ORIGINAL RESEARCH ARTICLE

Alternative clean energy for sustainable growth and development of the Nigerian telecommunications sector

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DOI: https://doi.org/10.57046/TIPM1584

Abstract

Telecommunications plays a crucial role in facilitating the transmission of voice, data, and multimedia over extended distances. This paper explores the significance of telecommunications, particularly in Nigeria, the largest ICT market in Africa, where telecom and internet usage hold substantial importance. However, the sector's heavy reliance on fossil fuels has resulted in environmental challenges. This research underscores the imperative to transition to clean energy sources, aligning with the commitment of the Nigerian Communications Commission. The paper presents a case study of a solar hybrid system designed to enhance Base Transceiver Station (BTS) coverage, emphasizing notable challenges such as elevated costs and the industry's familiarity with fossil fuels.

The optimal power configuration for a BTS, as identified in the study, features a 16kW PV (photovoltaic) array, 14kW Diesel Generator (DG), 32kWh Battery Energy Storage System (BESS), and Utility, achieving the lowest Levelised Cost of Energy (LCOE) at $0.255/kWh. The production summary for the Solar PV array is 24,767 kWh/year (76%), the Diesel Generator is 1,250 kWh/year (4%), and the Utility is 6,503 kWh/year (20%). Consequently, the total estimated production is 32,520 kWh/year, constituting 100% of the energy requirement for the BTS.

The study proposes solutions to challenges, including local clean energy component production, capacity building, and regulatory alignment. In conclusion, the adoption of clean energy is deemed essential for sustainability, with recommendations for policy adoption and efficient equipment utilisation.

Keywords: *Clean energy, telecommunications, base transceiver station.*

1. Introduction

1.1 *Overview of telecommunication components and Nigeria's ICT landscape*

Telecommunication is a complex field that involves various components and technologies to transmit voice, data, and multimedia information over long distances. Within the global telecommunications industry, a "facility" is a fixed or mobile structure that includes all installed electrical & electronic wiring, cabling, and equipment[1]. Additionally, the facility is supported by structures like utilities and ground networks. Telecommunications (telecoms) facilities are used to transmit and receive signals to and from local and international networks (Singh, 2023). The facilities are primarily used for two-way communications for commercial, industrial, and government purposes (Atapattu et al., 2020). Telecoms systems vary significantly depending on the type of communication, the technology used, and the specific application. The telecommunication components illustrated in Figure 1, include a data source, transmission medium, receiver, and destination. They work together to facilitate the transmission of information over distances. These components work cohesively to enable effective and reliable telecommunication, whether it's through wired or wireless networks. Furthermore, the specific functions and operations can vary based on the type of telecommunication system and the technologies involved.

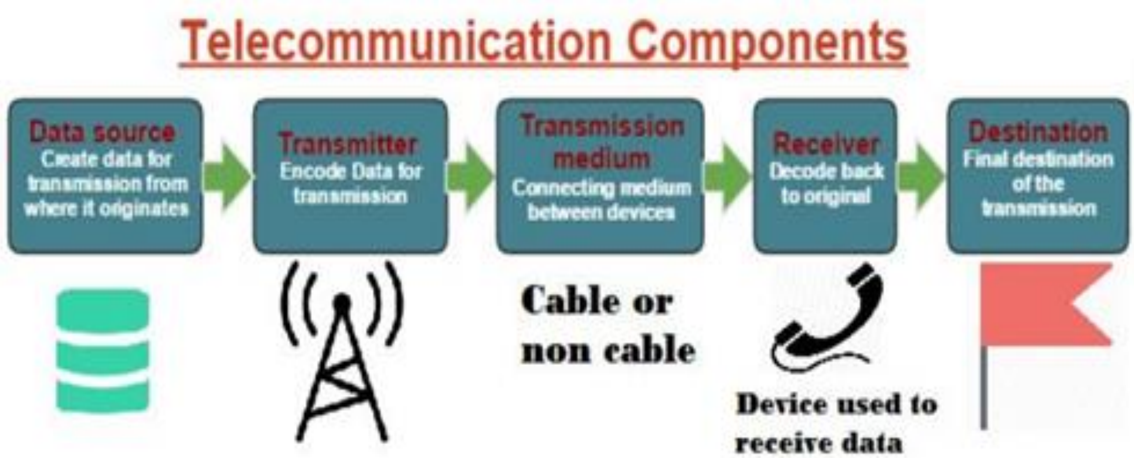

Figure 1: Telecommunication components (Beugnard, 2000)

