

Affordable and Clean Energy: Unlocking Nigeria's Sustainable Energy Future

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Abstract

Unlocking Nigeria's potential for affordable and clean energy is a multifaceted challenge that demands innovative solutions and a holistic approach. This comprehensive study delves into the heart of this complex issue, exploring the nation's abundant renewable energy resources, such as solar, wind, and biomass, and their untapped potential for driving sustainable development. With a focus on decentralized energy solutions, including mini-grids and off-grid systems, the study presents a compelling pathway for addressing energy poverty in rural areas and empowering underserved communities. Additionally, it examines the policy landscape, highlighting the need for a coherent and enabling framework that fosters investment, technological innovation, and public-private partnerships. Dive into this in-depth analysis to uncover the economic, environmental, and social implications of transitioning to clean energy sources and discover how Nigeria can leverage its natural resources to achieve energy security and sustainable progress.

***Keywords:** Nigeria, affordable and clean energy, renewable energy, decentralized energy solutions, energy poverty*

1.0. Introduction

In a world grappling with the existential threat of climate change and the pressing need for sustainable development, Nigeria stands at a pivotal crossroads, confronted by a cruel paradox. Despite being endowed with abundant natural resources, a substantial portion of its population remains trapped in energy poverty and deprived of reliable and affordable energy sources (IEA, 2019; World Bank, 2020). This stark reality undermines the very fabric of society, hampering economic growth, hindering educational opportunities, and perpetuating a cycle of deprivation that threatens to erode the nation's progress towards a sustainable future.

Addressing this critical challenge demands a bold, multifaceted approach that transcends mere rhetoric and embraces bold action. At the heart of this endeavour lies the untapped potential of renewable energy sources, such as solar, wind, and biomass, which promise to improve energy access and mitigate the adverse effects of climate change (Sambo, 2009). Realizing this potential

requires a decisive shift in policy, fostering an enabling environment that incentivizes investments and technological innovations in the renewable energy sector (Ley et al., 2016).

Yet, the path to affordable and clean energy has its obstacles. Nigeria's energy landscape is plagued by inefficient infrastructure, unreliable distribution networks, and an overdependence on fossil fuels, further exacerbated by distortions in energy pricing and subsidization policies (Aliyu et al., 2015; Oyedepo, 2012). Overcoming these challenges necessitates a holistic approach encompassing policy reforms, strategic investments, and promoting energy efficiency and conservation measures across various sectors (Oyedepo, 2014).

Ultimately, pursuing affordable and clean energy in Nigeria is not merely a technical or economic endeavour but a pursuit of justice, equity, and sustainable development. Ensuring access to energy for rural and underserved communities is a moral imperative that demands decentralized solutions, capacity building, and community engagement (Okunlola et al., 2021). Furthermore, fostering collaboration between academia, industry, and government is crucial for driving innovation, research, and the commercialization of new technologies (Akuru & Okoro, 2014). Only through a concerted effort from all stakeholders can Nigeria pave the way towards achieving SDG 7 and securing a sustainable energy future for all.

2.0. Objectives

The primary objective of this study is to provide a comprehensive analysis of the challenges and opportunities associated with achieving Sustainable Development Goal 7 (SDG 7) – Affordable and Clean Energy – in Nigeria. Specifically, the study aims to assess the current state of energy access, affordability, and reliability in Nigeria, evaluate the potential of renewable energy sources, such as solar, wind, and biomass, examine the policy and regulatory landscape governing the energy sector, analyze the technical, economic, and social viability of decentralized energy solutions, such as mini-grids and off-grid systems, investigate the role of academia, research institutions, and the private sector and propose a comprehensive set of recommendations and a roadmap for policymakers, stakeholders, and relevant actors to address the challenges and leverage the opportunities in achieving SDG 7 in Nigeria.

3.0. Methodology

The methodology will involve a document research approach to achieve the stated objectives. The data sources are primarily secondary and gathered through a thorough review of pertinent journals, articles, books, relevant publications, reports from international organizations, and national policy documents on sustainable development goal 5 – clean water and sanitation.

4.0. Discussion

Affordability (Poor)

Energy poverty is a pervasive challenge that enslaves millions of Nigerians in a vicious cycle of deprivation and underdevelopment. Low-income communities, particularly in rural areas, grapple with the harsh reality of limited access to affordable and reliable energy sources, hindering their ability to improve living standards and break free from poverty (IEA, 2021).

The socio-economic factors contributing to this dire situation are multifaceted. Poverty itself is a significant barrier, as the high upfront costs of modern energy solutions, such as grid connections or renewable energy systems, are often beyond the reach of those struggling to meet their basic needs. Additionally, a lack of access to financing options and microcredit programs further exacerbates the problem, making it virtually impossible for low-income households to invest in energy-efficient technologies or alternative energy sources (Sustainable Energy for All, 2020).

Moreover, the need for more robust infrastructure and a reliable energy supply in many rural areas compounds the issue. Energy providers frequently overlook remote communities or deem them unprofitable, leaving residents to rely on traditional and often hazardous energy sources like kerosene lamps or firewood, which pose significant health and environmental risks (World Bank, 2018).

To address this pressing challenge, a multifaceted approach is necessary. Governments and policymakers must prioritize the development of targeted subsidies and financial assistance

programs to make modern energy solutions more accessible and affordable for low-income households. Microcredit initiatives and innovative financing models tailored to the unique needs of these communities could empower them to invest in energy-efficient technologies and renewable energy sources (United Nations Development Programme, 2021). Additionally, promoting developing and disseminating low-cost, decentralized energy solutions, such as solar home systems or improved cookstoves, could significantly enhance energy access while minimizing environmental impact.

Figure 1: Access to electricity (% of the population) – Nigeria (World Bank, 2023).

