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Adopting Hybrid Energy Technology for Carbon Emissions Reduction in Nigeria's Telecommunications Industry

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Abstract: Telecoms cell sites, powered by petrol and diesel generators, have high carbon footprints and contribute increasingly to global warming, and thereby climate change. Utilizing primary data from telecom cell sites of a major operator in Nigeria, this study empirically determines the firm's CO₂ emissions and considers how hybrid energy technology (HET) could be adopted to reduce the industry's carbon footprint. Data of fuel utilization in power generation are applied to compute CO₂ emissions. Towards reducing the firm's and industry's emissions, hybrid energy technology options for incorporating solar in the energy mix are considered. Hybrid energy technologies optimize existing hydrocarbon generating plants with photovoltaic panels and storage batteries to provide minimum capacities for powering the electronic devices. Results show that HET opportunities exist for most telecom firms' cell sites given Nigeria's geographical advantage to access sunlight. In addition, through the adoption of hybrid energy, average daily fuel usage is reduced by 50% (apart from periods of peak demand and weather disruptions). If adopted by the major telecoms operators, as recommended, greenhouse gas emissions level in the industry will reduce significantly. A few notable challenges are highlighted in the paper. However, job creation in the renewable energy industry is a notable advantage of transforming power generation in the telecommunications industry.

Keywords: Carbon, Emission Reduction, Hybrid Energy, Greenhouse Gas, Telecommunication

1.0 INTRODUCTION

Global CO₂ emissions in 2010 approached 30 gigatons (Gt). Approximately 12Gt (40%) are emitted from electricity generation sector through the combustion of fossil fuels. Burning these fuels results in the production of carbon dioxide (CO₂) in addition to other nitrogen and sulphur oxides responsible for various environmental impacts. Over the past two centuries, mankind has increased the concentration of CO₂ in the atmosphere from 280 to more than 380 parts per million by volume, and it is growing faster every day. As the concentration of CO₂ has risen, so has the average temperature of the planet [1], [2].

Despite mounting evidence of the dangers posed by climate change, efforts to limit carbon emissions remain insufficient, ineffective, and, in most countries, non-existent [3]. For example, 500 million liters of diesel is consumed by telecommunication sites in Nigeria, which produce about 1.3 million metric tons of resulting CO₂ [8]. Given current trends and the best available scientific evidence, mankind probably needs to reduce total CO₂ emissions by at least 80% by 2050.

Electricity sector is the major source of the total global CO₂ emissions responsible for approximately 40% worldwide, followed by transportation, industry, and other sectors. To stem this upward tide of CO₂ emissions, the world has turned gradually to renewable energy. Research and development in renewable energy have shown excellent potential as a form of contribution to the improvement of conventional power generation systems [15]. Renewable technologies offer clean, sustainable, environmentally friendly, reliable as well as low operating and maintenance cost of power supply [5]. It has been observed and verified that the green energy sources reduce the level of diesel usage, thereby lessen carbon emission and bring in expansion of telecoms infrastructure to off-grid areas



at reasonable cost. Among these energy sources, solar and wind have proven their abilities to meet the rapidly growing energy demand and contribute substantially to global climate protection effort - reduction in greenhouse gas emission [6]. However, standalone solar and wind system alone cannot provide reliable power supply due to the intermittent nature of the resources because of changes in atmospheric conditions. Therefore, in order to meet the continuous typical load demand of a mobile base station during varying atmospheric conditions, different energy sources need to be integrated for extended usage of alternative energy[15].

