zhang et al [34] reinforced this positon albeit within the framework of a fibre-optics network design using an IP-over-WDM[35] (Internet Protocol over Wavelength Division Multiplexing) network. As an example, they observed that energy consumption is occurs both at the routing and transmission levels. At the routing level, the main energy consumers are Digital Cross-Connects (DXC) and IP routers for switching electric signals at the electronic layer, while Optical Cross-Connects (OXC) are used to switch optical signals in fibers at the optical layer. Other components of the WDM network include multiplexers and demultiplexers which are used to join and split signals at both ends of transport system, boosters, transponders, amplifiers. They concluded generally that all the components of the WDM network consume energy and specifically that energy consumed by the electronic layer is much larger than that of the optical layer. In other words, optical switching is more energy-efficient than electronic switching which is one of the basic reasons for the preference of optical technology in network designs with energy efficiency focus.

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[33] Ghani, N. Dixit, S. and Wang, T.S, 2000. On IP-over-WDM integration.*IEEE Communications. Magazine*, Vol. 38, No. 3, Mar. 15: 72–84; Manchester, J. Anderson, J. Doshi, B. and Dravida, S (1998) IP over SONET, *IEEE Communication Magazine.*, Vol. 36, No. 5, May:8: 136–142.

[34] Zhang, Y., Chowdhury, P., Tornatore, M. and Mukherjee, B. 2010 Energy efficiency in telecom optical networks.*IEEE Communications Surveys & Tutorials Journal*, 12.4: 441 – 458

[35] WDM is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths of laser light to carry different signals

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Table 1 - Typical Energy Consumption Data of Different Components in Telecoms Optical Networks. Source: Global Climate Change Network

Network Segment	Component	Capacity	Energy Consumption
Core Network	Core Router (Cisco CRS-1 Multi-shelf System)	92 Tbps	1020 kW
	Optoelectronic Switch (Alcatel-Lucent 1675 Lambda Unite Multi-Service Switch)	1.2 Tbps	2.5 kW
	Optical Cross-Connect (MRV Optical Cross-Connect)	N/A	228 W
	WDM Transport System (Ciena Core-Stream Agility Optical Transport System)	3.2 Tbps	10.8 kW
	WDM transponder (Alcatel-Lucent WaveStar OLS WDM Transponder)	40 Gbps	73 W
Metro Network	EDFA (Cisco ONS 15501 EDFA)	N/A	8 W
	Edge Router (Cisco 12816 Edge Router)	160 Gbp	4.21 kW
	SONET ADM (Ciena CN 3600 Intelligent Optical Multiservice Switch)	95 Gbps	1.2kW
Access Network	OADM (Ciena Select OADM)	N/A	450 W
	Network Gateway (Cisco 10008 Router)	8 Gbps	1.1 kW
	OLT (NEC CM7700S OLT)	1 Gbps	100W
	ONU (Wave7 ONT-E1000i ONU)	1 Gbps	5W

Source: Global Climate Change Network. Investing in Clean Energy: How to maximize clean energy deployments from international climate investments, Global Climate Network Discussion Paper No. 4.[36]

Table 1 above shows energy consumption data for the different network layers and their corresponding elements in an optical network. Scott et al[37] on their part observed that with the advent of new services such as high-definition (HD) video, gaming, coupled with the growing trend of video-calling and conferencing, online streaming, online applications and hosted services, reduction in demand for connectivity services is nowhere in sight. Without changes in telecom network architecture and their associated equipment and power sources, network

36 Anon. 2010 Global Climate Change Network.*Investing in Clean Energy: How to maximize clean energy deployments from international climate investments*, Global Climate Network Discussion Paper No. 4. Retrieved Mar. 8, 2016 from http://www.american progress.org/issues/2010/11/pdf/gcnreport_nov2010.pdf

37 Scott, H.M., Morawski, T.B., Nagengast, A.L., O'Reilly, G.P., Picklesimer, D.D., Sackett, R.A., & Wu, P.P, 2010. Planning Energy-Efficient and Eco-Sustainable Telecommunications Networks.Bell Labs Technical Journal Vol 15(1), 215–236. Retrieved Mar. 27, 2016 from Wiley InterScience Library www.interscience.wiley.com; DOI: 10.1002/bltj.20434