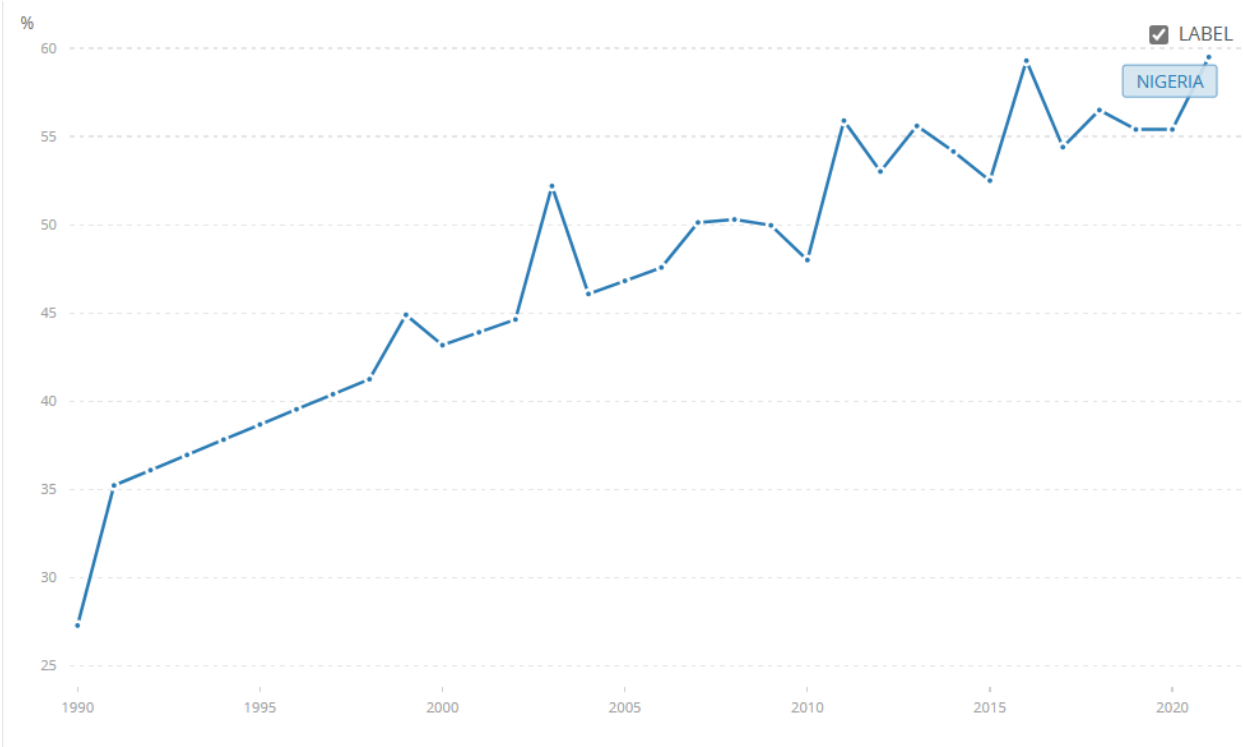


Table 1: Access to electricity (% of the population) - Country Ranking (World Bank, 2021)

Rank	Country	Value	Year
1	Albania	100.00	2020
1	France	100.00	2020
1	Morocco	100.00	2020
164	Nigeria	55.40	2020
165	Sudan	55.39	2020
170	Ethiopia	51.09	2020
190	Dem. Rep. Congo	19.10	2020
195	Chad	11.08	2020

Table 2.0: Access to electricity (% of the population) - Country Ranking – Africa (World Bank, 2021)

Rank	Country	Value	Year
1	Egypt	100.00	2020
1	Morocco	100.00	2020
1	Seychelles	100.00	2020
1	Tunisia	100.00	2020
5	Algeria	99.80	2020
10	Ghana	85.87	2020
20	Cameroon	64.72	2020
24	Nigeria	55.40	2020
25	Sudan	55.39	2020
30	Mali	50.56	2020
40	Benin	41.41	2020
50	Central African Republic	15.47	2020
51	Malawi	14.87	2020
52	Burundi	11.74	2020
53	Chad	11.08	2020

Solar, Wind, Biotechnology, and Other Options

Nigeria's abundant renewable energy resources, such as solar, wind, and biomass, present a compelling opportunity to address the nation's energy challenges sustainably and cost-effectively. With its vast landmass and favourable climatic conditions, Nigeria boasts immense potential for harnessing these renewable sources to meet its growing energy demands while mitigating environmental impacts (Adeyanju et al., 2020).

The solar energy potential in Nigeria is particularly promising, with the country receiving an average of 5.5 hours of peak sunlight per day and an annual average of total solar radiation ranging from 12.6 MJ/m²-day in coastal areas to 25.2 MJ/m²-day in the far north (Energy Commission of Nigeria, 2022). The declining costs of solar photovoltaic (PV) technology and the increasing efficiency of solar panels have made solar energy an increasingly viable option for both on-grid and off-grid applications, empowering rural communities and reducing reliance on fossil fuels (IRENA, 2022).

Wind energy is another renewable source with significant potential in Nigeria, particularly in the northern regions, where wind speeds can reach up to 4 m/s at 10 m heights (UNDP, 2021). Advanced wind turbine technologies and improved site selection methods have made wind power increasingly cost-competitive, offering a clean and sustainable alternative to traditional energy sources. Additionally, developing small-scale wind turbines suitable for rural electrification could play a crucial role in improving energy access in remote areas (Simonyan & Fasina, 2013).

Biotechnology, focusing on producing biofuels from agricultural and organic waste, presents a remarkable opportunity for Nigeria to leverage its vast agricultural resources while addressing energy needs and promoting sustainable waste management practices. The Nigerian government has already promoted blending biofuels with fossil fuels, recognizing this technology's economic, environmental, and social benefits (Energy Commission of Nigeria, 2022).

Figure 2: Total primary energy demand in Africa by scenario, 2018-2040 (IEA, 2019).