Several studies on the feasibility, techno-economic analysis and performance of hybrid RES have been captured in literature[14], [9], [13]. In the literature, the importance of hybrid system solution has been highlighted. In their work, [15] considered a hybrid model based on SPV/battery/diesel generator (DG) set for remote BTS. Techno-economic analysis with environmental benefits was carried out and presented. In addition, sensitivity analysis was equally performed. The result showed reduced cost of energy (COE) at \$ 0.217 as compared to \$ 0.266 for the existing diesel generator system. Also, the reduction in CO₂, CO, UHC, PM, SO_x and NO_x emission was 17.138, 0.419, 0.0473, 0.0318, 0.344, 3.78 tonnes per year respectively. Similarly, Olatomiwa[15] carried out a study on the two best optimal system configurations namely PV–diesel–battery and PV–wind–diesel–battery systems, comparing results with the stand-alone conventional DG system. Their Findings revealed that PV array (10 kW) – DG (5.5 kW) – battery (64 units Trojan L16P) remains the most if not the best economically viable option with total Net Present Cost of \$69,811 and per unit cost of electricity of \$0.409. Sensitivity analysis was carried out to determine the effects of possible variation in solar radiation, wind speed, and diesel price in the optimal system configurations. The environmental benefit of hybrid systems over the conventional stand-alone diesel system was equally tested. The results gotten showed that the hybrid PV/battery/diesel system revealed a reduction in carbon dioxide emission by about 16.4 tons per year as compared to the stand-alone DG system.

Given the above, this paper is focused on reducing carbon emission from electricity generation at cell sites with the aid of the hybrid power system. The paper seeks to determine ways by which mobile cell sites operators can reduce their carbon emission. The paper is focused on typical cell sites operations within Port Harcourt city (PHC) where key data has been obtained and used to determine results. The paper is divided into six sections. The first section provides an overview of a typical mobile cell site routine operation locally in Nigeria. The second section discusses hybrid power systems based on renewable energy sources, as well as, telecoms operations and CO₂ emissions, highlighting carbon emission from cell sites operations and discussed steps to reduce them. The third section discusses the economic and environmental importance of carbon emission reduction via RSE for mobile cell sites in Port Harcourt, the fourth section highlights some challenges facing renewable energy development and the last section concludes.

In the course of writing this paper it was discovered that the use of renewable energy sources to generate electricity instead of the traditional method will lead to fossil fuel conservation and environmental improvement[4]. But there are challenges impeding the rapid acceptance and development of renewable technologies around the world which includes the political will to put necessary policies in place, financial burden on organizations and government agencies to replace existing technologies for renewable ones.

1.1 Overview of a Typical Mobile Cell Site Operation

In Nigeria, cell sites acquisition, rollout and daily operations and maintenance have seen tremendous growth over the last decade. A race geared towards meeting the increasing demand of the country's vibrant youthful population and data hungry customers. Given the current poor electric power supply by the national grid and the desire to meet the demands of these customers, GSM operators and service providers like IHS have designed their power infrastructure around conventional use of diesel generators (DG) which combust fossil fuel (Diesel) to run daily. This design involves the use of two 20kva DGs running 12hourly and an IP55 panel that allows for smooth transfer of power between DGs during

changeovers. The DGs are connected to rectifier plants which charges eight batteries at every site. The batteries act as backup in event of DG failures. This design has been put in place to prevent power supply interruptions and it is completely independent of the national grid. The design is replicated in Port Harcourt and all across the nation. For many years Mobile cell site operators relied on this power system which indeed has provided remarkable and successful support for network operations. The down side of this design is the costly effect on the environment following daily CO₂ emissions from burning of diesel oil by the generators. In the adjoining sections we shall take a deeper look at the amount of CO₂ emissions as a result of the system currently in place at cell sites in Port Harcourt. Some ways to reduce mobile cell sites' carbon footprint has equally been suggested through the use of the hybrid power system.

2.0 HYBRID POWER SYSTEMS BASED ON RENEWABLE ENERGY SOURCES

A careful observation of the electrification world map will show that remote and isolated areas are in dire need of clean, affordable and reliable electricity to achieve development. Likewise, an overview through the most important literature on modern electrification will prove that renewable energies (RES) are one of the most suitable and environmentally friendly solutions to provide electricity globally. Autonomous decentralized off-grid electrification based on the generation of renewable energy power on site through the installation of stand-alone power systems at cell sites, and the set-up of electricity distribution mini-grids, fed by RES or mixed, have been proven capable of delivering high quality and reliable electricity for lighting, communication and motive power, among others.

2.1. What Is A Hybrid Power System?

Off-grid renewable energy technologies satisfy energy demand directly and avoid the need for long distribution infrastructures. A combination of different but complementary energy generation systems based on renewable energies or mixed (RES- with a backup of Liquefied Petroleum Gas (LPG)/diesel/gasoline DG), is known as a hybrid power system or simply "hybrid system" [17].

