

Research Article

Towards Ensuring Energy Security in Africa: A Proposal of Technologies and Policies

Barnabas Babatunde * 

Department of Electrical and Electronic Engineering, University of Lagos, Lagos, Nigeria

Abstract

Energy security is the ability of a region to affordably access sufficient energy, and to utilize such energy for its growth, well-being, and overall economic development. Africa is a continent rich in both renewable and non-renewable energy resources. An irony lies in the fact that Africa's access to energy is nearly insignificant when compared to developed parts of the world. Africa has tremendous energy resources at its disposal, however, the technological, socio-economic, and policy-oriented systems required to fully harness these resources have eluded the continent for years. This paper offers insights on how the gap can be bridged – moving Africa from being merely a depository of energy resources, to a continent that harnesses its natural energy endowments towards improving the well-being of its people. The paper begins by providing an introduction to the current state of Africa's energy sector. It then goes further to discuss the challenges militating against energy security in Africa. Most importantly, it provides insights into the technical, socio-economic and policy-oriented approaches and strategies that can be taken to turn Africa into an energy-secure continent. The paper concludes by summarizing the actionable steps that can be taken to achieve a sustainable energy future for the African continent.

Keywords

Energy Security, Africa, Renewable Energy, Policy, Non-Renewable Energy, Smart Grids, Energy Access

1. Introduction

It is without doubt that Africa has at its fingertips, an enormous amount of energy resources sufficient to meet its energy needs. It is also the case that Africa accounts for less than 6 percent of global energy consumption, and about 600 million people lack access to electrical energy in Africa [1]. This is as a result of the lack of clear strategies and initiatives to fully take advantage of available energy resources – only about 25 out of 54 African countries have clear energy access strategies [1]. In Nigeria for example – Africa's most populous nation – energy generation and wheeling infra-

structures remain in a deplorable state. This is evident in the incessant collapse of the national grid and failure of distribution networks, to mention a few. There is a growing need for private sector participation and innovation in energy generation, transmission and distribution in order to improve energy access and subsequent economic outcomes.

Changing Africa's narrative vis-à-vis energy security starts with identifying the energy resources at its disposal. Energy resources are broadly classified as renewable or non-renewable. Renewable energy includes resources that

*Corresponding author: babatundebarnabas@gmail.com (Barnabas Babatunde)

Received: 26 September 2024; **Accepted:** 15 October 2024; **Published:** 13 September 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

restore themselves, while non-renewable energy includes resources that cannot restore themselves [2]. Africa's renewable energy resources include: solar energy, wind, biomass and hydropower [3]. West African countries experience elevated levels of sunshine, placing them in an advantageous position to harness solar energy on a large scale [4]. The total wind potential in Africa is estimated at about 180,000 Terawatt-hours per year, which is 250 times the current demand of the continent, and about 27 African countries can satisfy the entire continent's electrical energy demand [5]. Africa's hydropower potential is estimated at about 340 Gigawatts, most of which are ascribed to the Eastern, Southern and Central regions of the continent [6].

There are several challenges standing in the way of Africa's emergence as an energy-secure region. Amongst such challenges, to mention a few, are: the lack of a clear energy access strategy and the lack of adequate energy investments in the region. For Africa to emerge as an energy-secure region, strategy and investments must synergize. Despite Africa's enormous energy resources, it draws in only about 3% of global energy investment [7]. In sub-Saharan Africa, thirteen countries have less than 25% energy access, compared to just 1% in the developing parts of Asia [8]. Technocrats, policymakers and governmental administrators should lean towards formulating strategies that can transform Africa's energy landscape, gearing the continent towards a sustainable energy future, and consequently improving future economic outcomes.

2. Deployment of Renewable Energy

2.1. Concept

Renewable energy refers to energy obtained from naturally-occurring sources that replenish themselves at a rate higher than the rate of consumption [9]. Examples of such sources include wind, sunlight and hydro (flowing water). They are the reverse of non-renewable energy sources, such as oil, gas and coal, which are irreversibly depleted. The law of conservation of energy states that energy can neither be created nor destroyed, but may be transformed from one form to another. As such, mankind has devised methods to convert energy from these naturally-occurring sources into useful electrical energy to power industries and homes. With the use of wind turbines, energy from the wind can be converted into electricity. Through photovoltaic cells, sunlight energy can be harnessed and converted into electrical energy. Also, kinetic energy from flowing water can be used to drive turbines for electricity generation. Several ambitious energy projects across the world consist of large-scale installations of solar panels (panels of photovoltaic cells), wind turbines and hydroelectric turbines to generate sufficient electrical energy to power homes, industries and businesses.