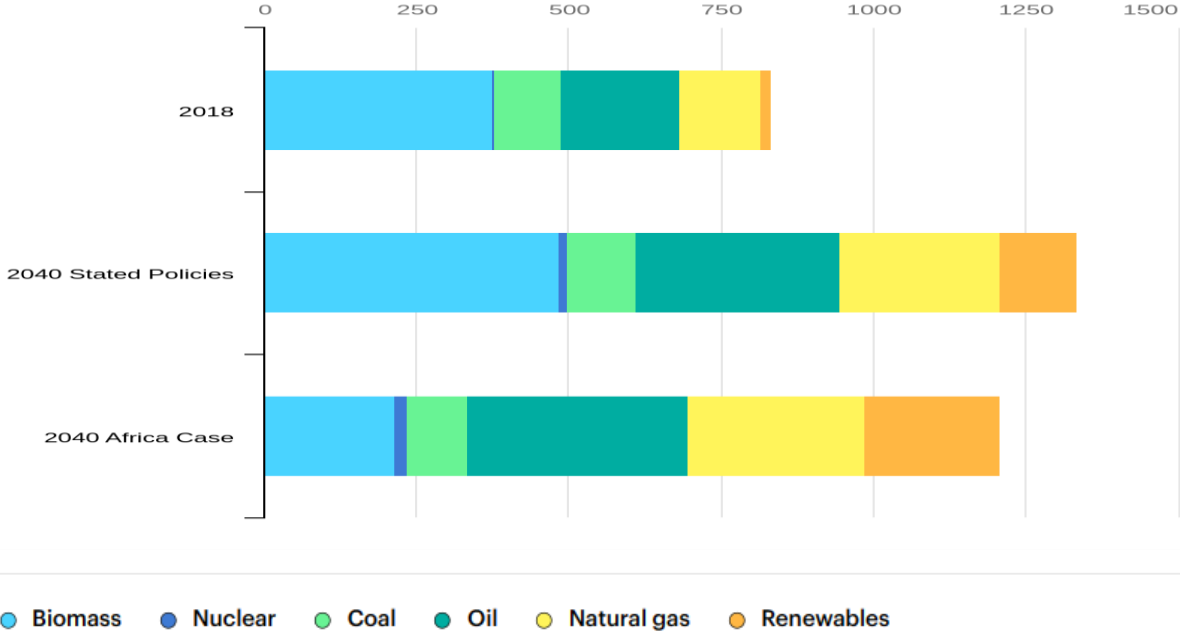
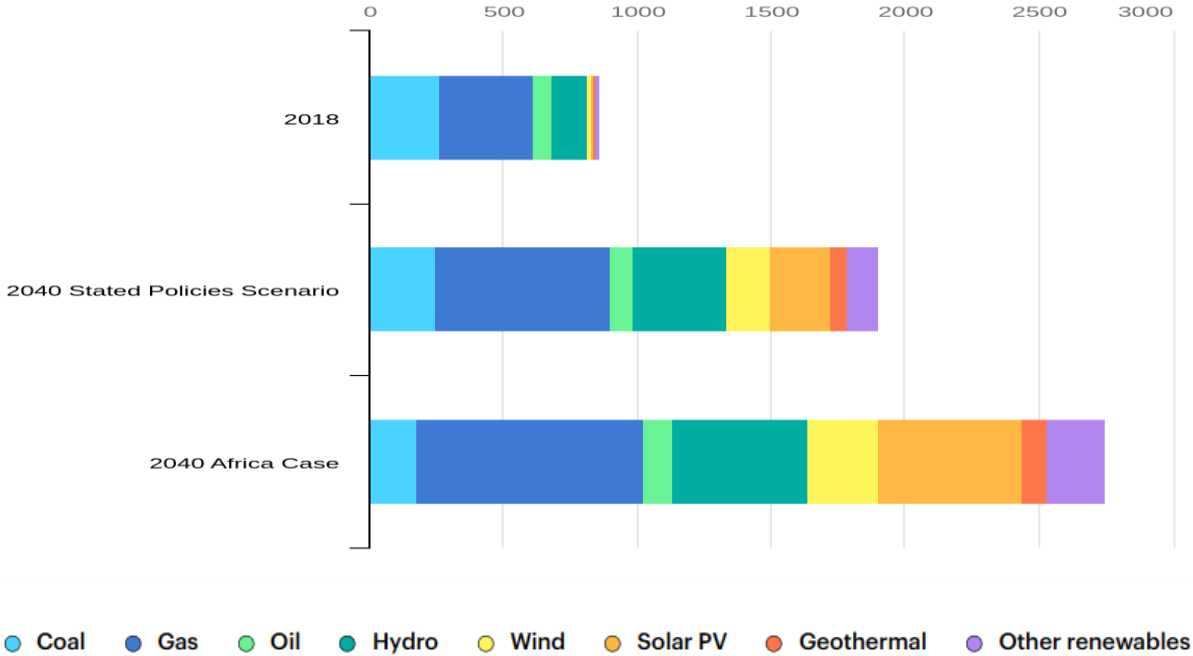


Figure 3: Electricity generation in Africa by scenario, 2018-2040 (IEA, 2019)



Rural Areas

Unlocking the energy potential of rural areas in Nigeria is not only a matter of economic development but also a crucial step towards achieving inclusive growth and social equity. These communities are often overlooked and marginalized, face daunting challenges in accessing reliable and affordable energy sources, hindering their ability to improve their quality of life and participate fully in the nation's progress (IEA, 2021).

One of the most significant obstacles rural dwellers face is the need for more access to the national grid, as utility companies often deem extending transmission and distribution lines to remote areas economically unviable (Adeyanju et al., 2020). This disconnection from the centralized energy system perpetuates a cycle of energy poverty, forcing communities to rely on traditional biomass fuels, such as firewood and charcoal, which pose severe health risks and contribute to deforestation and environmental degradation (World Bank, 2018).

However, the advent of decentralized energy solutions presents a compelling opportunity to bridge the energy gap in rural Nigeria. Off-grid solar photovoltaic (PV) systems, ranging from small-scale solar home systems to community-based mini-grids, offer a cost-effective and environmentally sustainable alternative to traditional energy sources (REA, 2020). These solutions provide reliable electricity for lighting, communication, and productive activities and unlock opportunities for income generation, education, and improved healthcare services in rural areas (UNDP, 2021).

Furthermore, the abundance of biomass resources in rural Nigeria, such as agricultural residues and animal waste, presents a unique opportunity for developing bioenergy projects (Simonyan & Fasina, 2013). Adopting efficient biomass conversion technologies, like biogas digesters and improved cookstoves, can simultaneously address energy needs, improve indoor air quality, and promote sustainable waste management practices in rural communities (WBA, 2019).

Figure 4: Nigeria - Access to electricity, rural (% of rural population) (World Bank, 2021).

As of 2020, 24.58% of Nigeria's rural population had access to electricity. According to the World Bank (2021), this figure peaked at 33.97% in 2016, while its lowest point was 4.04% in 1990.