Hybrid systems capture the best features of each energy resource and can provide "grid-quality" electricity, with a power range of 1 kilowatt (kW) to several hundred kilowatts. They can be developed as new integrated designs within small electricity distribution systems (mini-grids) and can also be retrofitted in diesel-based power systems [17]. The Hybrid power systems can equally generate a stable rural-level electricity service, which includes village electrification and now cell sites electrification. Additional advantages of the hybrid system include their high levels of reliability, long term performance and efficiency which allows these systems to be used as an important backup solution to the public grid during blackouts or weak grids, and for professional energy solutions, such as telecommunication installations or hospital emergency rooms.

2.2. Technological Configurations for Hybrid Systems

A typical hybrid system combines more than one energy sources, from renewable energy technologies, such as wind or photovoltaic panels and small hydro turbines; and from the familiar conventional technologies, mostly diesel or LPG DGs. In addition, it includes power electronics and electricity storage batteries. The hybrid systems are designed using different configurations to effectively utilize the locally available renewable energy sources and to serve all power appliances (requiring DC or AC electricity). The technological configurations can be classified according to the voltage they are coupled with; this is, using DC, AC and mixed (DC and AC) bus lines.

2.3 Telecoms Operations and CO₂ Emissions

Rapid and globally unrestricted information exchange has become an indispensable service in our daily lives due to technologically and commercially successful breakthrough of telecommunication facilities. ICT is continuously providing innovative products from simple mobile phones to micro-computer chips to the internet. According to ICT 2011, One third of the world's population is online and 45% of Internet

users are below 25 years [11]. But following facts and figures, Mobile-cellular penetration rates stand at 96% globally; 128% in developed countries and 89% in developing countries [11]. The current facts also point out that 2.7 billion people which is almost 40% of the world's population are online.

Power hungry devices are growing around the world, which are increasing mobile traffic that in turn affects the environment. In fact, the contribution of ICT equipment to the global emission of CO₂ due to manufacture, use and disposal is likely to increase from present 2% to 3% by 2020 [12]. For instance, base transceiver stations (BTS) are powered by using DGs and batteries as backup. This design is used world over and cell sites in Nigeria are not an exception. For example, an indigenous GSM company generates about 4MW of power from DGs from over 200 sites within Port Harcourt city alone. Hence, the impact of CO₂ emissions on the environment continues unabated. The key question then is, in what ways can mobile telecoms operators analyze, interpret and improve the environmental performance of their operations to reduce carbon emission from Wireless mobile communication networks?

2.3.1 Mobile Cell Sites Carbon Emissions Data (Cell Sites DG Emission) Cell sites operations requires daily running of 20kva DGs at 12hours intervals. These DGs consumes 70 litres of diesel fuel daily. On average between 2800litres to 3000litres is required monthly for successful uninterrupted operation. These generators vary in age given their various run hours therefore they have different levels of efficiencies. Their age and efficiencies determine their levels of CO₂ emissions. Table 1 shows actual data obtained from a typical indigenous telecommunication firm's field operations in Port Harcourt – for confidentiality, actual cell site locations (ID codes) have been replaced with A1, B1, C1, D1, E1, F1. From Table 1, it can be seen that the DGs at all the sites are of the same brand and of equal age. But they all have different run hours given different periods of breakdown and MTR after repairs which reflect in the differences between their efficiencies, consumption

3. METHODS

To determine CO₂e emission by the generators from each of the sites, it was important to put into consideration the DG brand, specification, efficiency and their fuel consumption daily. It is then calculated knowing that every gallon of diesel fuel contains 2,778 grams of pure carbon. Every gram of atomic carbon, when oxidized with oxygen, forms 3.666 grams of carbon dioxide – in other words, each molecule of CO₂ weighs 3.66 times more than an atom of carbon alone). In an average liquid hydrocarbon-burning engine, it can be assumed that about 99 percent of the fuel will oxidize. As such, less than 1% will fail to completely oxidize, and will be emitted as particulates or unburned hydrocarbons instead of CO₂.