Data shows that Nigeria is Africa's largest ICT market, accounting for 82% of its telecom subscribers and 29% of its internet usage[2]. It plays a significant role in the

[1]Sambo, A. S. (2023). Refocusing Academic Research & Development Towards Alternative Clean Energy: Panacea to Paucity of Energy in the Nigerian Telecommunications Sector. Lead Paper Presented at NCC's Stakeholders Roundtable, Kano, Nigeria. 16 – 17 August 2023.

[2]Mabika, V., & Ogu, E. (2022). Internet impact brief: Nigeria's Protection from Internet Falsehood and Manipulation Bill 2019. Internet Society. *https://www.internetsociety.org/resources/2022/internet-impact-brief-nigerias-protection-from-internet-falsehood-and-manipulation-bill-2019/*

continent's telecommunications and internet sectors. The considerable rise in Nigeria's telecom subscribers is driven by increased smartphone penetration, improved internet infrastructure, and the popularity of social media platforms (Forenbacher et al., 2019). Notably, the availability of affordable mobile phones has made it easier for a more significant segment of the population to access telecom services. Globally, Nigeria is ranked 11th in the number of internet users and 7th in the number of mobile phones[3]. Furthermore, Nigeria's telecom market is expected to grow by 4.7% from USD 8.68 billion in 2023 to USD 10.92 billion by 2028 (Gambo et al., 2023 and [4]). Hence, the telecoms market has a massive potential in Nigeria.

Considering the continued growth of telecoms, the power needs of telecommunications equipment depend on the equipment's type and function. Generally, most telecom equipment uses a 48V direct current (DC) power supply, while most IT equipment use alternate current (AC) input power (Darla et al., 2021). The power distribution and monitoring units are designed to provide electric power to the equipment in a data or networking centre. Some telecom systems power supplies include AC/DC converters, DC/DC converters, and battery chargers. The average cellular base station power requirement, comprising the tower and radio equipment attached, can be anywhere between 1 – 5 kW (Qazi, 2016). However, this depends on whether the equipment is air-conditioned, the number of transmitters in the base station, and the tower's age.

Renewable energy sources are increasingly being adopted as an alternative to power telecommunication systems, particularly in remote or off-grid locations. Studies have reported that renewable energy for telecommunications has several advantages, including reducing operating costs, increasing reliability, and minimizing environmental impact (Deevela et al., 2023). Recently, the Nigerian Communications Commission (NCC), the regulatory authority of the telecommunications industry in Nigeria, at the 2023 World Consumer Rights Day held on 15th March 2023, announced its commitment to ensuring the adoption of renewable energy for powering the nation's telecommunications sector (Ozoegwu et al., 2021). This is not only to ensure that the sector complies with the 'Just Energy Transition Plan' of the Nigerian Government and the advice of the International Telecommunications Union (ITU), but also because renewable

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[3]Eromosele, E. ITPulse (2022-08-12). No to the proposed excise duty on telecommunications services. *https://itpulse.com.ng/2022/08/12/no-to-the-proposed-excise-duty-on-telecommunications-services-by-elvis-eromosele/*

[4]Chibuikem, P. O. (2022). The Policy of Privatisation and Commercialisation of Public Enterprises in Nigeria: A Case Study of Telecommunication Industry. Science Open Preprints. *https://www.scienceopen.com/hosted-document?doi=10.14293/S2199-1006.1.SOR-.PPCK0UD.v1*

energy (RE) power systems have become cheaper than their fossil fuel counterparts, especially in the long term.

