Environmental Impact Assessment of Mobile Communication Networks in Lagos State

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Abstract
The exponential increase in the energy demand and carbon footprint of Information and Communications Technology (ICT) services are problems of global concern. There is no general solution to this problem globally because energy sources and the resulting environmental impacts differ from country to country. However, there is a need to identify the causes of these pollutants and locally assess their impacts to proffer a lasting solution. In this paper, we evaluate the energy demands of the telecommunication sites in Lagos, Nigeria and the environmental impact resulting from their operations. The periods the base transceiver stations (BTSs) are powered by the national grid were investigated and we considered the emission generated from the alternative energy sources the service providers adopt in the absence of national grid supply. The findings from our study revealed that the service providers depend largely on diesel generators (DG) for their operations, and the entire management of the site is not energy-efficient. Based on the peculiarity of our study location, we present viable green approaches and achievable recommendations that can be implemented by the service providers and the major stakeholders to reduce the negative environmental impact resulting from the operations of these telecommunication sites.

Keywords: Telecommunication, Energy, Pollution, Carbon footprint, Grid, Diesel Generators.

1.0 INTRODUCTION

The telecommunication sector, which is an important aspect of information and communication technology (ICT), has raised a lot of concern due to its energy usage and carbon footprint. Efforts of the network providers to meet the increasing cellular service demand of the network users and to accommodate new users necessitate the deployment of additional base transceiver stations (*BTSs)* which in turn increases their energy usage, operational expenditure (OPEX), and the environmental impact resulting from their operations. The operation of the mobile communication network requires a consistent electricity supply and this is a major limitation in most developing countries around the world and Nigeria is not an exemption. The current electricity access rate in Nigeria is 45% with 36 % in rural areas and 55% in urban areas and there are twenty million households without power supply according to USAID (2019). These limitations in the power sector have placed a major embargo on the advancement of the country despite being the largest economy in sub-Saharan Africa.

The telecommunication sector in Nigeria is also affected by the country's erratic power supply that has forced telecommunication companies to depend either solely or largely on alternative energy sources for their operations.
Several scholarly contributions have addressed the issue of power supply in Nigeria as related to the telecommunication industry. The cost implication of poor power generation on the operation cost of the telecom business in Nigeria was analyzed in the works of Nkordeh *et al.,* (2017). Parts of the effect of poor power supply identified by the authors are low access to telecom services in rural areas, increased operation expenditure, poor quality of service offered to the users, and increased cellular service tariffs. Tebepah (2015) presented the associated effects of the lack of reliable electricity supply to mobile communication sites in Nigeria. The economic and security challenges emanating from this issue were discussed as well as the roadmap for a comprehensive framework that embraces renewable energy sources for sustainable telecommunication operations. In the work of Ojo *et al.,* (2019), the challenges of

the telecommunication industries in southwestern Nigeria as a result of poor power supply were considered. The authors proposed a green power delivery system for the *BTSs* in this geographical location with hybrids of renewable energy sources.

Besides the increased OPEX of the service providers as discussed in the above works of literature, there is a need to locally investigate the entire operation of the service providers, identify the pollutants resulting from their operations, and assess the resulting environmental impact to proffer an achievable and lasting solution that is currently lacking. In this paper, we investigate the entire operation and management of telecommunication sites in Lagos, Nigeria by evaluating the energy requirement of the radio equipment, the period these equipment are powered by the national grid, the emission generated from the alternative power adopted in the absence of grid supply, and the impact of their overall operations on the environment.

2.0 MATERIALS AND METHOD

The location of the study presented in this paper is Lagos State, Nigeria. It is a state in South-Western Nigeria with an estimated population of about twenty-one million inhabitants, averaging 6,800 people per km^2 in population density according to World Population Review (2019). Lagos is an important ICT hub and the leading mobile telecom market in Nigeria and Africa. It is a major location for diverse port activities and the abode of several multinational companies. The choice of this study location is because the telecommunication activities in Lagos are at its peak when compared with the other states in Nigeria. It has the highest number of BTSs and collocation towers in terms of the geographical spread of telecommunication infrastructure in Nigeria according to the Nigeria Communication Commission (NCC, 2018). Lagos also has an enormous number of end-users that require one or more telecommunication services.