Therefore, one can multiply the amount of carbon per gallon of diesel by the ratio of carbon weight to CO₂ weight by 99 percent:

$$2,778\text{g} \times 3.66 \times 0.99 = 10,084\text{g} \quad (1)$$

So, each gallon of diesel fuel produces, on average, 10,084 g of CO₂, or about 22.2 lb.

If the Diesel Generation (DG) uses, for example, 15 gallons of diesel fuel per hour, it will be producing:

$$15 \text{ gallons/hour} \times 22.2 \text{ lb./gallon} = 333 \text{ lb} \quad (2)$$

On the average, for the major telecom firm being considered here, 70litres of diesel fuel is used by the DGs daily. Therefore 70litres/4litres = 17.5gallons of diesel fuel used daily.

Hence to calculate daily CO₂ emission, we have:

$$17.5 \text{ gallons/day} \times 22.2 \text{ lb/gallon} = 388.5 \text{ lb} \quad (3)$$

This calculation is repeated for each of the sites using data provided in table 1 to determine each site's CO₂e emission.

3.1 Reducing Mobile Cell Sites Carbon Emission through Hybrid Power System

Hybrid power systems with a backup DG run with minimal fuel consumption because the DG comes on-line only to assist in periods of high demand or low renewable power availability. This result in a large

reduction in fuel consumption as compared to a DG only powered system. As stated, a typical hybrid system combines two or more energy sources, from renewable energy technologies, such as photovoltaic panels, wind or small hydro turbines; and from conventional technologies, usually diesel or LPG DGs.

Table 1: Daily field operations from a typical mobile cell site with daily CO₂ emission Data

SITE ID	GEN1 & 2 BEAND	GEN 1&2 AGE	GEN 1 RUN HOURS	GEN 2 RUN HOURS	GEN 1 EFFICIENCY IN %AGE	GEN 2 EFFICIENCY IN %AGE	GEN 1 & 2 TOTAL DAILY CONSUMPTION IN LITRES/24 HOURS	SITE DAILY CO ₂ e EMISSION IN IB
A1	SDMO	4 YEARS	17280	17284	88	87	67	371.5
B1	SDMO	4 YEARS	17288	17286	83	86	70	388.5
C1	SDMO	4 YEARS	17277	17287	87	84	68	377.5
D1	SDMO	4YEARS	17281	17275	89	79	69	382.5
E1	SDMO	4YEARS	17271	17281	79	88	68	377.5
F1	SDMO	4 YEARS	17279	17289	78	83	70	388.5
			TOTAL CO ₂ EMISSION					2,286

In the case of mobile cell sites in Port Harcourt, what is proposed is the use of photovoltaic panels across all the sites mixed with DG supply and backup batteries. In this design, the photovoltaic panels will provide power to the sites from sun rise till sun set and in turn charge the batteries for 12 hours daily. At sun set, the DG will run for another 12 hours till dawn further charging the batteries in the process. With this design, the DGs run for 12 hours instead of the present 24hours. Consequently, there will be a massive CO₂ emission reduction across all the sites within Port Harcourt city by 12hours daily.

Table 2: Significant (50%) reduction in carbon emissions

SITE ID	GEN1 & 2 BEAND	GEN 1&2 AGE	GEN 1 RUN HOURS	GEN 2 RUN HOURS	GEN 1 EFFICIENCY IN %AGE	GEN 2 EFFICIENCY IN %AGE	GEN 1 & 2 TOTAL DAILY CONSUMPTION IN LITRES/12 HOURS	SITE DAILY CO ₂ e EMISSION IN IB
A1	SDMO	4 YEARS	17280	17284	88	87	33	186
B1	SDMO	4 YEARS	17288	17286	83	86	35	194
C1	SDMO	4 YEARS	17277	17287	87	84	34	188
D1	SDMO	4YEARS	17281	17275	89	79	35	194
E1	SDMO	4YEARS	17271	17281	79	88	34	188
F1	SDMO	4 YEARS	17279	17289	78	83	35	194
			TOTAL CO ₂ EMISSION					1,144

Given the geographical location of Nigeria and the significant availability of the tropical sun all year round, there exists adequate sun intensity to effectively provide energy for the photovoltaic panels to charge and power electronics devices at the cell sites. Table 2 shows reduction in CO₂ emission or Mobile cell sites carbon emission from DGs for the sample sites mentioned in table 1 following the introduction of the hybrid system. With introduction of the hybrid system, half the quantity of daily fuel usage will be required.