2.2. Technology

African countries are rich in renewable energy resources. A good strategy should begin with identifying these resources within each part of the continent, and exploiting them for electricity generation. For instance, in the south of the Tenere Desert, lies Niger's eastern region of Diffa which is surrounded by an oasis called the Agadem – known to be one of the sunniest areas on earth [10]. Out of the 10 sunniest nations on earth, 7 come from Africa: Kenya, Niger, Sudan, Egypt, Chad, Madagascar and South Africa [10].

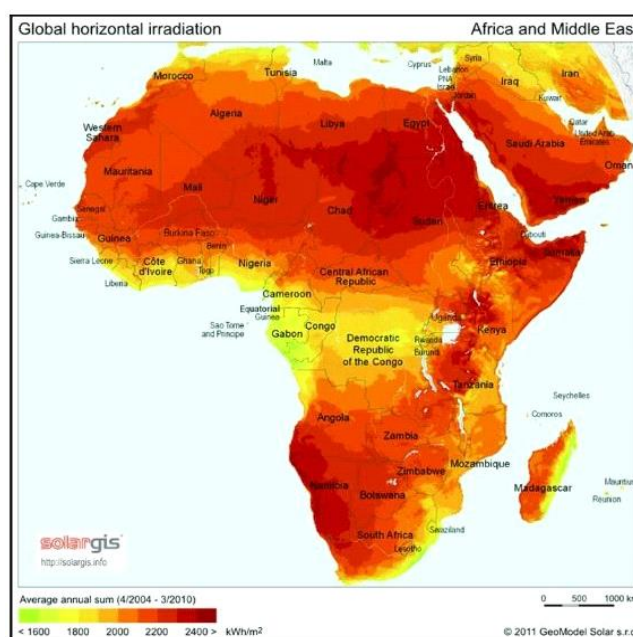


Figure 1. Map of Solar Radiation Levels in Africa [11].

Solar plants can be built in these sunny regions to meet their energy needs, in part. Such plants would require the installation of thousands of solar panels (connected in series) to form solar arrays capable of producing usable voltage. An electrical equipment known as a combiner box would be installed to combine all the DC (Direct Current) electricity emanating from the solar panels. The combined DC would then be fed into an inverter. The role of the inverter is to convert DC into AC (Alternating Current). This conversion stage is crucial, as national electrical grids run on alternating current. Finally, the AC voltage would be fed into a static electrical machine called a transformer. This transformer serves the purpose of stepping up the voltage from a low value to a high value, for long-distance transmission through the national grid. Alternatively, this AC voltage could be served directly into people's homes and small businesses, without having to go through the national grid – this method is often used in rural areas that are underserved by the grid. Figure 2 shows a typical solar plant installation.

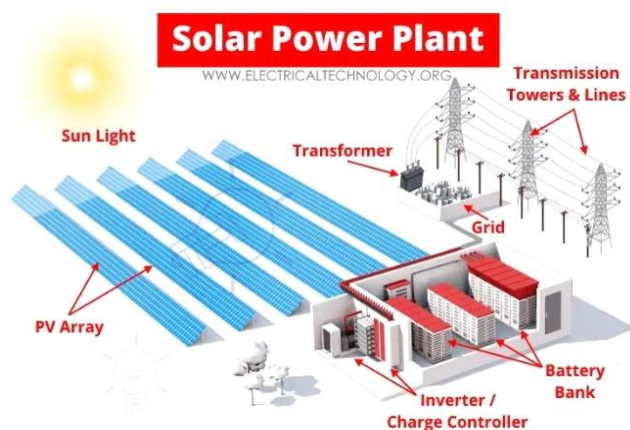


Figure 2. A Solar Power Plant Installation [12].

An engineered system is expected to be reliable and available to serve its purpose at all times. To ensure that electricity generation, transmission and distribution systems in Africa are reliable and available, it is important that certain concepts are factored into their design. One of such critical concepts is redundancy. Redundancy is an important concept in infrastructure planning and engineering which involves the inclusion of duplicate components in a system's design, to ensure its continuous operation with near-zero downtimes. To ensure that underserved regions in Africa have access to a continuous supply of electrical energy, it is essential to ensure that generation, transmission and distribution systems are designed with component redundancies, consequently eliminating single points of failure. For example, in a solar power plant, multiple transformers can be installed, such that when one transformer fails due to electrical fault, duty can be transferred to another transformer, thereby ensuring continued service and minimizing downtime. Similarly, duplicate transmission pathways can be built so that energy can flow through another (healthy) pathway when the main pathway has an electrical fault.