2.1 The Telecommunication Sites in Lagos State

Diverse telecommunication services are provided in Lagos by telecommunication companies which include Airtel Networks Limited, Globacom Limited, MTN, Ntel, 9 mobile, Swift Network Limited, Smile Nigeria, and Spectranet. Each of these companies has a unique operation policy and target market. In this study, the environmental impact from the operations of the telecommunication sites in Lagos state was investigated. The scope of our study covers the telecom sites that belong to MTN, Airtel Networks Limited, Globacom Limited, and Ntel which are the leading telecommunication companies with the highest number of base stations and cellular subscribers in Lagos state and Nigeria (NCC, 2018).

As at the beginning of this study, four thousand seven hundred and sixty-four (4,764) base stations (*BS*) have been deployed within the Lagos metropolis and four thousand seven hundred and thirty-four (4,734) are specifically used for mobile services according to NCC (NCC, 2018). We visited the sites which belong to Airtel, Globacom, NTEL, and MTN during the period of this study. Most of the sites are ground stations and a majority have their digital equipment which includes transmitters, receivers, radio base station series, inverters, and batteries within an aluminum enclosure known as shelter, other mobile signal transmission enabling equipment like radio antennas, transceivers and remote radio unit, are mounted on masts. Some other sites have outdoor digital equipment, hence, they have no equipment in the shelter and do not require air conditioners. Two diesel generating sets and a diesel tank for fuel storage are common to all the sites and they are generally bounded either with an aluminum bar or average height concrete fence. Depending on the site load capacity, common power ratings of these

generators are 9kVA, 15kVA, 16kVA, 22kVA, or 27kVA.

Two diesel generating sets with automatic transfer switch (*ATS)* synchronization are used in order to provide an uninterrupted power supply to the equipment at each site since most sites are either with unreliable power supply or without access to the national grid. Each generator either work twelve (12) hourly or work for a period of ten (10) days before changing over to the other generator automatically. The physical outlook of a typical telecommunication site in Lagos is shown in Figure 1.

Figure 1: A typical Base Transceiver Station in Lagos State

3.0 RESULTS AND DISCUSSION

Based on the study and investigation carried out in this work, the major source of energy used in the absence of a national grid supply for the operation of the telecommunication site in Lagos is diesel generator (DG). About 6 % of the sites in Lagos were identified as using a hybrid power system consisting of DG and Solar Photovoltaic System and interviews with some of the operators revealed that the output power from the solar system is low and usually require some form of optimization. A few other sites were identified to be connected to the national grid and they experience power outage of more than 15 hours daily while there were times when the power outage persisted for a few days or weeks. Therefore, these sites can be classified as bad-grid sites.

Table 1: The approach of powering the telecom site in Nigeria (GSMA, 2014a)

Base Station Power Context	Nigeria
Total Base Stations for Mobile	30,637
% of Off-Grid BTSs (DG Only)	64%
% of On-Grid BTSs + DG Only	25%
% of Green and Hybrid Powered BSs	11%
Growth in the number of Off-Grid (2014 - 2020)	3,200
Growth in the number of Bad-Grid (2014 - 2020)	4,700

The summary of the growth and the current approach of powering the telecom sites in Nigeria is shown in Table 1. The comparison of this statistics with the tower estimation and green power model of other African countries shows that Nigeria has the highest number of *BTSs* deployment that is completely off-grid and in bad-grid locations which independently account for 12% of the global value according to the report of global system for mobile communications (GSMA) on green power for mobile (GSMA, 2014a), (GSMA, 2014b).

The market survey and interaction carried out with mobile network operators (*MNOs)* personnel during the study presented in this paper revealed that telecommunication companies are one of the largest end-users of diesel generators in Lagos state and Nigeria with over 85% of the purchased generator within the range of 9kVA to 30kVA capacity. The remaining percentage is for generators whose ratings are within 30 – 60kVA and 300 – 500kVA which are primarily used at the switching centers.