Hence, 70litres of diesel fuel used by the DGs on the average daily will become 35 liters. Therefore, $\frac{35\text{litres}}{4\text{litres}} = 8.5\text{gallons}$ of diesel fuel used daily.

To calculate the new daily CO₂ emission, we have

$$8.5\text{gallons/day} \times 22.2\text{lb/gallon} = 194\text{lb}$$

This is repeated for all the sites and with the introduction of the hybrid power system results in a significant reduction in daily total CO₂ emission – 50% reduction from 2,288lb to 1,144lb daily (in Table 2).

4. THE ECONOMIC AND ENVIRONMENTAL IMPORTANCE OF CARBON EMISSION REDUCTION

A combination of energy efficiency measures with the use of renewable energies will not only reduce electricity consumption and peak demand, thereby increasing the electricity service, but also reduce the production of conventional energy and greenhouse emissions from the combustion of fossil fuels. Hybrid technology has become the best replacement for diesel fuel based power systems. Diesel based power systems will sooner or later, grow to be a barrier for rural areas and now cell sites due to the operating costs (elevated fuel and transport prices), the high needs of maintenance, their acoustic and environmental polluted nature and the geographical difficulties to deliver the fuel to remote areas (cell sites). Retrofitting hybrid power systems to the existing diesel based plants will significantly minimize delivery and transport problems and will drastically reduce maintenance and emissions, representing an advantageous and more suitable solution for cell sites.

A combination of improved technology and economies of scale has pushed down the costs of renewable energy technologies. Unlike most conventional energy sources, the cost of producing electricity from renewable energy sources will decrease significantly in the future, given the necessary conditions. However, despite the favourable trends of renewable energy sources, they are still perceived as high cost options. The reasons can be found within the benefits enjoyed by the conventional energy systems such as favourable policy frameworks and public financing advantages, giving as a result low capital costs, though leaving the evidence of significant operating costs. Renewable energy systems seldom enjoy direct or indirect subsidies, because of their environmental benefits. Still, renewable energy technologies are already the least cost electrification option for cell sites, even without internalizing environmental costs. The initial high capital costs are offset by the low operation and maintenance costs, the onsite production (fuel delivery cost can exceed the wholesale fuel price), as well as the inexistent or little fuel expense which is the single largest cost.

With the reliability and longer expected useful life of renewable energy technology, Cell sites operators can take advantage through cost cutting measures by introducing the hybrid power system thereby reducing the numbers of DGs per site. The current design accommodates two 20kva DGs per site with high cost of maintenance and replacement after a given period of time. With the hybrid power system this operational cost will be reduced by half if all the sites run for half day requiring 1 DG to power the sites at night and are made to use the photovoltaic panels to power the sites at day times. Other key factors that must be put into consideration which makes leaning towards renewables by cell sites operators important include:

4.1 The Uncertainty of Oil Based Solutions

A critical factor of the oil-based solution is the development of the crude oil price and, consequently the price of fuel on a national level. The drastic rise of crude oil price and the continuing depletion of this resource are leading to long-term constraints on economic development worldwide. Hybrid systems based on RES are independent of oil price shocks and the consequences [19]. Even if these systems may include LPG/DGs as a backup, still renewable energy will supply, at least 50% of the energy, with DGs providing the balance 50%.

4.2 Carbon Credit

Nigeria's accent in 2016 to the Paris Climate Agreement(2015) shows a willingness and readiness to reduce CO₂ emissions in the country. Organizations that are willing to reduce their carbon footprints are bound to enjoy certain measures of carbon credit. Mobile cell operators can enjoy certain levels of tax holiday as reward if funds are spent to embrace renewable energy technologies in order to reduce their carbon footprint which in turn reduces the nation's CO₂ emissions. Rewards for firms are clearly stated in the Clean Development Mechanism (CDM) under "Incentives", a major part of the flexible mechanism narrative following the Koyoto Protocol (IPCC, 2001) and the climate change agreement [18]. Also, provisions for rewards of this nature are enshrined in the united nations' Reducing Emissions from Deforestation and Forest Degradation (REDD) programme.