Africa also has an enormous wind potential. According to the International Finance Corporation, Africa has sufficient wind resources to meet 250 times its entire electricity demand [13]. Wind power still remains largely untapped in Africa. The continent has less than 1 percent of the world's installed wind capacity, facing lack of financing and policy support [13]. Shown below is a map of Africa's wind energy potential, according to African Development Bank (AfDB 2014):

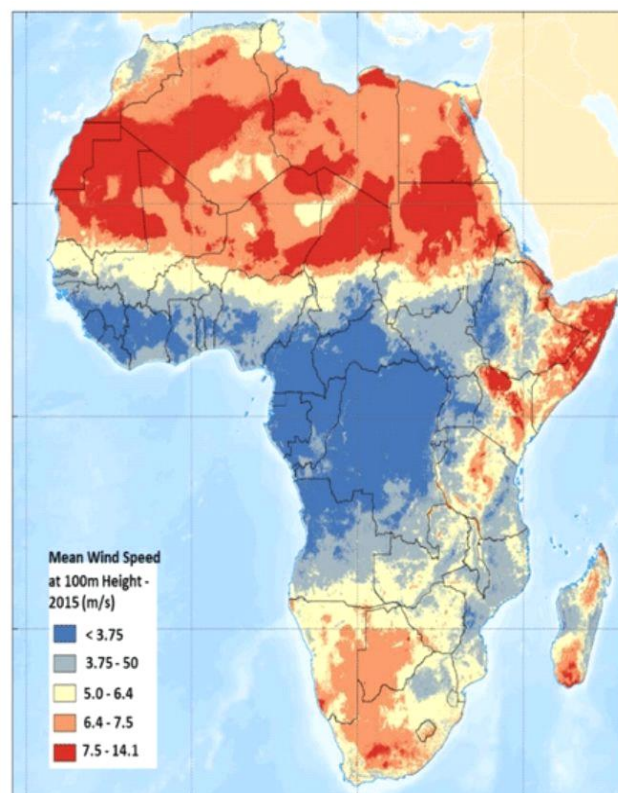


Figure 3. Map Showing Africa's Wind Energy Potential [14].

Regions with high average wind speeds should be populated with wind farms consisting of several wind turbines installed to generate electricity from wind energy. Wind power plants are green in that they have less impact on the environment because they do not require fuel.

Wind power plants consist of wind turbines as the main component. Wind turbines are vertical structures with large rotating blades connected to a rotor. As wind blows over the blades, the rotor spins. The rotor is connected to a generator through a shaft which transmits the rotational kinetic energy. The generator then converts this rotational kinetic energy into electrical energy through electromagnetic induction. A collection point collates all the low voltages emanating from the generators. At this point, the low voltage undergoes transformation and is stepped up to a high magnitude that is suitable for long-distance transmission through transmission lines and substations. With the use of sensors and computer software, wind speed and direction can be measured, so that the orientation of the turbines can be adjusted to access maximum wind energy.