3.1 Diesel Consumption at the Telecommunication Sites in Lagos

An erratic power outage is one of the major challenges of the telecommunication companies in Nigeria and to meet the user quality of service, operators have resorted to providing their power supply. About 90% of the BTSs in Lagos State are off-grid and depend on DG for their operation. The remaining BTSs that are connected to the grid also depend largely on back-up generators for their effective operation because of the frequent power outage. The use of these diesel engines releases a considerable large quantity of toxic pollutants to the atmosphere alongside emissions from other sources like smoky vehicles, industrial fossil fuel burning, improper disposal and management of chemicals. According to a study presented in Wolf (2014), the exhaust from a running diesel engine is a combination of different gases, water vapour, and aerosols while the major emission pollutants from the exhaust are carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen oxides (NO_x).

To accurately evaluate and quantify the emissions from the diesel generators used for mobile telecommunication activities in Lagos, site parameters which include the number of operating DG, estimate of hours per day each DG is operated, capacity rating, average weekly diesel consumption, fuel efficiency, the power factor of each of the generators, and the grid power availability for each site was investigated. The diesel consumption per hour test (DCPHT) of the generators at the BTS sites in Lagos that was investigated and measured in this study is shown in Table 2**.** The measurement entails the generator's diesel consumption per hour (CPH), consumption per day (CPD), consumption per month (CPM) and consumption per year (CPY).

Table 2: Diesel Consumption per Hour Test for BTS Sites in Lagos (May –August, 2019)

S/N	DG (kVA)	CPH (Litres)	CPD (Litres)	CPM (Liters)	CPY (Litres)
1	9	1.50 – 2.02	36.00 – 48.48	1080 – 1454	12960 – 17453
2	15	1.80 – 2.82	43.20 – 67.68	1296 – 2030	15552 – 24365
3	16	1.50 – 2.41	36.00 – 57.84	1080 – 1735	12960 – 20822
4	22	2.40 – 4.35	57.60 – 104.40	1728 – 3132	20736 – 37584
5	27	2.60 – 4.72	62.40 – 113.28	1872 – 3398	22464 – 40781

The CPH differs from generator to generator even for generators of the same capacity. This is based on factors that include fuel efficiency, electrical load, and the generator age; a majority of these generators are more than 4 years while some are slightly over 3 years. There were reports of diesel theft in some of the sites during the test period as well as diesel leakage from the outlet of the diesel fuel tank. The diesel consumption of the generators at the switching centers and MNO offices were not quantified in our study. From Table 2, the estimated diesel fuel consumption at the BTS sites in Lagos is approximately five hundred and thirty million liters per year with the exception of the volume of diesel consumed at the data and switching center as we were unable to access these locations during this study.

Diesel fuel typically releases 2.68kg of carbon dioxide CO_2 per liter of consumption in addition to the other gases and pollutants emitted based on the work of Davies (2019). Using the standards from Davies (2019) and the National Environmental Standards and Regulation Enforcement Agency (NESREA) standards (FRN Gazette, 2011), about 4.1 million metric tonnes of CO_2 are emitted from the operation of telecom sites in Lagos annually with the addition of other pollutants like oxides of sulphur and nitrogen. Though the telecommunication sector is very promising and one of the leading sectors in the nation, the operation of the network service providers will continue to be carbon intensive if they depend on diesel generators for their operations. Figures 2 and 3 show the monthly and yearly CO_2 emissions for the generators considered based on the 2.68kg of carbon dioxide CO_2 per liter of diesel consumption.