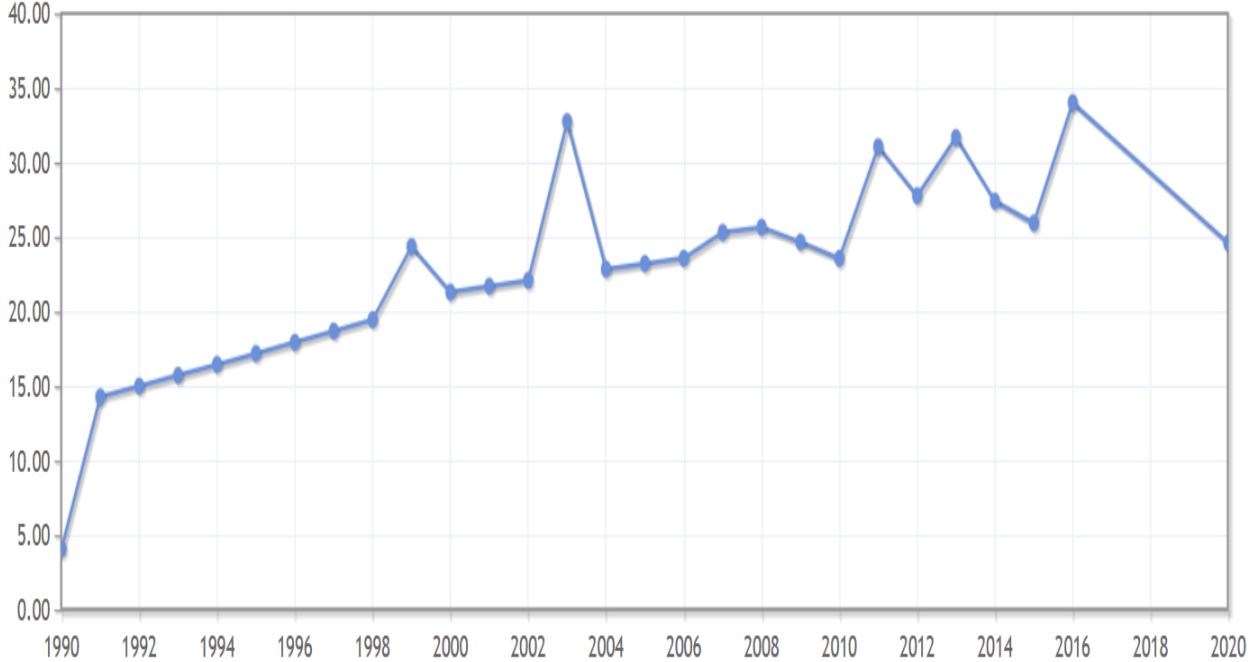
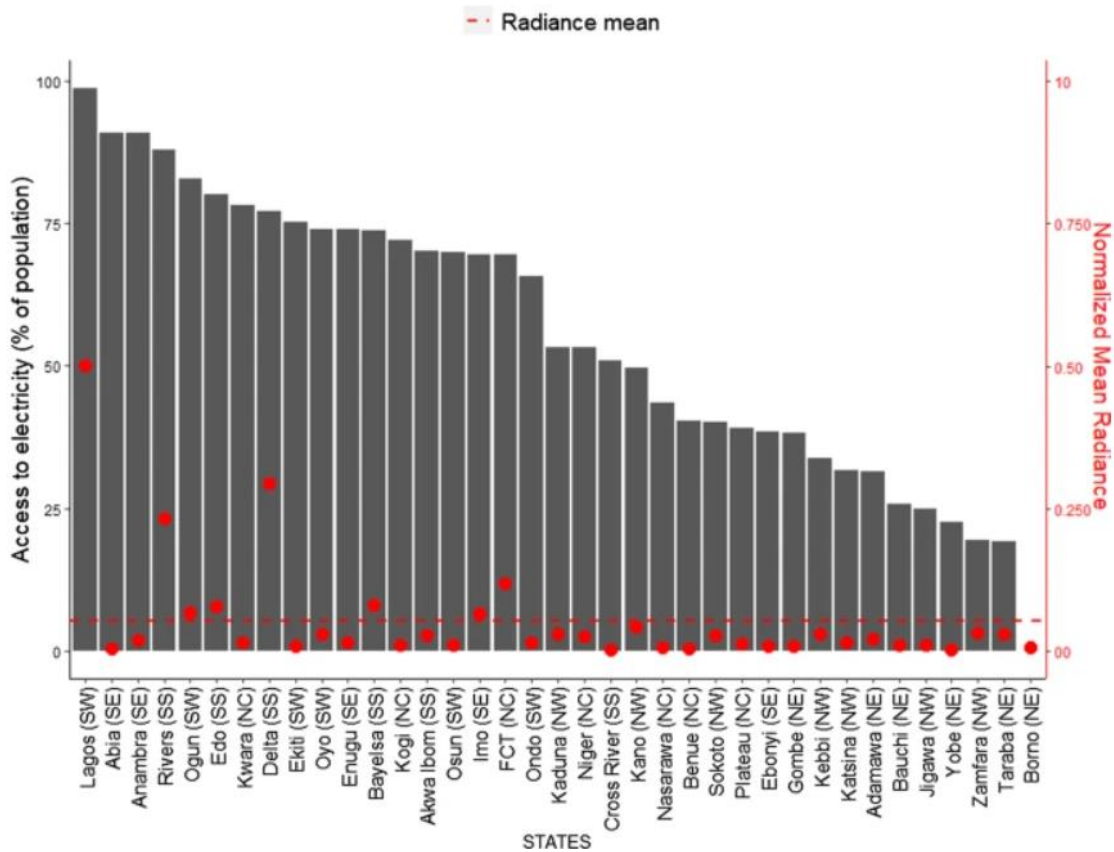


Table 3: Nigeria - Access to electricity, rural (% of rural population) (World Bank, 2021).

Year	Value
1990	4.04
1995	17.16
2000	21.27
2005	23.19
2010	23.54
2015	25.90
2020	24.58

Figure 5: SNLs and electricity sources (NBS, 2020).