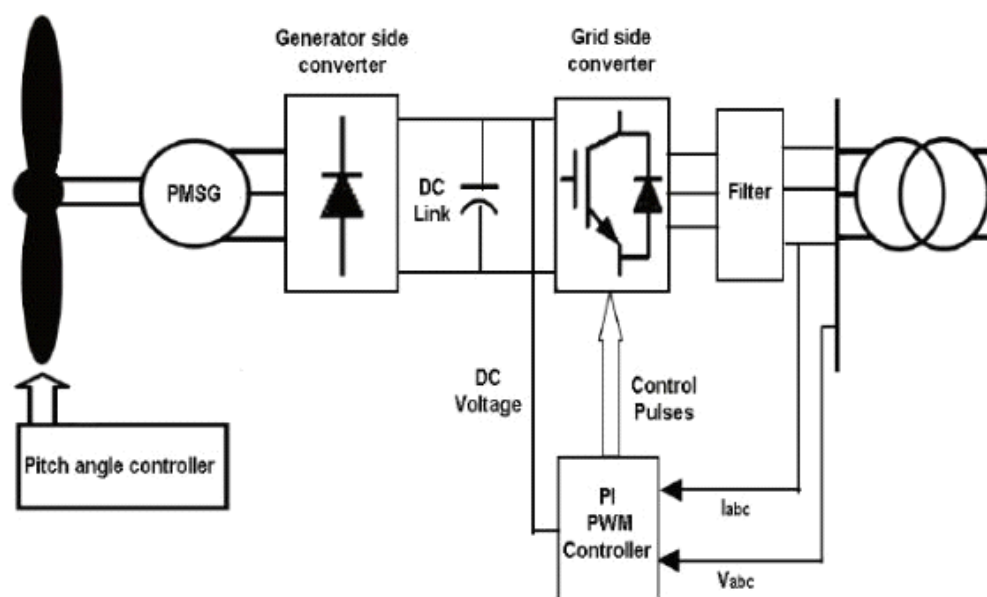


Figure 4. Wind Power Generation System [15].

Shown in Figure 4 is the block diagram of a typical wind power generation system. A pitch angle controller influences the angle of the turbine blades, helping to maximize the amount of energy extracted from the wind while also preventing mechanical damage to the turbine. The rotational energy from the turbine is transferred to a synchronous generator through a shaft. The generator then produces electricity at a constant frequency (usually 50 or 60 Hertz). The AC electricity from the generator flows through a generator-side converter and an intervening DC link which helps to smoothen-out fluctuations in electrical power. A GSC (Grid Side Converter) helps to synchronize the voltage output with the grid. It adjusts the frequency and phase angle to match the requirements of the grid. Finally, the synchronized voltage can be conveniently stepped up for long-distance transmission along transmission lines and substations, for eventual distribution to homes, businesses and industries.

Hydropower potential in Africa is considerably large. As of 2023, Ethiopia had the greatest hydropower capacity in Africa, reaching about 4.9 Gigawatts, followed by Angola and South Africa at about 3.7 and 3.5 Gigawatts respectively [16]. Hydropower's share in energy generation exceeds 80% in countries such as Malawi, Uganda, Mozambique and Zambia, however, only 11% of the continent's current hydropower potential is utilized [17]. Public-Private Partnerships should be created with the aim of allocating sufficient capital towards the development and execution of more hydropower projects in water-rich regions of the continent.

2.3. Socio-Economics

Low access to energy has negative impacts on education, health, and sustainable growth in Africa [18]. Household pollution caused by lack of clean cooking technology result-

ed in about 700,000 deaths in Africa in 2019 [18]. According to a report by the United Nations, Africa has the lowest electricity access in the world due to lack of energy supply grids, or due to the use of unstable and outdated grids.

Increased access to affordable clean energy can improve socio-economic outcomes in Africa, because energy is correlated with economic growth (higher Gross Domestic Product levels are linked with greater energy access, affordability and use) [19]. With the injection of more electrical energy into the grid, and the adoption of smart grids and embedded generation technologies, energy can be served to communities, businesses and industries at lower cost (economies of scale). Industries require sufficient energy to operate manufacturing plants and machinery, for increased output. With increased output comes increased GDP (Gross Domestic Product). Energy is also essential for the delivery of healthcare services, for educational administration, and to promote innovation and entrepreneurship.

African governments, technocrats and policymakers should focus on improving energy access as the first step towards socio-economic advancement of the continent. Financing and investments should be directed towards the development of robust energy generation, transmission and distribution systems across the continent.

2.4. Policy

Policy plays an important role in improving energy access outcomes in Africa. Through the creation of clear regulatory frameworks, African governments can attract private sector investments in energy. These frameworks would guide the generation, transmission and distribution of energy within each nation. To improve energy security in Africa, governments should lean towards creating regulatory commissions

that will be responsible for ensuring reliability, efficiency and fair practice in the energy sector. These commissions should be led by competent professionals who would implement policies concerning tariff regulation, licensing, monitoring and renewable energy integration.

African governments can also improve energy security through the provision of financial incentives to energy firms and renewable energy projects. By subsidizing taxes and providing grants to growing renewable energy firms and startups, their operations can expand to provide affordable energy to communities, businesses and industries.

African governments can stimulate energy investments through the issuance of energy bonds to the public, raising sufficient capital to finance renewable energy generation and integration projects across the continent. Through the issuance of Green Bonds, governments can access the capital markets to finance ambitious renewable energy projects that will transform the lives of Africans and improve future economic outcomes.