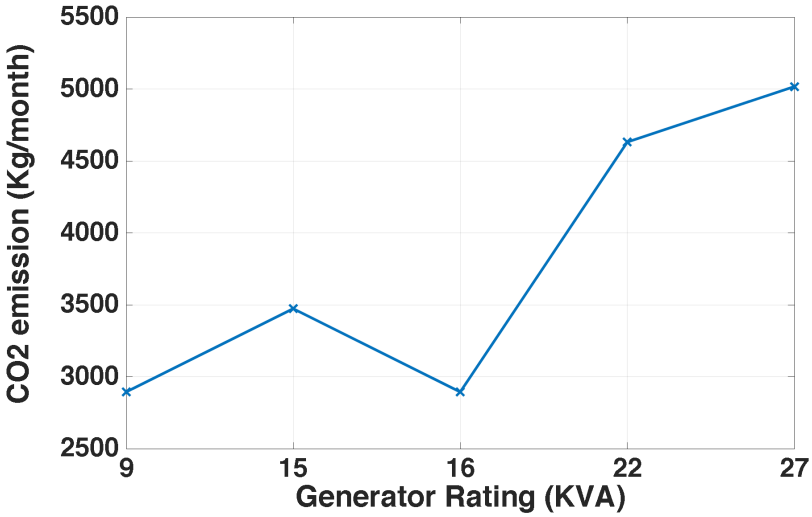

Figure 2: CO_2 monthly emission due to diesel consumption

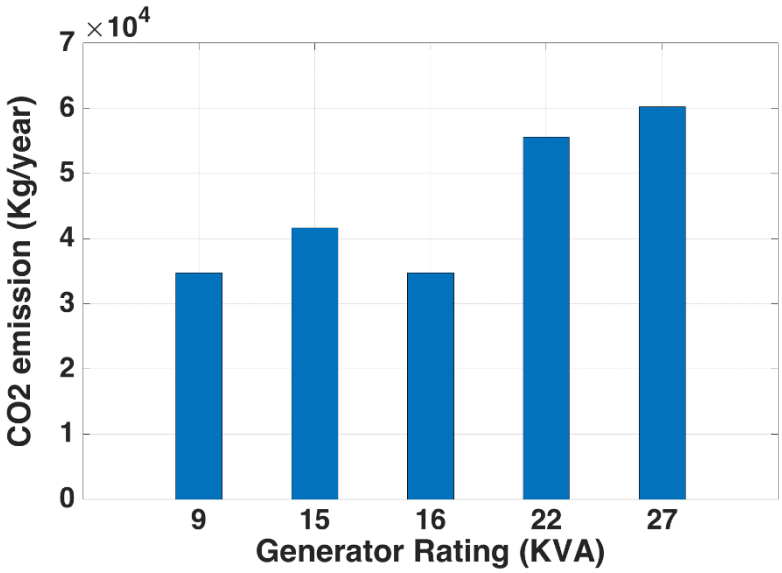

Figure 3: CO_2 yearly emission due to diesel consumption

3.2 Other Observations and Findings at the *BTS* Sites in Lagos

a. Outdoor lightings are permanently switched on and this is not energy efficient.
b. The generators are always powered on and majority are very noisy and smoky.
c. Most of the generators on the sites are up to 4 or 5 years according to our interaction with the personnel at the site.
d. Some of the sites are dirty and appeared to be poorly maintained. Used engine oil spillage was seen on the floor around the generator area and within the site premises.

e. The two-hybrid powered *BTS* sites were seen to mainly operate on diesel generator (DG). Interview with the on-site personnel revealed that the output power from the solar photovoltaic system is too poor to be reliable.

4.0 ENVIRONMENTAL IMPACTS FROM THE OPERATION OF BTSs IN LAGOS

Telecommunication service providers operate round the clock and as a result, their radio equipment is always powered on and they depend on DG. The notable environmental impacts from the operations of the telecommunication sites in Lagos based on the investigation carried out in this study are discussed under the following subsections.

4.1 Climate Change

Carbon dioxide is an important part of the carbon cycle and one of the key compositions of greenhouse gases (GHG) that help trap heat in the atmosphere. Variations in solar radiation and other natural occurrences, that humans have little or no control over, results in climate change. Therefore, human activities that increase the amount of atmospheric carbon emission is of great concern. The effect of the over-dependence of the telecommunication service providers in Lagos on diesel generators is a major activity that increases the percentage of greenhouse gases in the atmosphere. The continuous diesel-burning for powering telecommunication sites in addition to other extreme activities such as a change in land use and poor waste management has the potential to impact the climate by increasing the warmth on the earth surface which can be destructive with the increase in the intensity, duration, and frequency of heat waves.

A previous study revealed an increase in the air temperature in Lagos State while the pattern of rainfall, water quality, and availability in Lagos is threatened based on the work of Idowu *et al.,* (2011) and Onyenechere (2010). Also, the groundwater resources which serve as the alternative source of water for most Lagos inhabitants have been reported to have depleted due to climatic changes. Therefore, the continuous use of DG at the BTSs sites should be exceedingly minimized and future BTSs should be deployed and planned with an alternative source of energy. This is a necessity because if the trend continues, the state will be greatly affected because of its rising population and increased industrial activities.