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operator energy demands and its attendant energy costs will continue to soar. The authors noted that network operators are seeing this trend and are concerned with evolving commensurate initiatives to deal with this increased energy demand from network operations. Therefore operators are faced with the daunting task of adopting the right options that creates the proper balance in the light of the competing needs of planning an environmental friendly network aimed at reducing their carbon footprint while remaining profitable for the long term. The authors situated their study both within the wireline and wireless context. In the wireline context, they observed that an average traditional core network requires approximately 1,500 kW of power, out of which the network equipment (such as multiplexers, muxes, routers and switches) accounting for 42 percent of the energy usage, while cooling accounts for 35 percent, and the remaining 23 percent is consumed by rectifiers and other direct current (DC) power.[38] The authors noted that it is common for TDM switching equipment to operate at a 50 percent fill rate. When added to old and outdated rectifiers operating at less than 60 percent efficiency and inefficient cooling system, then it is easy to see numerous opportunities to reduce energy usage. They argued that reductions can climb into the range of 40 to 80 percent. As is shown in the breakdown above, cooling is often one of the two largest contributors to the total power usage in the core network. Reducing energy consumption in the form of wasted heat from network equipment, rectifiers, and other sources can often provide a doubling of the savings when considering the reduced cooling load.

In the context of wireless network architecture, the authors noted that Base Transceiver Stations (BTS) deployed near subscribers is a major feature of wireless networks. They observed that radio frequency and power amplifier uses most of the power in BTS and next to these two components is cooling, which they found to consume 20 percent or more of the energy of the BTS. They also noted that location of the power amplifiers relative to the radio frequency antenna causes the largest variability in power usage in the base station. The power amplifier produces so much heat that it doubles the cooling load if it is installed near the antenna. An added power benefit is the closer the power amplifier is placed to the antenna, the less output power is required from the power amplifier due to reduced transmission line loss.

[38] These estimates are based on a Bell Labs analysis simulation of a typical core network architecture. Quoted in Zhang, Y., Chowdhury, P., Tornatore, M. and Mukherjee, B. 2010 Energy efficiency in telecom optical networks. *IEEE Communications Surveys & Tutorials Journal*, 12.4: 441 – 458

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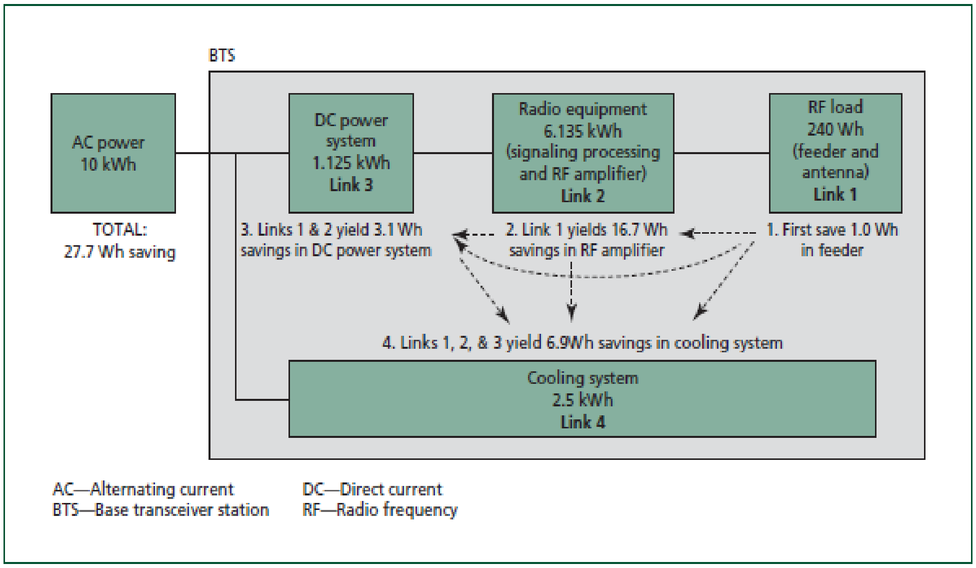

Fig. 3 BTS Energy Savings Chain (read from right-to-left).
Source: Scott, H.M., Morawski, T.B., Nagengast, A.L., O'Reilly, G.P., Picklesimer, D.D., Sackett, R.A., & Wu, P.P, 2010 Planning Energy-Efficient and Eco-Sustainable Telecommunications Networks Bell Labs Technical Journal Vol 15(1), 215–236. [39]