3. Smart Grid Innovations

3.1. Concept

Smart grids are modern-day electrical grids that utilize advanced digital technologies, communication systems, con-

trol and automation to improve the reliability and efficiency of the electrical grid. Smart grids incorporate grid monitoring and control strategies, state-of-the-art metering infrastructure, cybersecurity and energy storage integration, amongst other features. Smart grid is an improvement of the 20th century electrical grids [20].

3.2. Technology

Smart grids incorporate AMI (Advanced Metering Infrastructure) in their design. Smart meters are installed at consumers' premises, allowing for bi-directional communication between the consumers and utilities. These meters provide data on the consumers' energy consumption in real-time.

Through control and automation systems, smart grids enable the access to real-time data on the operating conditions of the grid, thereby allowing for quick response to electrical faults and disruptions. A quick response to electrical disruptions reduces overall system downtime and increases system availability.

Legacy electrical grids have challenges managing the variability of renewable energy systems. However, smart grids possess advanced control, monitoring and storage systems that allow for easier integration of renewable energy. These systems provide the necessary adjustments to match renewable energy supply and store excess energy.

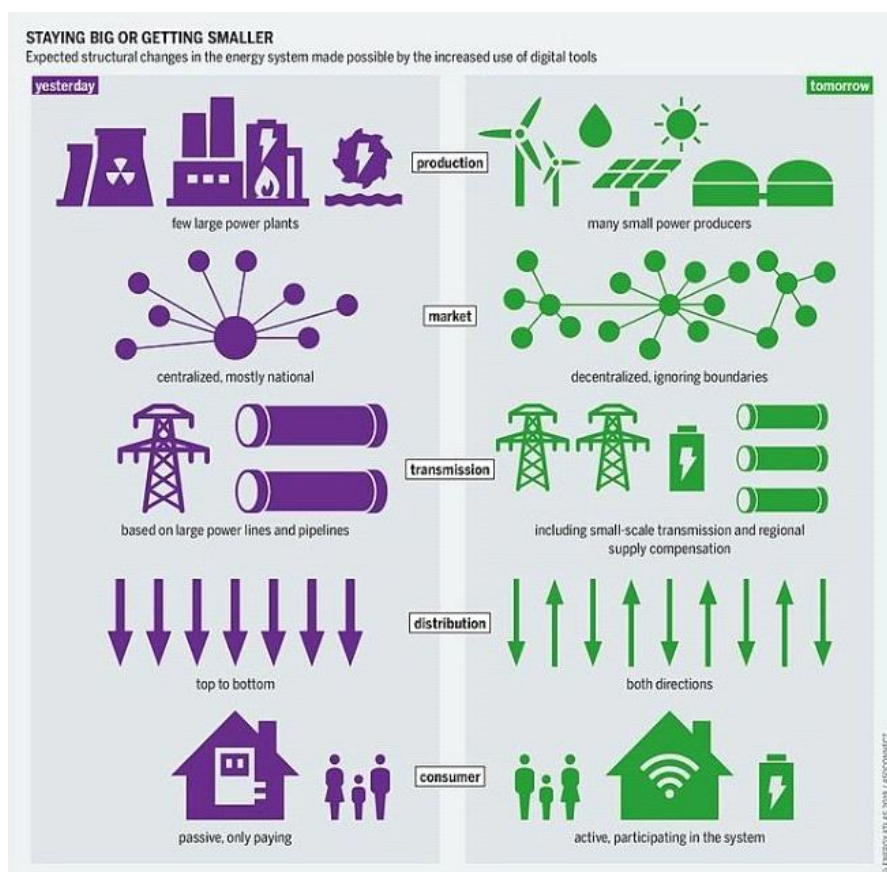


Figure 5. Electrical Grids of the Future [20].

Shown above is an illustration of the intended transition from undigitized electrical grids to fully digitized electrical grids.

The decentralized nature of smart grids makes them valuable to Africa's energy security. A decentralized electrical grid ensures the elimination of single points of failure within the grid, through the incorporation of redundancy and diversity in electricity transmission systems. This will ensure continuity of service to consumers, providing them with sufficient energy to improve their standard of living.

3.3. Socio-Economics

The deployment of smart grids in African countries has positive socio-economic implications. One of such implications is that smart grids will ensure the efficiency and reliability of energy supply to industries and manufacturing plants, reducing operational downtimes significantly. With reduced downtimes comes increased industrial output per unit time – the cumulative effect being an increase in the Gross Domestic Product of African countries. An increased GDP implies an increased GDP per capita (assuming population does not increase by the same extent).