2. Clean energy systems for the telecommunications sector in Nigeria

The Nigerian telecommunications sector presently relies heavily on fossil fuels such as diesel to run its operations and power its equipment (Amole et al., 2023; Tebepah, 2015). This practice produces carbon emissions, which can negatively impact the environment (Ayompe et al., 2021). Some negative impacts include climate change, loss of biodiversity, rising sea levels, and poor air quality (Roy et al., 2023; Steiner, 2019). In addressing this issue, several clean energy systems have been proposed, including a telecommunications base station's solar power supply system. An example of the solar power supply system of a telecommunication base station is the outdoor base transceiver station (BTS) located in Nasarawa State, North Central Nigeria, whose study and design of its power system are reported in this article. The solar photovoltaic (PV) cell is the primary power source due to abundant sunshine than wind or hydro in this region. Nevertheless, the methodology can be applied to other situations with slight modifications. A hybrid power plant requires technical expertise and experience (Mayadevi et al., 2014). It is critical as it involves making numerous trade-offs to strike the right balance between performance and cost. Achieving an optimum solution requires careful consideration and analysis of various factors. A solar hybrid power outdoor system integrates solar power with other energy sources or storage solutions to provide electricity for outdoor applications (Indiria et al., 2022). The systems are designed to harness the benefits of solar energy while incorporating additional components for enhanced reliability and continuous power supply. A case study on a solar hybrid power outdoor system is described in the next section.

3. Case study: Design overview of a solar hybrid power system for an outdoor BTS to improve coverage at a site in Nasarawa State, North Central Nigeria

STEP 1: Load profiling

The load profile is best obtained via an energy audit involving data loggers for weeks and sometimes months. As shown in Figure 2, the proposed load profile assumes a maximum demand of 3kW that occurs during working hours 0700 – 1700 hours) when there is more traffic on the network. The minimum demand is 1 kW, which occurs at night and during the early morning hours (2200 – 0600 hours) when there is less traffic. It is further assumed that 2kW power is consumed from 1800 – 2100 hours after work hours to bedtime. Notably, the load profile assumes that the site lacks air conditioning. The load would be significantly higher for sites equipped with air conditioning systems.

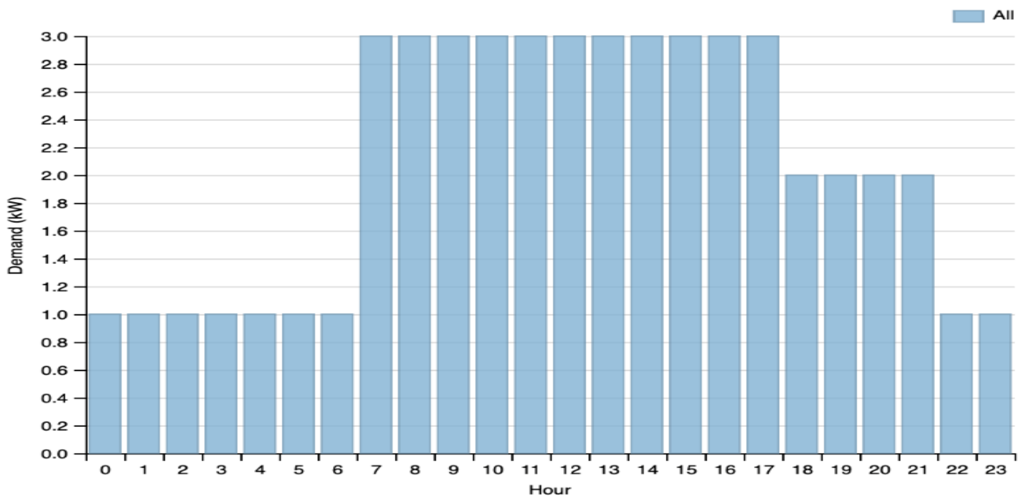

Figure 2: Proposed load profile

STEP 2: Solar resource analysis

The solar resource analysis aims to estimate the solar energy the PV plant would receive throughout a typical year. It includes a series of hourly values for irradiance and temperature over one year. This series is referred to as the Typical Meteorological Year (TMY). A photovoltaic geographical information system (PVGIS) database was used to generate the TMY. The database depicted in Figure 3 included meteorological data from 2005 to date with a spatial resolution of 4 km by 4 km. Nonetheless, the actual period used may vary depending on the location. Direct Normal Irradiance (DNI) represents the solar radiation that comes in a straight line from the sun to the surface of interest. Global Horizontal Irradiance (GHI) represents the total solar energy that is incident on a flat surface, such as a solar panel or a solar collector, regardless of the angle of the sun in the sky. GHI and DNI characterise different components of solar radiation.