Scott et al [40] further observed that the layer of the network with the highest power saving potential is the access network in both wireline and wireless network architecture. This they attributed to the status of the access network as the closest to the end-user consumer thereby requiring multiple nodes scattered across different parts of the city. The quantity of these access nodes make them relatively larger in number than the core nodes. Therefore a small unit of power savings at an access node when aggregated over the different access nodes in a network will amount to significant energy savings. The authors demonstrated this with an analysis of the energy footprint of a typical wireless BTS in which they noted that a BTS has four (4) key energy consuming elements namely; the RF load (consisting of the feeder and antenna), radio equipment (consisting of the signal processor and power amplifier), Direct Current (DC) power system and the cooling system. They noted that the BTS initially requires an input energy of 10kWh out of which the cooling system alone consumes 2.5kWh, accounting for about one third the power consumption of the other three elements combined. Sutton and Angus [41] on their part argued that increase of in the energy costs of wireless networks has led to consequential increase in operating costs. This resulting increase arises from the daily expansion of the mobile networks driven by large volumes of data being consumed by end users which amounts to significant network traffic.

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[39] Scott, H.M., Morawski, T.B., Nagengast, A.L., O'Reilly, G.P., Picklesimer, D.D., Sackett, R.A., & Wu, P.P, 2010. Planning Energy-Efficient and Eco-Sustainable Telecommunications Networks.Bell Labs Technical Journal Vol 15(1), 215–236. Retrieved Mar. 27, 2016 from Wiley InterScience Library www.interscience.wiley.com; DOI: 10.1002/bltj.20434

[40] Ibid

[41] Sutton, A. and Angus, C. 2011. Building better backhaul.*Engineering and Technology,* 6(5): 72–75.ISSN: 1750-9637.

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It is important to highlight that through a research interview conducted with the Director of Technical Standards and Network Integrity at the NCC, the study found that there exist incidences and practices that are at variance with the principles and requirements of energy efficiency within the Nigerian telecoms industry. Some of these include proliferations of obsolete and outdated equipment both at the network and consumer segments of the telecoms industry. According to the Director, telecoms equipment are mostly energy efficient when they are new and within their recommended life span, however with constant usage, these equipment become inefficient and poses significant risk to operations in the form of power outage, weakened resistance to power surge leading to equipment failure to reboot and explosion or fire in some other extreme cases. This old and outdated equipment tend to be the mostly utilized in Nigeria even for telecoms operations owing to our penchant for second-hand products which, unfortunately, would have exceeded their recommended life span before shipment into the Country. Added to this, the Study also found that poor maintenance of telecom infrastructure also result in higher energy consumption of telecom equipment and infrastructure.

Legal and policy framework for energy efficiency in telecommunication operations

A vibrant legal and policy framework is central for energy efficiency to function effectively, thus it is important to examine the existing framework that is obtainable in Nigeria and determine how much leverage the nation can draw from such framework. The principal legislations that bears some meaning to a relationship on energy efficiency in Nigeria are The Nigerian Communications Act[42], Energy Commission of Nigeria Act,[43]Standards Organization of Nigeria Act,[44] and The Electric Power Sector Reform Act[45].

A careful review of the different statutory laws, applicable policies and efforts of the Nigerian government that is relevant to telecoms energy efficiency reveals that there is no specificenergy efficiency law in Nigeria today. Interestingly, countries that have recorded significant results and gained the benefits of energy efficiency did so through enacting and implementing specific energy efficiency legislations. Good examples here are Germany where seven laws and one ordinance were passed by the *Bundestag* and *Bundesrat* which are the country's upper and lower houses respectively to deal with issues of energy efficiency.[46] In Japan there is the Energy Conversation Law and in Ghana there is the Energy Commission Act[47] with various regulations

42 The Nigerian Communications Commission Act Cap N9, L.F.N. 2004

43 This is the law that established the Energy Commission of Nigeria. Precisely, Act No. 62 of 1979, as amended by Act No. 32 of 1988 and Act No. 19 of 1989. Now Cap E10, LFN, 2004.