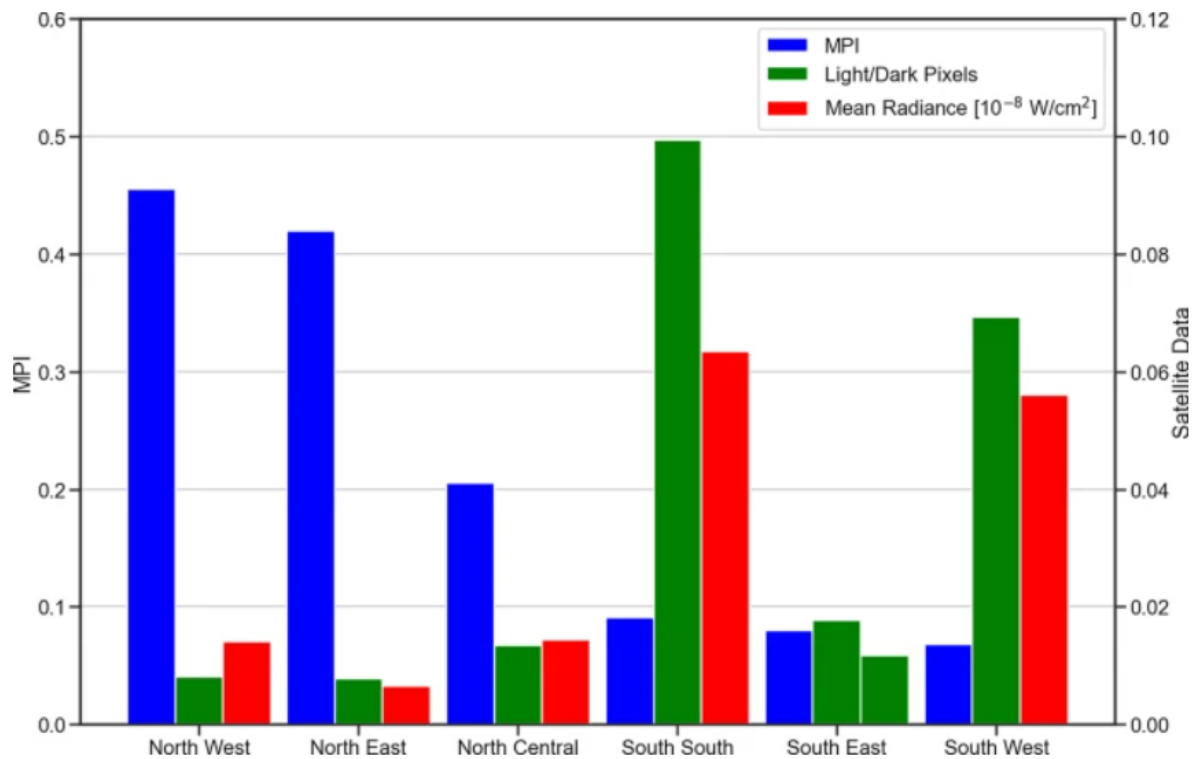
The availability of electricity shows a significant disparity across Nigerian states. In Lagos, over 98% of households have access to electricity, while in Taraba state, only 19.2% enjoy the same privilege. This disparity highlights an evident energy imbalance between the southern and northern regions of the country. Among the twenty-one states where at least 50% of households have access, only eight exhibit high radiance levels, including Abuja (FCT), Imo, Bayelsa, Delta, Edo, Ogun, Rivers, and Lagos states (Alabi et al., 2023).



SNLs and electricity sources

There is a significant disparity of over 60% in the poverty headcount rate between Lagos State in the South West and Yobe State in the North East. The lowest poverty headcount rate is observed among the three states within the Yola DISCO. This disparity reflects an inverse correlation across the states, highlighting the strong relationship between poverty and energy access. Similar patterns can be seen in states like Abia, Osun, and Anambra, which may appear affluent but have limited evidence of poverty reduction. This trend is consistent with the MPI analysis, where all geographical zones, except the Southeast zone, show an inverse relationship (NBS, 2020). The average SNLs and normalized mean radiances for the six Nigerian geographical zones are also provided (NBS, 2020).

Figure 6: SNLs and electricity sources (NBS, 2020).



Average SNLs and normalised mean radiances for the six Nigerian geographical zones

Availability of Natural Resources

Nigeria's vast and diverse natural resources present a compelling opportunity to establish a robust and sustainable energy sector to drive economic growth and development. With its substantial reserves of fossil fuels, abundant renewable resources, and untapped geothermal potential, the nation can meet its energy demands while mitigating environmental impacts and promoting socio-economic progress (Energy Commission of Nigeria, 2022).

The country's proven crude oil and natural gas reserves, estimated at 36.9 billion barrels and 203 trillion cubic feet in 2019, position Nigeria as a major player in the global energy market (OPEC, 2020). However, exploiting these resources must be balanced with environmental considerations and a strategic shift towards cleaner energy sources to ensure long-term sustainability and reduce greenhouse gas emissions (IEA, 2021).

Nigeria's renewable energy resources, particularly hydropower, solar, and biomass, offer immense potential for diversifying the country's energy mix and promoting energy security. With a total exploitable large-scale hydropower potential of over 24,000 MW, Nigeria can harness this clean and renewable source for electricity generation, reducing reliance on fossil fuels and mitigating environmental impacts (Adeyanju et al., 2020). Additionally, the country's abundant solar irradiation and vast agricultural lands make it well-suited for the development of solar and biomass energy projects, which can drive rural electrification and create employment opportunities in rural communities (UNDP, 2021)

Furthermore, Nigeria's geothermal resources, concentrated in regions such as Nasarawa, Jos, and Bauchi, present a largely untapped energy source with significant potential for electricity generation and direct heat applications (Chukwu & Folayan, 2019). Developing geothermal energy projects could contribute to the country's energy mix, promote economic diversification, and provide opportunities for technological advancement and knowledge transfer (World Bank, 2020).

Technology – Imported and Foreign

In Nigeria's quest for energy security and sustainable development, adopting foreign technologies presents compelling opportunities and formidable challenges. On the other hand, technology transfer offers a powerful mechanism to leapfrog traditional development stages and rapidly scale up the country's energy infrastructure (IEA, 2021). By leveraging the expertise and innovations of more technologically advanced nations, Nigeria can access cutting-edge energy production, distribution, and efficiency solutions.

However, the process of technology transfer has its complexities. Intellectual property rights and licensing agreements can create barriers to access and adoption, potentially limiting the benefits of foreign technologies (WIPO, 2022). Additionally, the successful integration of imported technologies often requires significant investments in infrastructure, training, and local adaptation to ensure compatibility with Nigeria's unique environmental, cultural, and socio-economic contexts (Adeyanju et al., 2020).