4.3. Other Benefits

With little diesel required at cell sites following the use of RES, Cell sites operators will not only reduce their emission but will also reduce cost incurred due to diesel theft at cell sites as well as energy theft. Diesel theft at cell sites remain a recurrent decimal and stolen diesel replacement cost remains a sticking point in these organization's daily operations. Energy theft is equally prevalent given the poor power situation in Nigeria. Since the hybrid power system configuration supports DC output, all electronic devices at cells sites can be DC powered and only DC power points will be enabled to prevent easy access for energy theft. This is significant as all homes in Nigeria are AC powered requiring AC input. The benefit to GSM operators is that DGs will stop aging quickly due to excessive load as a result of energy theft and will run effectively for the given duration they are designed and planned for. Again, cost of frequent turn around maintenance will be eliminated and cost of replacing weak and none performing DGs will be significantly reduced.

This present proposal can bring about improvement in the standard of living and increase in the economic activities among the rural dwellers in the locations where cell sites are situated, as the excess electricity generated from such hybrid systems can serve to supply dump loads (water pumping and street lighting) as a form of social responsibility on the part of the telecoms companies to the area. For instance excess energy generated from hybrid systems can help rural areas in developing countries like Nigeria meet some sustainable development goals (SDGs) such as improved maternal health [20]. In addition, energy services offer rural dwellers access to better medical facilities like vaccine refrigeration, equipment sterilization, operating theatres, and lighting for local health centres. Second, achieving universal primary education at the rural level will improve as access to electricity will enable access to educational media and communications, Lighting in schools for evening classes and lighting at home which will encourage home study. Finally, electricity will help ensure environmental sustainability because traditional fuel use contributes to erosion, reduced soil fertility and desertification [7]. Electricity can be used to pump and purify contaminated water. Using cleaner fuels will reduce Greenhouse Gas Emissions.

5.0 CHALLENGES FACING RENEWABLE ENERGY DEVELOPMENT AND HET

Several factors mitigate the rapid development of renewable energies around the world. Here is a brief look at some of them. Renewable energy policies passed or reviewed today are mostly focused on the power sector, but the challenges facing the renewable energy industry in general, comes from heavily subsidised conventional energy which provides stiff competition. Other significant policy challenges for developing countries such as Nigeria and emerging economies include the issue of policy formation for economic development, where growth becomes a priority and where traditional methods and deep-rooted

mechanisms are difficult to part with. Energy companies and households interested in investing in renewable energies are often discouraged given the lengthy pay-back times. Hence, without political will or measures by governments to enhance easy access to the market and increase consumer demand, manufacturers of renewable energy devices like Photovoltaic (PV) panels will increasingly find it very difficult to produce the volume en mass needed to bring down prices and drive home technological innovation.

Lack of policy frameworks from nations' governments and key policy makers within organizations to encourage private sector participation in financing renewable energy projects portends a major setback for RE development. Carrying out renewable energy demonstration projects in remote areas to spread information and decentralizing its implementation may foster the spread of renewable energy projects. These kinds of actions will equally aid build a better equipped and sustainable renewable power industry, generate profits and create jobs, and also improve efficiency in financing. Currently, developing countries only enjoy support from international donors for renewable energy policies and technology development, a situation which undermines their sustainability, as the necessary funds required often fluctuate following changes in priorities and crises.

6.0 CONCLUSION

This study has considered the feasibility of hybrid energy technologies as means to reducing GHG emissions from telecoms cell sites across Nigeria. Results in this study indicate that PV solar panels could be combined with hydrocarbon fueled power generators in Nigeria. Hybrid energy technology (HET) have been shown to be effective in delivering energy in rural areas, and could be adopted across cell sites at low economic cost. However, a careful design of the hybrid system to meet requirements of telecommunication service providers and a responsible choice of system components in Nigeria is needed. Meanwhile, it is recommended that mobile cell sites operators adopt HET towards ensuring reduction of CO₂ emissions while increasing utilization of telecom services. Widespread use of hybrid energy technologies - based on renewables - is a sustainable alternative that could possibly improve standard of living among rural dwellers. Such technological innovation could ensure developing countries - like Nigeria - meet some sustainable development goals.

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