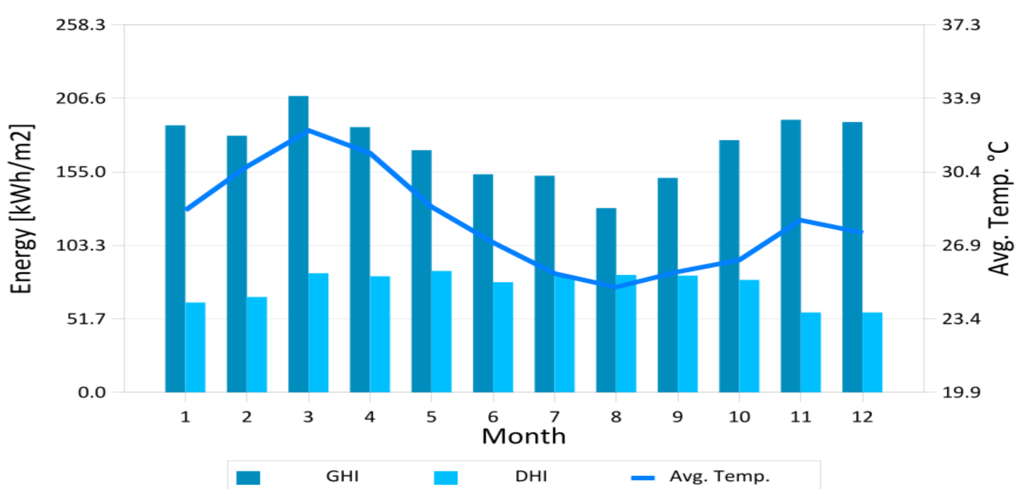

Figure 3: Typical meteorological year

STEP 3: Technology assessment

In determining which technology options are suitable for the system components, several technologies will be identified and analysed using the Hierarchal Decision Model (HDM). This decision model determines the optimal technologies for solar PV modules, battery storage, or alternative power sources. The four criteria that will be used for assessment, as shown in Figure 4, include Efficiency, Technology Maturity, and Local Experience, Lifetime Costs (LCOE), and Environmental Impact (Mousavi & Yousefi, 2022; Steffen et al., 2020).

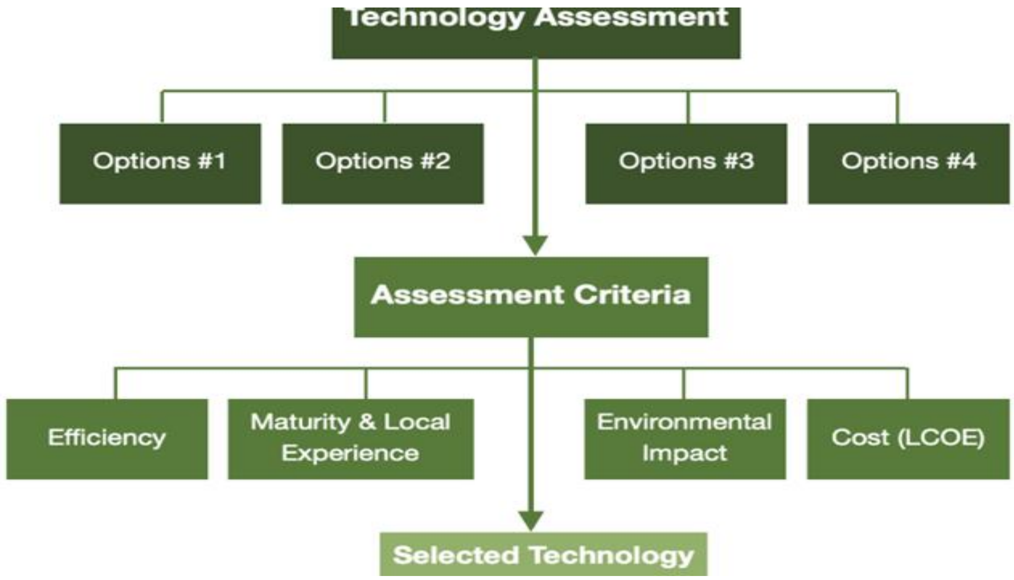

Figure 4: Application of HDM structure for selection of renewable energy technology options