Furthermore, an overreliance on foreign technologies may stifle the development of domestic research and development capabilities, perpetuating a cycle of technological dependence and hindering Nigeria's ability to innovate and create tailored solutions to its specific energy needs (AFDB, 2021). Striking the right balance between leveraging foreign expertise and fostering local innovation is crucial for long-term sustainability and self-determination in the energy sector.

To navigate these challenges, Nigeria must prioritize capacity building and knowledge transfer, ensuring that imported technologies are accompanied by robust training programs and knowledge-sharing initiatives (UNIDO, 2019). This empowers local communities and cultivates a skilled workforce capable of adapting and maintaining these technologies over time. Additionally, strategic partnerships and collaborations with technology providers can facilitate the transfer of intellectual property rights and foster mutually beneficial arrangements for technology sharing and co-development (UNCTAD, 2020).

No Government Support (Policies)

Nigeria's journey towards a sustainable and inclusive energy future hinges heavily on the strength and effectiveness of its policy framework. While the nation has made commendable strides in recognizing the importance of renewable energy and energy efficiency, the existing policy landscape needs to be more cohesive, with significant gaps hindering the full realization of its energy potential (Adeyanju et al., 2020).

One critical challenge is the lack of a comprehensive and coherent policy framework that aligns the nation's energy goals with its broader economic and social development objectives. The patchwork of disparate policies and regulations across various sectors often leads to inconsistencies, creating uncertainty for investors and impeding the widespread adoption of clean energy technologies (IEA, 2021).

Furthermore, robust incentive mechanisms and financial support structures have been a significant barrier to deploying renewable energy projects and energy efficiency initiatives. The lack of tax incentives, subsidies, and favourable financing options has made it challenging for private and public entities to invest in these crucial areas, hampering progress towards a diversified and sustainable energy mix (UNIDO, 2019).

To address these challenges, Nigeria must prioritize the development of a holistic and integrated energy policy that harmonizes the nation's energy objectives with its broader socio-economic and environmental goals. This policy framework should provide clear guidelines and targets for renewable energy development, energy efficiency standards, and greenhouse gas emissions reduction (Olabode and Gbadegesin, 2021). Additionally, it should foster an enabling environment for private sector participation by offering attractive incentives, such as tax credits, feed-in tariffs, and streamlined permitting processes (REEEP, 2020).

Moreover, robust institutional frameworks and governance structures that ensure effective implementation, monitoring, and accountability should complement the policy framework. This could include establishing dedicated agencies or task forces responsible for overseeing and

coordinating energy policies and mechanisms for stakeholder engagement and public participation (Energy Commission of Nigeria, 2022).

The Commercial Viability of Clean Energy (Producers) and Universities' Research (Commercialization of Research)

The path towards a sustainable and affordable energy future in Nigeria lies at the intersection of commercial viability, academic research, and strategic collaborations. As the nation strives to transition towards cleaner energy sources, the private sector and universities play crucial roles in driving innovation, commercialization, and knowledge transfer (Adeyanju et al., 2020).

On the commercial front, the private sector's ability to identify viable market opportunities and leverage cutting-edge technologies is instrumental in propelling the adoption of clean energy solutions. However, the current landscape is fraught with challenges, including high upfront costs, regulatory hurdles, and limited access to financing (IEA, 2021). Overcoming these barriers requires a concerted effort from policymakers to create an enabling environment that incentivizes private investment, fosters public-private partnerships and facilitates technology transfer from research institutions to industry.

Universities and research institutions, on the other hand, serve as incubators for groundbreaking discoveries and technological advancements in the realm of clean energy. From developing cost-effective solar photovoltaic cells to exploring novel biofuel production methods, Nigeria's academic community possesses a wealth of intellectual capital that still needs to be explored (Olabode and Gbadegesin, 2021). Bridging this gap between research and commercialization necessitates robust university-industry collaborations, where private entities can access cutting-edge research and intellectual property. At the same time, universities benefit from industry expertise, funding, and real-world applications.

The successful commercialization of clean energy technologies hinges on forming strategic partnerships that leverage the private sector's and academia's strengths. Technology incubation centres and innovation hubs offer fertile ground for such collaborations, providing resources,

mentorship, and a nurturing environment for entrepreneurs and researchers to transform their ideas into market-ready products and services (AFDB, 2021).

Moreover, effective knowledge transfer mechanisms, such as licensing agreements, spin-off companies, and joint research ventures, can facilitate the seamless transition of academic discoveries into commercially viable solutions. By fostering an ecosystem that encourages the cross-pollination of ideas and resources, Nigeria can unleash its full potential in driving the development and deployment of affordable and clean energy technologies (UNIDO, 2019).

Global and National Need for Clean Energy Validity

The urgency of transitioning to clean energy sources has never been more palpable as the world grapples with the existential threat of climate change and the far-reaching consequences of relying on finite and polluting fossil fuels. This global imperative resonates profoundly within Nigeria, where pursuing sustainable and renewable energy sources is critical to unlocking a future of environmental stewardship, economic resilience, and social progress (Energy Commission of Nigeria, 2022).

On the environmental front, the implications of inaction are stark. Like many nations, Nigeria is already experiencing the devastating impacts of climate change, including rising sea levels, erratic weather patterns, and threats to biodiversity (UNEP, 2020). Transitioning to clean energy sources, such as solar, wind, and hydropower, offers a path towards mitigating these effects by reducing greenhouse gas emissions and minimizing the nation's carbon footprint.

Moreover, the economic case for clean energy is compelling. Nigeria's over-reliance on fossil fuels has rendered its economy vulnerable to volatile global oil prices and the eventual depletion of these finite resources (IEA, 2021). Diversifying the energy mix through renewable sources enhances energy security and creates job opportunities, technological innovation, and sustainable economic growth.

Beyond environmental and economic considerations, the transition to clean energy carries profound social implications. Access to reliable and affordable energy is a fundamental human

right, yet millions of Nigerians, particularly in rural areas, remain disconnected from modern energy services (World Bank, 2018). Decentralized renewable energy solutions, such as solar home systems and mini-grids, offer a transformative pathway to empowering these communities, improving quality of life, and fostering inclusive development.