44 Standards Organization of Nigeria Act 2015

45 Electric Power Sector Reform (EPSR) Act, 2005

46Federal Ministry of Economics and Technology (BMWi) 2012, Germany's New Energy Policy. Restructuring of the Legal Framework for the Promotion of Electricity Generation from Renewable Sources Act; Energy Sources including the year 2011 first hand report on the Renewable Energy Sources Act; Measures to Accelerate the Expansion of the Electricity Grid Act; Act to Restructure Provisions of the Energy Industry Act; Act for the Amendment of the Act to Establish a Special Energy and Climate Fund; 13th Act to Amend the Atomic Energy Act; Act strengthening Climate-Friendly Measures in Towns and Municipalities;

47 Energy Commission Act, 1997 (Act No. 541).

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enacted[48] thereto dealing with energy efficiency issues. From a policy perspective, relevant energy efficiency polices in Nigeria are the National Energy Policy of 2003 (which was reviewed in 2013), National Energy Master Plan of 2014, National Renewable Energy and Energy Efficiency Policy of 2015, National Energy Efficiency Action Plans of 2016, Renewable Energy Master Plan of 2012 National Policy on Telecommunications of 2000, National Broadband Plan of 2013, ECOWAS Energy Efficiency Policy of 2013.

From the analysis of the existing legal and policy framework we understand that added to the lack of an energy efficiency law in Nigeria, the various existing policies that are highlighted above contains very broad and general policy statements with respect to energy efficiency and these statements are inadequate in driving energy efficiency into the fabrics of the Nigerian society generally and telecommunications sector specifically. Most of these policy statements remain lofty and are without any quantitative target to drive the implementation of these statements and objectives. It appears therefore that it was in response to this lacuna in the National Energy Policy that the National Renewable Energy and Energy Efficiency Policy (NREEEP) and National Energy Efficiency Action Plan (NEEAP) were formulated, to give life and impetus to the broad policy statements as contained in the National Energy Policy, yet these action plans have also not received the much needed will on the part of government to drive implementation across the various sectors of the economy including telecommunications. On the other hand, the ECOWAS Energy Efficiency Policy (EEEP) provided the framework for leveraging external support that may be required to achieve these broad policy objectives in terms of access to regional partnerships and collaborations within the West Africa sub-region that will accelerate the integration of energy efficiency into the Nigerian economy. It is worth mentioning, that with the advent of the NREEEP, the place of energy efficiency as a resource base was recognized in Nigeria. This is very laudable as the NREEEP has properly positioned energy efficiency within its pride of place of being a resource, as obtainable in developed nations of the world. On the whole, the study found therefore that there exist a general policy framework upon which energy efficiency can find expression in the Country but sadly, the political will on the part of government is lacking to drive implementation.

This Study also found that the NEEAP attempted to capture various sectors of the Nigerian economy where potentials exists for the integration of energy efficiency and developed energy efficiency targets on five broad categories of; lightning, high performance distribution of electricity, standards and label, buildings and industries. Among these five categories, the category under which the telecommunications sector may fall will be the industrial sector or standards and labels from an equipment standardization perspective due to the heavy utilization

[48] Regulation LI 1958.Energy Efficiency Standards and Labelling (Household Refrigerating Appliances) Regulations, 2009; Regulation LI 1970 Energy Efficiency Standards and Labelling (Household Refrigerating Appliances) (Amendment) Regulations, 2010; Energy Efficiency Standards and Labelling (Non-Ducted Air Conditioners and Self-Ballasted Fluorescent Lamps) Regulations, 2005.Retrieved from http://energycom.gov.gh/files/LI_1815.pdf.on Oct. 26, 2018.

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of various equipment in telecommunication operations, however the discussions and target set under both categories has no direct reference or application to the telecommunications sector. The NEEAP also identified key agencies of government with direct and indirect responsibilities across the five categories and tasked these agencies with specific inputs and responsibilities toward the implementation of the energy efficiency targets. However, the study found that the Nigerian Communications Commission was not listed as one of such agencies. This suggests that the NAEEP did not consider the telecommunications sector as one of the sectors under its targets and applications whether directly by listing it in the same way it did for transport and power or indirectly by application of objectives of the Action Plan to some segments of the sector. The study conceives this as an unfortunate lacuna because the telecommunications sector is energy intensive, with significant energy consumption footprints, especially as the sector has emerged as the second biggest GDP contributor to the Nigerian economy[49].

Additionally, from a telecoms perspective, the existing regulatory framework for the telecoms sector as contained in the National Telecommunications Policy and the Nigerian Communications Act, as well as regulations made pursuant to the Nigerian Communications Act[50], being principal legislations governing the telecoms industry, cannot adequately drive energy efficiency integration within the sector. Specifically, the study found that there are no provisions dealing with energy efficiency in these documents, whether from the perspective of network planning, service roll out obligations, license conditions, equipment type approval, standardization, and other regulatory processes within the operations of the Nigerian Communications Commission (NCC) as sector regulator. This finding was further confirmed during a research interview session with the Director of Technical Standards and Network Integrity at the NCC, who opined that energy efficiency issues does not fall within the purview of the NCC but that of the Energy Commission of Nigeria. The NCC has adopted a posture on the issue that suggest that energy efficiency is a commercial consideration that will enable operators to save on operational cost and help optimize their networks and as such the NCC cannot compel its adoption by operators. According to the Director, the NCC can only encourage and persuade operators to adopt energy efficiency in network planning and their operations. This, amongst other reasons, accounts for the huge energy intensity being experienced in the Nigerian telecoms sector.