STEP 4: Solar PV module selection and technology options for storage systems and inverters

The prevailing solar PV technologies in Nigeria consist primarily of mono-facial mono-crystalline and poly-crystalline varieties (Alami et al., 2022). This mirrors the global trend, where crystalline silicon holds a market share of about 95%, with thin-film technologies accounting for approximately 9% (Buonomenna, 2023). The ongoing worldwide transition toward mono-crystalline silicon modules is similarly observed in Nigeria, particularly in recent mini-grid and utility-scale projects nationwide (REA, 2023).

In this step, the selection process also encompasses technology options for battery energy storage systems and inverters.

Step 5: Simulations

During this phase, simulations were conducted using solar PV design software, including Homer, PVSyst, and PVDesign. These simulations were based on the aforementioned inputs, constraints, or assumptions, exploring various scenarios to derive options for the Minimum Levelised Cost of Energy (LCOE), Minimum Operation and Maintenance (O&M) Costs, and Maximum Renewable Fraction.

The outcome of the initial simulation is visualized in Figure 5, where the scenarios encompass all realistic combinations of system components, aimed at identifying the optimal configuration.

PARAMETERS	SCENARIOS								
	DG/PV/BESS/GRID	DG/PV/BESS	PV/BESS/GRID	PV/BESS	DG/BESS/GRID	DG/BESS	BESS/GRID	DG/GRID	DG
PV (kW)	16.00	19	46	67	–	–	–	–	–
Diesel Generator (kW)	14.00	14	–	–	14	14	–	14	14
Storage (kW·h)	32.00	47	64	60	37	13	115	–	–
Inverter (kW)	10.00	10	25	13	5	8	46	–	–
Initial Capital ($)	50,113.00	60,180	102,681	117,235	31,222	22,926	84,766	12,256	12,256
Net Present Cost ($)	81,708.00	83,444	121,104	131,247	145,902	167,262	175,318	224,260	284,039
Operating Cost ($/yr)	1,803.00	1,327	1,051	799	6,543	8,235	5,166	12,095	15,506
LCOE ($/kWh)	0.255	0.261	0.379	0.410	0.456	0.523	0.548	0.701	0.888
Fuel (L/yr)	387.00	745	0	0	4,625	6,302	0	9,607	12,568
Generator (hrs/yr)	118.00	241	0	0	1,516	1,806	0	5,469	7,309

Figure 5: Simulation outcome 1

The superior configuration, featuring a 16kW PV array, 14kW Diesel Generator (DG), 32kWh Battery Energy Storage System (BESS), and Utility, is highlighted in Figure 6. This configuration attains the lowest LCOE of $0.255/kWh. The production summary for the Solar PV array is 24,767 kWh/year (76%), the Diesel Generator is 1,250 kWh/year (4%), and the Utility is 6,503 kWh/year (20%). Consequently, the total estimated production is 32,520 kWh/year, constituting 100%.