As the global community coalesces around the Paris Agreement's objectives and the United Nations' Sustainable Development Goals, Nigeria's commitment to clean energy transition aligns with its international obligations and positions the nation as a responsible global citizen, poised to contribute to the collective effort to combat climate change and promote sustainable development (UNDP, 2021).

Clean Energy vs Affordable

The perceived trade-off between clean energy and affordability has long been a contentious debate. Sceptics cite the high upfront costs of renewable technologies as a barrier to widespread adoption. However, this perception fails to capture the long-term economic benefits and cost savings accompanying a transition to clean energy sources (IEA, 2021).

While the initial investment required for renewable energy projects may seem daunting, it is crucial to consider the lifetime cost savings and averted expenses associated with traditional fossil fuels. Burning fossil fuels impose a staggering economic burden on societies through environmental and health impacts, such as air pollution, climate change, and respiratory illnesses (WHO, 2022). By embracing clean energy sources, Nigeria can mitigate these costs and redirect resources towards productive sectors of the economy.

Moreover, the rapid advancements in renewable energy technologies have driven down costs significantly, making clean energy more accessible and affordable than ever before. For instance, solar photovoltaic (PV) module prices have fallen by over 80% since 2010, while wind turbine prices have dropped by 40% (IRENA, 2022). As these technologies mature and achieve economies of scale, their cost-competitiveness will only increase, rendering the trade-off argument increasingly obsolete.

Innovative financing mechanisms and strategic policy interventions can play a pivotal role in further bridging the affordability gap. Initiatives such as green bonds, tax incentives, and feed-in tariffs can attract private investment and reduce the financial burden on individual consumers (REEEP, 2020). Developing decentralized energy solutions, such as solar home systems and mini-grids, can provide affordable and reliable energy access to remote and underserved communities (REA, 2020).

By embracing a holistic and long-term perspective, the perceived trade-off between clean energy and affordability can be reframed as a false dichotomy. Investing in clean energy safeguards the environment and public health, unlocks economic opportunities, fosters energy security, and contributes to sustainable development (UNDP, 2021).

5.0. Recommendations

The government should develop a comprehensive and integrated national energy policy harmonising Nigeria's energy objectives with broader socio-economic and environmental goals. This policy framework should provide clear guidelines and targets for renewable energy development, energy efficiency standards, and greenhouse gas emissions reduction. Additionally, it should offer attractive incentives, such as tax credits, feed-in tariffs, and streamlined permitting processes, to foster an enabling environment for private sector participation (Aliyu et al., 2015; Oyedepo, 2012).

To address energy poverty in rural and underserved communities, there is a need to prioritize decentralized energy solutions, such as mini-grids and off-grid solar systems. Establish dedicated funding mechanisms, capacity-building programs, and community engagement initiatives to facilitate the adoption of these technologies. Moreover, it promotes sustainable business models, such as energy cooperatives and pay-as-you-go schemes, to empower low-income households to access renewable energy solutions (Bertheau et al., 2019; Okunlola et al., 2021).

The government should foster innovation and technological development within the renewable energy sector through increased investment in research and development, collaboration between

academia, industry, and government, and the establishment of technology incubation centres and innovation hubs. Integrate renewable energy curricula into educational institutions to build a skilled workforce capable of driving the transition to a sustainable energy future (Akuru & Okoro, 2014; Oyewo & Aghahosseini, 2020). It is essential to leverage strategic partnerships and collaborations to facilitate the transfer of intellectual property rights and foster mutually beneficial arrangements for technology sharing and co-development. There is a need to encourage cross-pollination of ideas and resources by promoting university-industry collaborations, joint research ventures, and the commercialization of academic discoveries into market-ready solutions.

6.0. Conclusion

Nigeria's path towards affordable and clean energy is fraught with challenges but presents immense opportunities for sustainable development and economic growth. By harnessing the nation's abundant natural resources, embracing innovative technologies, and fostering an enabling policy environment, Nigeria can unlock its vast renewable energy potential and ensure energy security for all its citizens. However, this transformation requires a collective effort from all stakeholders, including policymakers, private sector actors, civil society organizations, and local communities. Only through a coordinated and inclusive approach can Nigeria overcome the barriers and pave the way for a future where affordable and clean energy is a reality for all.

References

- Adeyanju, G.C., Osobajo, O.A., Otitoju, A. et al. (2020). Exploring the potentials, barriers and option for support in the Nigeria renewable energy industry. *Discov Sustain* 1, 7. <https://doi.org/10.1007/s43621-020-00008-5>
- African Development Bank (AfDB). (2021). Promoting Energy Innovation in Africa: Challenges and Opportunities. Retrieved from <https://www.afdb.org/en/documents/promoting-energy-innovation-africa-challenges-and-opportunities>
- Alabi, O., Abubakar, A., Werkmeister, A. et al. Keeping the lights On or Off: tracking the progress of access to electricity for sustainable development in Nigeria. *GeoJournal* 88, 1535–1558 (2023). <https://doi.org/10.1007/s10708-022-10689-2>
- Aliyu, A. S., Ramli, A. T., & Saleh, M. A. (2015). Nigeria electricity crisis: Issues, challenges and solutions. *Journal of Energy and Power Engineering*, 9(3), 383-392. <https://doi.org/10.17265/1934-8975/2015.03.011>
- Akuru, U. B., & Okoro, O. I. (2014). Renewable energy investment in Nigeria: A review. *Renewable and Sustainable Energy Reviews*, 25, 499-508. <https://doi.org/10.1016/j.rser.2013.05.036>
- Bertheau, P., Oyewo, A. S., Cader, C., Blechinger, P., & Breyer, C. (2019). Overcoming the challenges of mobile households in increasingly mobile societies: Economic and technical opportunities of offgrid electrification in Nigeria. *Energy for Sustainable Development*, 53, 1-12. <https://doi.org/10.1016/j.esd.2019.07.003>
- Chukwu, M., & Folayan, C. O. (2019). Geothermal energy resources in Nigeria: A review. *International Journal of Renewable Energy Research*, 9(4), 1727-1738.
- Energy Commission of Nigeria. (2022). Approved Revised National Energy Policy 2022.