Smart grids can also help to reduce the cost of operation of electrical power systems, through more efficient management and monitoring. This will reduce the cost of accessing energy for African consumers, ultimately improving the quality of their lives.

3.4. Policy

African governments should seek to create PPPs (Public-Private Partnerships), whereby both the public and private sectors can synergize to stimulate smart grids adoption. With the fusion of the private sector's innovation and capital, and the public sector's long-term vision for national development, African countries can record significant progress in integrating smart grid technologies into their energy delivery systems.

African governments can also drive the adoption of smart grid technologies by allocating funds to research and development in the field of smart grids engineering and design. Research grants should be allocated to professors, students and laboratories carrying out smart grids research so as to stimulate smart grids adoption at an exponential rate.

Lastly, through the adoption of sound regulatory frameworks, African governments can steer the continent towards a more energy-secure future. These frameworks will help to guide technical practices and ensure transparency and fairness in energy pricing and sale.

4. Powering Underserved Communities

Underserved communities in Africa lack access to afford-

able clean energy, usually as a result of limited grid connectivity, high energy cost to household income ratio, etc. Some communities suffer limited energy access due to their remote locations, making them largely inaccessible by the national grid. Investments and innovation should be directed towards the adoption of off-grid solutions such as embedded generation and microgrids.

4.1. Embedded Generation

Embedded generation involves the deployment of small-scale energy generation systems connected directly to local distribution networks, instead of going through the central electricity grid. Embedded generation could serve as a reasonable alternative towards improving the energy security of remote communities. Such remote communities usually lack grid connectivity owing to the fact that it may be financially unfeasible to extend grid infrastructure to them, especially when profit and cost comparison is made. Through embedded generation, the energy needs of these communities can be catered to.

4.2. Microgrids

Microgrids offer an excellent opportunity towards improving the energy security of remote underserved communities in Africa. They are local distribution networks that can function independently without the central grid. A typical microgrid offers a distributed energy structure encompassing renewable energy sources, storage and control systems. One advantage that characterizes microgrids and other off-grid innovations is energy cost saving. This cost saving is attributed to the fact that energy is generated closer to where it is utilized, eliminating the need for long-distance transmission with its attendant real power losses.

Africa can improve its energy security through the adoption of both centralized-grid and off-grid energy infrastructure.

5. Energy Access Initiatives

5.1. Case Studies

The African Development Bank is spearheading the deployment of renewable energy through its Desert-to-Power initiative, aimed at delivering clean energy to about 250 million Africans [21]. It is currently one of the world's most ambitious energy projects. It is set to target 11 countries, namely: Chad, Ethiopia, Mali, Mauritania, Nigeria, Niger, Sudan, Senegal, Eritrea, Djibouti and Burkina Faso. By harnessing the solar abundance of the Sahel, the project aims to generate about 10 Gigawatts of electrical power by the year 2030.

The SASGI (South African Smart Grids Initiative) is one

other initiative aimed at improving energy security on the African continent. Having created the smart grid vision for South Africa, the initiative is currently working towards the deployment and utilization of smart grid technologies in the country's electricity supply system.

Energy access initiatives are essential to the improvement of energy security in African countries. Through such initiatives, a clear vision can be forged, paving a path for the adoption of technologies and systems that will amplify the supply of energy to homes, businesses and industries for economic growth.

5.2. Success Stories

Kenya has, to a large extent, been able to overcome its energy challenges by investing heavily in its renewable energy sector. The country currently has one of the most developed renewable energy sectors in Africa [22]. This is as a result of the implementation of clear strategies and reforms aimed at improving electrification. Through the implementation of such reforms, Kenya has moved up the scale from an 8.83% electrification rate in 1997 to a 71.44% electrification rate in 2020 [23].

In Nigeria, smart grids are beginning to gain traction. The TCN (Transmission Company of Nigeria) has developed strategies to digitize the country's electricity supply grid by the deployment of sophisticated machine learning algorithms which spot patterns in energy generation loss via real-time data analytics [24]. This will allow for an optimal operation of the grid and an increased availability of energy supply systems.

Renewable energy and smart grid technologies are still mostly underutilized in Africa [24]. However, efforts are being made in some countries within the continent, who have reaped positive outcomes. Countries like South Africa, Morocco, Kenya and Egypt are good examples. These countries have begun to appreciate the importance of energy security and its role in economic development.