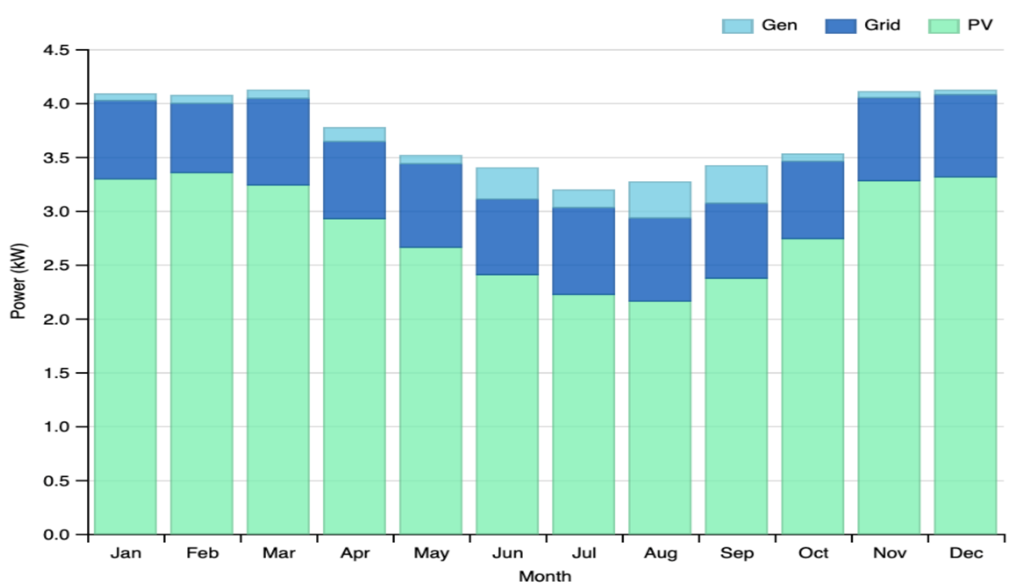

Figure 6: Simulation outcome 2

4. Challenges

Designing a solar hybrid power system for an outdoor Base Transceiver Station (BTS) to improve coverage presents several challenges that must be addressed for a successful and reliable implementation. Some key challenges include:

a. The components of renewable energy power systems are expensive as they are mainly imported from abroad. Despite the valuable LCOE of clean energy systems, the initial capital costs of renewable energy power systems are relatively high.

b. Telecommunications industry members are more familiar with fossil fuel-operated power systems, particularly in regions where fossil fuels have historically been the primary energy source for backup and off-grid power solutions.

c. The enactment of the Electricity Act 2023 is a game changer for adopting renewable energy; however, it will take a few years for the Nigerian Electricity Regulatory Commission (NERC) and the state governments to be fully prepared to leverage its provisions.

d. Protecting solar panels, batteries, and other system components from theft and vandalism is challenging, especially in remote or less secure locations.

A comprehensive assessment of the specific site and its requirements, careful selection of components, and the implementation of advanced control and monitoring systems are essential to addressing these challenges. Collaboration with renewable energy and telecommunications experts can help design a solar hybrid power system that optimises coverage while addressing these challenges. Some suggestions for addressing these identified challenges will be discussed in the next section.

Addressing the challenges

Several measures have been taken to address the challenges highlighted in Section 3. For example, the Manufacturers Association of Nigeria (MAN) and the Nigerian Association of Chambers of Commerce, Industry, Mines, and Agriculture (NACCIMA), with the support of the African Development Bank (AfDB), plan to produce components of clean energy systems in Nigeria locally. They also aim to become self-sufficient in producing clean energy components and exporting them through the African Continental Free Trade Agreement. (AfCFTA). This strategy will ultimately reduce the cost of clean energy components, making it more cost-competitive than fossil fuel options. In Nigeria, the Borno State government and government agencies, including the National Agency for Science and Engineering Infrastructure (NASENI), the Sokoto Energy Research Centre (SERC) of the Usman Danfodiyo University Sokoto (UDUS), and private sector groups like Quantum, have commenced local production of solar modules.

Importantly, there is a need for massive capacity-building activities for the members of the telecommunications industry on the entire value chain of clean energy systems for the industry. It is essential for the NCC to organise a series of future workshops to sensitise and educate members of the Nigerian telecommunications industry on the new legal backing for the renewable energy industry, from which the telecommunications companies (Telcos) can benefit. Another point is the need for the NCC and Standard Organisation of Nigeria (SON) to ensure that the industry patronises certified components of clean energy power systems. Several Telcos can be grouped to outsource their power supply to a mini-grid provider, and the provider can be the winner of the renewable energy independent power producer procurement (REIPPP) auction process, like it is already happening in South Africa, India, and China and recently in some European and North African nations.

Moreover, the transition from diesel-generating sets to renewable energy power plants for the Nigerian telecommunications industry must be carried out carefully. Hence, it is critical to implement quality applied research and development, and techno-economic analysis should be routinely undertaken to transition the industry from fossil fuels to renewable energy successfully.