CONCLUSION

The study found that energy efficiency is an essential part of the solution to the challenges of climate change mitigation and carbon emission reduction especially in the light of Nigeria's commitment under the Paris Agreement. The study showed that energy efficiency contributes to climate change mitigation via reducing energy consumptions, thereby reducing greenhouse gasses emission and it has become the second largest contributor in attaining climate

[49] Ojobo, T. 2016. Investment in Telecoms Hits $68bn in Nigeria. *IT & Telecom Digest.* 197 Nov: 34. See also Tarpael, F. Nov. 28, 2016.

[50] Competition Practices Regulation of 2007, Universal Access and Universal Service Regulations of 2007, Type Approval Regulations 2008, Telecommunications Networks Interconnection Regulations 2007, Registration of Telephone Subscribers Regulations of 2011, Quality of Service Regulations of 2013, Numbering Regulations of 2008, Mobile Number Portability Regulations of 2014, Frequency Pricing Regulations of 2004, Enforcement processes Regulations of 2005, Consumer Code of Practice Regulations of 2007, Annual Operating Levy Regulations of 2007.

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stabilization targets up to 2030. Infact the study found that by 2020, energy efficiency will be responsible for 50% of the energy-related CO_2 emissions abatement necessary to bring down CO_2 concentration to the level compatible with limiting the long term temperature increase to 2 ^{0}C which is equivalent to 450 CO_2 Parts Per Million (PPM)[51]. Some of the approaches for mitigating greenhouse gasses emission espoused in this study include reducing demand for emission intensive goods and services, increasing efficiency gains, increasing use and development of carbon technologies and reducing fossil fuels emission. The need to mitigate climate change and escalating energy costs has made energy-efficiency a key element of telecommunication network planning, design and operations. The study showed that as demand for telecom service increases, network operators' energy costs will increase as well thus there is a need to adopt new network architecture that are inherently more energy-efficient and flexible enough to support continued increase in demand. Therefore telecom operators have a responsibility to develop optimal and energy efficient network through planning to mitigate climate change and manage network operating costs in Nigeria

Telecoms operators should be encouraged to "green" their operations. There is a need for government to formulate policies and initiatives that will drive the adoption of green technologies by telecoms operators. The focus here would be to create an incentive driven system whereby telecoms operators are incentivized based on their adoption of green technologies to drive energy efficiency in the operations of their respective network. Such a system may be in the form of a carbon credit regulatory regime for all telecoms network operators to reduce the carbon footprint of their network and set the sector on the part of "greening". This system would also include the adoption of renewable energy resources such as solar for energy supply to power base stations, network nodes, data centres and other telecom infrastructure thereby significantly reducing carbon emission for the sector. Also the framework may include ensuring green requirements reflects in the design and planning of telecoms networks. This may be in the form of siting base stations and data centres in locations that provide access to renewable energy and natural cooling from the environment to cool servers and network equipment, thereby reducing the need for grid energy or burning fossil fuel from generators. There is also need for the government to invest in research and development as way of developing home grown energy efficiency technologies that can help drive energy efficiency in the telecoms sector. Specifically, the NCC under its annual "telecoms based research innovation programme" where it makes request for telecommunication based research proposals[52] can specially dedicate one of such request for proposals to the development of telecoms based energy efficiency technologies and standards applicable to the Nisgerian telecoms sector. This way, the government will harvest relevant research work that will help in the formulation of energy efficiency regulations or guidelines for the sector and accelerate the adoption of relevant energy efficiency technologies and standards within the Nigerian telecoms sector.

51 See Note 72 above

52 Request for Proposal (RFP) - Telecommunications-Based Research Innovation from Academics in Nigerian Tertiary Institutions. 2008. Retrieved on January 2019 from https://www.ncc.gov.ng/stakeholder/media-public/public-notices/370-request-for-proposal-rfp-telecom-based-research-innovation-from-academics-in-nigerian-tertiary-institutions-2018

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