Other African countries that lag behind can employ tested and proven strategies, and adapt such strategies to their specific use cases. In so doing, the continent can achieve widespread energy security, thereby elevating the standard of living of its people and improving future economic outcomes.

6. Intersection of Technology and Community Development

6.1. Case Studies

M-KOPA Solar is a firm addressing the energy access challenge in Kenya. They enable low-income households in East Africa to buy solar home systems, through the use of mobile payments and GSM sensor technology [25]. With

their innovative solution, such households can gain access to clean energy at a one-off payment of USD 200, instead of having to pay the same amount annually on kerosene. The long-term outcome is a reduction in environmental pollution caused by the use of fossils.

Zola Electric is a firm that is leveraging the availability of mobile money to sell solar-powered electricity in East Africa. Through their innovative business model, they have been able to power about 10,000 households and over 45,000 individuals [26].

6.2. Success Stories

South Africa, Kenya and Morocco and Tanzania have implemented smart grid technologies to improve energy supply efficiency and reliability, and to provide electricity to their rural communities. The outcome – an improved electrification rate within their respective countries.

7. Conclusion

7.1. Summary

This paper has discussed the concepts of different renewable energy resources in Africa, providing insights on the technological and policy-oriented approaches that can be taken to harness these resources in order to achieve energy security. It has also touched on the socio-economic implications of renewable energy and smart grids deployment. Furthermore, approaches for powering underserved African communities were treated, citing relevant case studies and success stories afterwards.

7.2. Next Steps

African countries that are determined to begin the journey towards energy security should begin with a solid strategy. A clear energy access strategy would lay the core foundation for further steps and also motivate investors to invest capital in the continent's energy sector. Without strategy, no progress can be made.

Regulatory frameworks are also important to ensure that energy is generated, transmitted and distributed according to industry's standards and best practices. These frameworks would regulate the actions of private actors in the industry who are usually driven primarily by profit, and may want to exploit energy consumers. A sound regulatory framework would ensure that all actors abide by fair energy pricing and sale, and enforce transparency in the industry.

African governments should also encourage the establishment of energy start-ups so as to increase competition in the industry – this would lead to innovation and improved service delivery.

In conclusion, energy security is crucial to the economic development of the African continent. A continent that is

serious about its growth should first and foremost seek to resolve its energy challenges, through adequate investments and proper infrastructural planning. Achieving energy security involves both public and private sectors. The public sector contributes by aligning all objectives with the broader national development plan, while the private sector contributes through innovation and capital investments – both sides working hand-in-hand to ensure a sustainable future for Africa.

Abbreviations

DC	Direct Current
AC	Alternating Current
GSC	Grid Side Converter
GDP	Gross Domestic Product
AMI	Advanced Metering Infrastructure
PPPs	Public Private Partnerships
SASGI	South African Smart Grids Initiative
TCN	Transmission Company of Nigeria

Acknowledgments

The author's gratitude goes to all professors and lecturers in The Department of Electrical and Electronic Engineering, University of Lagos, Nigeria – for their sound academic teaching and instruction, and for imparting their wealth of knowledge.