Some key actions to be taken involve identifying readily available renewable energy power plant components used in the telecommunications industry in the country and conducting routine performance analysis on them. Additionally, the adoption of various design configurations for telecommunications renewable energy power systems and estimating their long and short-term cost-benefit analyses. It is essential to monitor the renewable energy market for the arrival of new renewable energy (RE) power components to assess their effectiveness. Furthermore, there is a need to undertake research and development, in collaboration with other Nigerian researchers, on the local development of RE power plant components for the telecom industry. Finally, the telecom market should be monitored for innovative products, which should be tested and certified before they are recommended.

Other needed actions concerning research include monitoring international developments on new RE telecommunications power systems like the generation of green hydrogen and fuels to stimulate them and domesticate R&D in novel areas. It will be useful to establish energy-efficient measures in the industry to reduce the increasing energy consumption in the Nigerian telecom sector. Regular involvement of the private sector in the entire R&D value chain, from the conception of the projects to the testing of the final products, is an avenue to explore. Besides, regular training and capacity-building programmes for telecommunications industry players in the design and development of RE power systems will improve the capacity of stakeholders in the telecom industry.

Furthermore, it is essential to identify competent Nigerians active in RE powering of telecommunications and engage them in relevant projects. Estimating the tonnage of carbon dioxide emissions avoided by adopting RE power systems for each telecom system provides a good starting point for discussion and further research. Future research should examine Nigeria's Nationally Determined Contributions for reducing climate change while recommending appropriate changes regarding the carbon footprints of the telecommunications industry.

5. Recommendations

Some recommendations include:

a) The government should formally adopt policies aligned with the Electricity Act 2023 to promote renewable energy.

b) The government should also incentivise Telcos to transition to RE power systems rapidly. This is to be facilitated through the adoption of the Triple Helix Partnership, involving Government, Industry, and Academia with the government providing a conducive policy environment for the promotion of the Telcos-Academia collaboration in addressing the identified research and development leading to the innovation of products and processes to enhance the achievement of the projected industrial policy goals.

c) NCC should develop appropriate proposal guidelines (to evaluate the research, development, and appropriate technical capacity of an institution) for the preparation and submission of proposals for the establishment of the National Centre for Telecommunications Energy Transition and Energy Efficiency (NCTETEE) in an institution of higher learning. Invitations should be thrown open to Nigerian universities to compete.

d) Telcos should adopt modern energy-efficient equipment, low-power base station components, routers, servers, and cooling systems to reduce energy demand significantly.

e) Acquisition of equipment with high energy efficiency ratings and low standby power consumption can substantially affect overall power usage.

f) Installation of software that enables the partial shutdown of equipment at night is needed.

g) Migration of all generated data to the cloud for storage and backup will reduce energy consumption.

h) Network buildouts should be optimised for resiliency and efficiency.

i) Transform operations to be dynamic and eliminate excess energy using Artificial Intelligence (AI).

6. Conclusion

In conclusion, this study has explored the critical importance of refocusing academic research and development towards alternative clean energy solutions as a panacea to the paucity of energy in the Nigerian telecommunications sector. Nigeria's telecommunications industry has experienced significant growth, accounting for a substantial portion of the continent's telecom subscribers and internet users. However, the industry's energy requirements, primarily met by fossil fuel-based power systems, come with adverse environmental consequences, including carbon emissions, and associated environmental challenges.

The case study presented in this paper highlights the design of a solar hybrid power system for an outdoor Base Transceiver Station to enhance coverage in Nasarawa State of the North Central part of Nigeria, showcasing the feasibility and benefits of adopting renewable energy in the telecommunications sector. Clean energy systems, particularly solar power, are environmentally friendly and economically viable in the long term.

However, several challenges must be addressed to facilitate a successful transition to clean energy solutions in the telecommunications industry. These challenges include the high initial capital costs, industry's more familiarity with fossil fuel-operated systems, the regulatory landscape, and security concerns. Accordingly, various measures and strategies have been proposed, including local production of clean energy components, capacity building, regulatory alignment, and continuous research and development. Hence, research and development will be pivotal in driving innovation and sustainability within the telecommunications sector. Ultimately, adopting clean energy solutions within the Nigerian telecommunications sector is a response to environmental concerns and a means of ensuring long-term energy reliability, reducing operating costs, and stimulating economic growth. As the industry evolves and embraces renewable energy, the nation will move closer to achieving its energy and environmental goals while providing improved services to its citizens.