4.2 Impacts from diesel and used engine oil spillage

Several telecommunication sites in Lagos are not properly maintained as seen from the evidence of diesel and used engine oil spillage within the premises of some of the sites**.** Figure 4a and Figure 4b show used engine oil poured directly beside the serviced generator.

The improper disposal and spillage of used engine oil have the following environmental impact:

a. It affects soil properties adversely depending on the quantity and how deep it sinks and spread into the ground and surrounding environment.
b. Evidence from the study presented in the work of Akintunde *et al.* (2015) revealed that exposure to used engine oil is toxic and poses a reproductive health risk to humans.
c. If it is mixed with floodwater runoff, it tends to have an adverse effect on the neighboring water body.

Diesel leakage from the downstream outlet of the diesel storage tank and spillage was also seen in most of the sites. The following are the environmental impact of diesel leakage and spillage:

a. Diesel spills can filter into the soil as well as underground water and as a result, contaminate drinking water from well. An incidence of this occurred in the Lekki area of Lagos where diesel

spillage from a BTS polluted a nearby well used for drinking. Though the MNO that owns the site dug another well, the new well is still at risk of future contamination.

b. Diesel is a fire hazard threat if not properly managed when spilled because of its chemical properties.
c. Diesel can have an adverse effect on the water body and aquatic creature if it mixes with surface water runoff.

Figure 4a: Used engine oil spillage beside the generator.

Figure 4b: Used engine oil spillage within the site premises.

4.3 Noise Pollution

All the sites within Lagos are associated with different sources of unwanted noise. A heavy-duty generator is always on and accompanied by noise, the RBS 6102 or RBS 6103 which are the common outdoor macro BTS in the RBS 6000 series are always on and making an unpleasant noise. Though the study presented in this paper did not quantify the noise from the base stations, it is evident that the continuous noise from the operations of the telecom site can cause adverse ill health such as increased stress level, headache, loss of sleep and diverse hearing defect to the people staying close to these sites most especially for the sites that are situated very close to residential premises. This does not conform to NESREA standard and permissible levels of generator setback of 6m from perimeter walls of residential premises and 8m for sites without a fence (FRN Gazette, 2011).

4.4 Potential Health Risk

The continuous emission from the dependence of the telecommunication service providers on diesel fuel for their operation results in air pollution and the study from Olowoporoku *et al.* (2012) revealed the relationship between cardiovascular infections, heart, and respiratory diseases with the air pollution in Lagos. The personnel and technicians that were seen working on the site during this study did not use any personal protective equipment (PPE). This is hazardous because life is at risk in case of slippage, fall, or any other site accident.

5.0 RECOMMENDATIONS ON GREENER APPROACHES FOR LAGOS STATE

The operation of the telecommunication companies has been studied and described in this paper and their operation has been seen to contribute to the abundance of the carbon dioxide in the atmosphere, climate change, noise pollution, health risk from air pollution, impacts from diesel

and used engine oil spillage. Achievable greener approaches based on the peculiarity of Lagos that can be implemented by the service providers to reduce these impacts are discussed below:

i. Renewable Energy Sources for powering the BTSs in Lagos

Several studies have investigated the potential of solar energy, wind and biomass as alternative energy sources that are fit for telecom operation. In this paper, we propose the use of solar energy as the most suitable renewable energy source that is most applicable for powering the BTS site in Lagos state. Solar energy is widely available in Lagos and it has proven to be reliable and sustainable with no adverse effect on the environment. Solar has the highest resource potential, market acceptance, commercial viability, technology availability, supply chain readiness, and commercial adoption stage in Lagos when compared with other energy sources like wind and biomass according to the report on tower power Africa (Kumar, 2014).