Author Contributions

Barnabas Babatunde is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

References

- [1] V. Djala, "Challenges and Opportunities of the African Energy Landscape," *The EU and the African Continent, The Energy Development Nexus*, Jun. 3, 2022.
- [2] "Energy and Sustainability in Contemporary Culture," EM SC 240N. <https://www.e-education.psu.edu/emsc240/node/506> (accessed Jul. 7, 2024).
- [3] "Renewable Energy Offers Africa's Best Opportunity to Achieve the Sustainable Development Goals, Expert Say." <https://www.afdb.org/en/news-and-events/press-releases/renewable-energy-offers-africas-best-opportunity-to-achieve-the-sustainable-development-goals> (accessed Jul. 7, 2024).
- [4] "West Africa has Great Potential for Solar Energy. It's Time to Release It." <https://climatepromise.undp.org/news-and-stories/west-africa-has-great-potential-for-solar-energy-its-time-to-release-it> (accessed Jul. 7, 2024).
- [5] S. Whittaker, "Exploring Africa's Untapped Wind Potential," Oct. 5, 2020.
- [6] "Multinational-Africa Hydropower Modernization Program – Project Appraisal Report." <https://www.afdb.org/en/documents/multinational-africa-hydropower-modernization-program-project-appraisal-report> (accessed Jul. 7, 2024).
- [7] "Increasing Energy Investment in Africa is Vital for the Continent's Sustainable Economic Growth." <https://www.iea.org/news/increasing-energy-investment-in-africa-is-vital-for-the-continent-sustainable-economic-growth> (accessed Jul. 7, 2024).
- [8] J. Corfee-Morlot, P. Parks, J. Ogunleye, F. Ayeni, "Achieving Clean Energy Access in Sub-Saharan Africa," *OECD Case Study Key Findings*.
- [9] "What is Renewable Energy?" <https://www.un.org/en/climatechange/what-is-renewable-energy> (accessed Jul. 7, 2024).
- [10] "Harvesting the Sun." <https://www.un.org/africarenewal/magazine/april-2016/harvesting-sun> (accessed Jul. 7, 2024).
- [11] "Solar Maps," GeoSun Africa, 2013.
- [12] "Solar Power Plant – Types, Components, Layout and Operation." <https://www.electricaltechnology.org/2021/07/solar-power-plant.html/amp> (accessed Jul. 7, 2024).
- [13] "Africa's Wind Power Holds Potential to Light Up the Continent." <https://aowenergy.com/articles/africas-wind-power-holds-potential-to-light-up-the-continent> (accessed Jul. 7, 2024).
- [14] S. T. Onifade, M. Altuntas, F. V. Bekun, "Synthesizing Urbanization and Carbon Emissions in Africa: How Viable is Environmental Sustainability and the Quest for Economic Growth in a Globalized World?" *Environmental Science and Pollution Research* 29(2), Apr. 2022.
- [15] M. Izadbakhsh, A. Rezvani, M. Gandomkar, "Improvement of Microgrid Dynamic Performance Under Fault Circumstances Using ANFIS for Fast Varying Solar Radiation and Fuzzy Logic Controller for Wind System," *Archives of Electrical Engineering*, Dec. 2014.
- [16] "Hydropower Capacity in Selected African Countries in 2023." <https://www.statista.com/statistics/1278106/leading-countries-in-hydropower-capacity-in-africa/> (accessed Jul. 7, 2024).
- [17] "Climate Risks to African Hydropower." <https://www.iea.org/reports/climate-impacts-on-african-hydropower/climate-risks-to-african-hydropower> (accessed Jul. 7, 2024).

- [18] “Improving Energy Access Key to Meeting Development Goals in Africa.” <https://unctad.org/news/improving-energy-access-key-to-meeting-development-goals-in-africa> (accessed Jul. 7, 2024).
- [19] “How Much Do We Know About the Development Impacts of Energy Infrastructure?” <https://blogs.worldbank.org/en/energy/how-much-do-we-know-about-the-development-impacts-of-energy-infrastructure> (accessed Jul. 7, 2024).
- [20] “Smart Grid.” https://en.m.wikipedia.org/wiki/Smart_grid (accessed Jul. 7, 2024).
- [21] “The African Development Bank’s Desert to Power Initiative.” <https://www.afdb.org/en/news-and-events/africa-development-banks-desert-power-initiative-71072> (accessed Jul. 7, 2024).
- [22] R. Janho, “Renewable Energy in Kenya: An Examination of the Legal Instruments and Institutional Changes that Successfully Attracted Foreign Investment,” *Energy Central*, Apr. 16, 2021. [Online]. Available: <https://energycentral.com/c/pip/renewable-energy-kenya-examination-legal-instruments-and-institutional-changes> (accessed Jul. (7, 2024).
- [23] H. Ritchie, M. Roser, “Access to Energy,” *Our World in Data*, Sep. 20, 2019. [Online]. Available: <https://ourworldindata.org/energy-access> (accessed Jul. 7, 2024).
- [24] “Smart Grids Take off in Africa.” <https://bird.africanofilter.org/stories/smart-grids-take-off-in-africa> (accessed Jul. 7, 2024).
- [25] “Innovative Player that Gives Low-Income Households in East Africa Access to Power.” <https://www.triodos-im.com/articles/projects/m-kopa-solar> (accessed Jul. 7, 2024).
- [26] “Ashden Winners Zola Electric (previously Off-Grid Electric) / Mobile Money Powers Solar Expansion in Rural East Africa.” <https://ashden.org/awards/winners/off-grid-electric-tanzania/> (accessed Jul. 7, 2024).