References

1. Alami AH, Rabaia MKH, Sayed ET, Ramadan M, Abdelkareem MA, Alasad S, & Olabi, A. G. (2022). Management of potential challenges of PV technology proliferation. Sustainable Energy Technologies and Assessments, 51, 101942.

2. Amole AO, Oladipo S, Olabode OE, Makinde KA, & Gbadega P (2023). Analysis of grid/solar photovoltaic power generation for improved village

energy supply: A case of Ikose in Oyo State Nigeria. Renewable Energy Focus, 44, 186-211.

3. Atapattu S, Fan R, Dharmawansa P, Wang G, Evans J, & Tsiftsis TA (2020). Reconfigurable intelligent surface assisted two–way communications: Performance analysis and optimization. IEEE Transactions on Communications, 68(10), 6552-6567.
4. Ayompe LM, Davis SJ, & Egoh BN (2021). Trends and drivers of African fossil fuel CO2 emissions 1990–2017. Environmental Research Letters, 15(12), 124039.
5. Beugnard A (2000, June). Communication services as components for telecommunication applications. In Proc. 14th European Conference on Object-Oriented Programming, ECOOP'2000.
6. Buonomenna MG (2023). Inorganic Thin-Film Solar Cells: Challenges at the Terawatt-Scale. Symmetry, 15(9), 1718.
7. Deevela NR, Kandpal TC, & Singh B (2023). A review of renewable energy-based power supply options for telecom towers. Environment, Development and Sustainability, 1-68.
8. Forenbacher I, Husnjak S, Cvitić I, & Jovović I (2019). Determinants of mobile phone ownership in Nigeria. Telecommunications Policy, 43(7), 101812.
9. Freeman RL (2005). Fundamentals of telecommunications. John Wiley & Sons.
10. Gambo D, Tekanyi AMS, Musa MJ, Al-Mustapha MD, & Ya'u I (2023). Beam Divergence Loss Mitigation in Free Space Optical Communication Channel Using Field of View Technique. SLU Journal of Science and Technology, 6(1&2), 30-43.
11. Indira SS, Vaithilingam CA, Sivasubramanian R, Chong KK, Narasingamurthi K, & Saidur R (2022). Prototype of a novel hybrid concentrator photovoltaic/thermal and solar thermoelectric generator system for outdoor study. Renewable Energy, 201, 224-239.
12. Mayadevi N, Vinodchandra SS, & Ushakumari S (2014). A review on expert system applications in power plants. International Journal of Electrical and Computer Engineering, 4(1), 116.
13. Mousavi Reineh SM & Yousefi H (2022). Effects of the Environmental Cost of Electricity Generation, Considering the LCOE Model. Environmental Energy and Economic Research, 6(1), 1-11.
14. Ozoegwu CG & Akpan PU (2021). A review and appraisal of Nigeria's solar energy policy objectives and strategies against the backdrop of the

renewable energy policy of the Economic Community of West African States. Renewable and Sustainable Energy Reviews, 143, 110887.

15. Qazi S (2016). Standalone photovoltaic (PV) systems for disaster relief and remote areas. Elsevier.

16. Roy P, Pal SC, Chakrabortty R, Chowdhuri I, Saha A, & Shit M (2023). Effects of climate change and sea-level rise on coastal habitat: Vulnerability assessment, adaptation strategies and policy recommendations. Journal of Environmental Management, 330, 117187.

17. Singh AK (2023). Digital Era in Papua New Guinea (PNG): Novel Strategies of the Telecom Service Provider Companies. In Social Capital in the Age of Online Networking: Genesis, Manifestations, and Implications (pp. 230-248). IGI Global.

18. Steffen B, Beuse M, Tautorat P, & Schmidt TS (2020). Experience curves for operations and maintenance costs of renewable energy technologies. Joule, 4(2), 359-375.

19. Steiner A (2019). Climate change, environment, and sustainable development in Africa. In African Economic Development (pp. 93-110). Emerald Publishing Limited.

20. Tebepah E (2015). The cost of telecommunications evolution in Nigeria. Journal of Energy Technologies and Policy, 5(10), 17-26.