Table 3: Average Monthly Global Horizontal Irradiance of Lagos (World Bank, 2018)

Months	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Solar Irradiation $(kW/m^2/d)$	5.28	5.49	5.46	5.21	4.76	4.04	3.95	3.98	4.09	4.55	4.55	5.17

The average monthly global horizontal irradiance of Lagos is shown in Table 3 and it shows Lagos has enough solar resources to generate the required amount of energy. The energy from the sun can deliver more than the energy required to power a BTS if properly designed, implemented and harvested. An adequately sized battery bank can power the BTS up to sixty hours without any auxiliary power source, which is more than enough to fix any fault in case of malfunction occurrence.

Figure 5: A poor solar photovoltaic system installed to power BTS in Lagos.

An example of a poor solar photovoltaic system shown in Figure 5 is seen at a BTS site situated in the Alimosho local government area of Lagos state. Interaction with the personnel at the site revealed its power output is very low and as a result, the site runs on DG. Observing the photovoltaic system, we could see that a major part of the installed panel is shaded, therefore minimizing the power output capacity. Factors such as shading, tilt angle, and the orientation of the solar panel should be carefully considered during solar photovoltaic installation to maximize the power output capacity from the sun.

The use of solar energy to power BTSs in Lagos will result in the availability of reliable power supply, and reduction in service providers OPEX, noise from the generators, and air pollution that eventually leads to environmentally friendly operation and protection. Also, utilizing the solar energy from the sun to power the BTSs in Lagos has the potential to reduce the operational cost spent on diesel consumption, DG weekly servicing and maintenance, and also ultimately reduce the volume of carbon dioxide emission from the telecommunication service provider in Lagos by 60% according to the GSMA report on the global market for energy in off-grid and bad-grid areas (GSMA, 2014a).

ii. Hybrid Power System

The combination of alternative power sources is known as a hybrid power system. The achievable hybrid power systems that can be implemented by MNOs in Lagos are solar with DG, DG with Battery, and DG with Battery and Solar. Though diesel usage is not eliminated in this approach, there is a significant reduction in diesel consumption that in turn saves cost and reduces CO_2 emission.

Other recommendations that can be implemented by the service providers in Lagos include:

a. Operators should commit to the replacement of their DG every two years to minimize noise pollution, prevent the increased concentration of black smoke, and maintain good fuel efficiency.
b. Increased telecommunication infrastructure sharing should be promoted. This has a great tendency to minimize environmental impacts but must be accompanied by increased tower maintenance and monitoring.
c. Full deployment of outdoor BTS by service providers to reduce the energy consumption of the cooling equipment.
d. Improved general site maintenance should be encouraged which includes the utmost prevention of diesel leakage and proper disposal of used engine oil.
e. Site operators should be encouraged to turn off their outdoor halogen during the day to reduce energy consumption.
f. Deployment of smart towers by operators should be encouraged.

Government, telecommunication operation regulators, environmental agencies, and other relevant stakeholders can implement the following suggested policies:

a. The Lagos state government and Nigeria Communication Commission (NCC) should implement more frequent and efficient monitoring of the activities in these telecommunication sites.
b. NCC and other relevant agencies should ensure the MNOs are improving their operational processes to preserve the environment and prevent pollution.
c. The government should invest in renewable energy solutions and policies that can make the migration from DG to renewable energy more productive and achievable.
d. MNOs should review their environmental policies regularly for effectiveness and also ensure their field staff are properly informed of their responsibility to environmental protection.
e. The government, NCC, and other relevant agencies should ensure MNOs invest in green energy solutions as much as they favor the technology upgrade of active radio equipment.
f. If possible, the energy distribution company should make the supply of power to BTSs a priority.

6.0 CONCLUSION

The environmental impacts from the operation of mobile communication service providers in Lagos State, Nigeria was evaluated in this paper. We considered the energy consumption of the telecommunication sites, the periods the *BTS* are powered by the national grid, the alternative energy sources deployed in the absence of national grid supply, and the resulting pollutants from their overall operations. The findings from our study revealed that the service providers depend largely on *DGs* for their operations because most of the BTS sites are off-grid while others are located in bad-grid locations. Viable green approaches based on the peculiarity of our study location and achievable recommendations were proposed which can be implemented by the service providers and major stakeholders to reduce the negative environmental impact resulting from the operations of the mobile communication service providers. Further findings can be made to this work by analyzing the energy consumption corresponding CO_2 of the mobile switching center MSC and base station controller BSC.

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