- IEA. (2019). Africa Energy Outlook 2019. International Energy Agency. <https://www.iea.org/reports/africa-energy-outlook-2019>
- IEA (2019). Total primary energy demand in Africa by scenario, 2018-2040, IEA, Paris <https://www.iea.org/data-and-statistics/charts/total-primary-energy-demand-in-africa-by-scenario-2018-2040>, Licence: CC BY 4.0
- IEA (2019). Electricity generation in Africa by scenario, 2018-2040, IEA, Paris <https://www.iea.org/data-and-statistics/charts/electricity-generation-in-africa-by-scenario-2018-2040>, Licence: CC BY 4.0
- International Energy Agency. (2021). Energy poverty: How to make modern energy access universal? Retrieved from <https://www.iea.org/reports/energy-poverty>
- International Energy Agency (IEA). (2021). Nigeria Energy Outlook 2021. Retrieved from <https://www.iea.org/reports/nigeria-energy-outlook-2021>
- International Renewable Energy Agency (IRENA). (2022). Renewable Power Generation Costs in 2021. Retrieved from <https://www.irena.org/publications/2022/Jul/Renewable-Power-Generation-Costs-in-2021>
- Nigerian Bureau of Statistics, NBS. (2020). Nigeria Living Standards Survey 2018–2019 (A Survey Report by the Nigerian National Bureau of Statistics (in collaboration with the World Bank)). National Bureau of Statistics (NBS)
- Ley, K., Gaines, J., & Ghatikar, A. (2016). The Nigerian energy sector: An overview with a special emphasis on the Nigerian power supply industry. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. <https://www.giz.de/en/downloads/giz2016-en-nigerian-energy-study.pdf>

National Energy Policy (NEP). (2022). Revised Edition [Approved 27th April 2022 by Government]. <https://energy.gov.ng/Media-and-Events/Press-Release/articletype/ArticleView/articleid/188/Revised-Edition-of-the-National-Energy-Policy-Approved.aspx>

Okunlola, O. A., Akinnubi, R. T., Makinde, F. V., & Akinbogun, S. B. (2021). Achieving universal access to modern energy services in rural areas of Nigeria: A review of technological options and challenges. *Energy Reports*, 7, 4272-4292. <https://doi.org/10.1016/j.egy.2021.07.040>

Olabode, A. S., & Gbadegesin, A. T. (2021). Renewable energy policy in Nigeria: A review. *Energy Reports*, 7, 5569-5589.

OPEC. (2020). Annual Statistical Bulletin 2020. Retrieved from https://www.opec.org/opec_web/en/publications/202.html

Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: The way forward. *Energy, Sustainability and Society*, 2(1), 1-17. <https://doi.org/10.1186/2192-0567-2-15>

Oyedepo, S. O. (2014). Towards achieving energy for sustainable development in Nigeria. *Renewable and Sustainable Energy Reviews*, 34, 255-272. <https://doi.org/10.1016/j.rser.2014.03.019>

Renewable Energy and Energy Efficiency Partnership (REEEP). (2020). Nigeria Renewable Energy Policy Brief. Retrieved from <https://www.reeep.org/publications/nigeria-renewable-energy-policy-brief>

Rural Electrification Agency of Nigeria (REA). (2020). Renewable Energy for Rural Economic Development in Nigeria. Retrieved from <https://rea.gov.ng/resources/reports/>

World Bioenergy Association (WBA). (2019). Fact Sheet: Bioenergy in Nigeria. Retrieved from <https://www.worldbioenergy.org/uploads/191129%20WBA%20FS%20Nigeria.pdf>

Sambo, A. S. (2009). Strategic developments in renewable energy in Nigeria. International Association for Energy Economics, 16-19. <https://www.iaee.org/en/publications/newsletterdl.aspx?id=75>

Simonyan, K. J., & Fasina, O. (2013). Biomass resources and bioenergy potentials in Nigeria. African Journal of Agricultural Research, 8(40), 4975-4989.

Sustainable Energy for All. (2020). State of the Global Mini-grids Market Report 2020. Retrieved from <https://www.seforall.org/publications/state-of-the-global-mini-grids-market-report-2020>

United Nations Conference on Trade and Development (UNCTAD). (2020). Technology Transfer and Innovation for Low-Carbon Development. Retrieved from https://unctad.org/system/files/official-document/dtl_stict2020d15_en.pdf

United Nations Development Programme. (2021). Achieving Affordable and Clean Energy for All. Retrieved from <https://www.undp.org/sustainable-development-goals#affordable-and-clean-energy>

United Nations Development Programme (UNDP). (2021). Renewable Energy for Rural Economic Renewal in Nigeria. Retrieved from <https://www.undp.org/nigeria/publications/renewable-energy-rural-economic-renewal-nigeria>

United Nations Environment Programme (UNEP). (2020). Sustainable Energy for All: The Role of Clean Energy in Combating Climate Change in Nigeria. Retrieved from <https://www.unep.org/resources/report/sustainable-energy-all-role-clean-energy-combating-climate-change-nigeria>

United Nations Industrial Development Organization (UNIDO). (2019). Promoting Energy Technology Innovation in Nigeria. Retrieved from

https://www.unido.org/sites/default/files/files/2019-04/UNIDO_Energy_Technology_Innovation_Nigeria.pdf

World Bank. (2018). Access to energy is at the heart of development. Retrieved from <https://www.worldbank.org/en/news/feature/2018/04/18/access-energy-sustainable-development-goal-7>

World Bank. (2020). Access to electricity (% of population) - Nigeria. <https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=NG>

World Bank. (2020). Harnessing Nigeria's Geothermal Energy Potential. Retrieved from <https://www.worldbank.org/en/news/feature/2020/01/31/harnessing-nigerias-geothermal-energy-potential>

World Bank (2021). Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program.

World Bank (2023). IEA, IRENA, UNSD, World Bank, WHO. 2023. Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC. © World Bank.

World Bioenergy Association (WBA). (2019). Fact Sheet: Bioenergy in Nigeria. Retrieved from <https://www.worldbioenergy.org/uploads/191129%20WBA%20FS%20Nigeria.pdf>

<https://www.undp.org/nigeria/publications/renewable-energy-rural-economic-renewal-nigeria>

World Intellectual Property Organization (WIPO). (2022). Technology Transfer and Intellectual Property Rights. Retrieved from https://www.wipo.int/ip-outrreach/en/ipday/2022/technology_transfer.html

World Health Organization (WHO). (2022). Air Pollution and Health: A Closer Look at the Economic Cost. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/air-pollution-and-health-a-closer-look-at-the-economic-cost>