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Review

Energy Status in Africa: Challenges, Progress and Sustainable Pathways

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Abstract: Access to modern energy is essential for socioeconomic development, yet Africa faces significant challenges in this regard. For example, Sub-Saharan Africa (SSA) is marked by economic underdevelopment and poverty largely due to the non-environmentally friendly energy used (wood, charcoal) and limited access to modern energy resources. Indeed, this review provides an overview of the African energy landscape; it provides a comprehensive renewables-focused energy pathway for developing a cleaner and more sustainable African energy system. It explores end-use sector electrification in both rural and urban areas in Africa. It emphasizes the rapid expansion of renewable generation, the challenges facing and solutions for the implementation of renewable energy, and the role of emerging technologies. It also presents technological pathways and investment opportunities that will enrich the regional debate and help accelerate the energy transformation across Africa. The analysis demonstrated that the current trends of renewable energy used are hydropower, wind power, biomass, and geothermal energy. The electrification rate in West Africa is less than 58% in urban areas and less than 25% in rural areas. Results show that 65% of the SSA population does not have access to electricity and 81% rely on wood and charcoal. In West Africa, only Ghana (70% or so) and Cape Verde (95.9% or so) have equitable access to electricity between rural and urban areas. The potentiality of solar irradiance in Africa ranges between 3 and 7 KWh/m^2/day. The wind speed ranges from 3 m/s to 10 m/s; the wave power can range from 7 to 25 kW/m per site in island regions. Egypt, Morocco, Ethiopia, Tunisia, and South Africa are, respectively, countries leading in wind power technology, and solar energy technology was more advanced in North Africa and South Africa. Finally, geothermal is only developed in Kenya and Tanzania and Kenya is the leader in that field. Although renewable energy in Africa is still growing year to year, it still faces power outages because most renewable energy potentialities are not yet exploited, the technologies used are weak, there is insufficient funding, there is ineffective infrastructure, and there are inadequate or no policies in that field.

Keywords: solar energy; Africa; wind power; energy status; energy policy

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1. Introduction

Africa is a continent known for its incredible diversity and vast untapped potential. The story of Africa's energy sector is a captivating narrative woven together with challenges, resilience, and progress. An increasing need for electricity is largely met through the use of fossil fuels for power generation. Across all African countries, the energy sector heavily relies on traditional resources like coal, natural gas, and oil, which make up nearly 80% of the total electricity production [1]. For example, limited access to modern energy services in Sub-Saharan Africa (SSA) was widely recognized as one of the key hurdles to the economic and social development of its population [2,3]. According to the estimation in 2016 of the

International Energy Agency, 65% of the population of Sub-Saharan Africa lack access to electricity and 81% use harmful and inefficient traditional forms of energy for cooking and heating [4]. While African nations contribute relatively small amounts of greenhouse gas emissions compared to more industrialized countries, they are exceptionally susceptible to shifts in climate patterns due to their geographical location [5,6]. Consequently, there is a growing need, particularly in Sub-Saharan regions, to create power generation systems that are both low in fuel usage and carbon emissions. One promising solution to address the energy accessibility issue, especially in Africa where transforming conventional energy resources to large power plants is very expensive, is the adoption of renewable energy sources. Africa is abundantly endowed with a valuable resource in the form of highly usable solar energy, particularly in Southern Africa, East Africa, and North Africa. This means there is significant technical potential to exploit solar power using existing technologies such as photovoltaic (PV) systems and concentrating solar power [7].

Africa, with its immense landscapes and rich natural resources presents a crucial energy scenario. It has some of the globe's most abundant sources of renewable energy, including copious sunlight, wind, and geothermal potential alongside substantial oil and gas reserves. Access to modern energy in Sub-Saharan Africa (SSA) has consistently lagged behind and the region has often been ranked as the least developed in terms of economic growth and contemporary progress. SSA is characterized by a high number of widely scattered rural communities, which poses significant technical and economic challenges for establishing extensive electricity grid connections despite the growing demand for electrical energy. Approximately 30% of the population in the region has access to electricity [8].

Indeed, Africa's energy has been dominated by traditional biomass sources like wood and charcoal, which still serve as the primary energy sources for cooking and heating in many areas [9]. While these biomass sources have been a salvation for millions, their unsustainable use contributes to deforestation, environmental degradation, and indoor air pollution, exacerbating health and environmental challenges due to incomplete combustion. Excessive energy consumption has both immediate and indirect impacts on the natural environment. These effects include changes in the climate, a decline in environmental quality, and an increase in air pollution [10,11]. For instance, in Sub-Saharan Africa, power plants running on fossil fuels release substantial amounts of carbon emissions into the atmosphere every year [12]. This has significant implications for environmental degradation and global warming. Furthermore, from June 2022 to June 2023 the global CO_2 level has increased by 0.62% [11]. According to scientific consensus it is crucial to limit the global temperature rise to no more than 1.5 degrees Celsius above pre-industrial levels to prevent the most severe consequences of climate change and ensure a habitable planet.

In Africa, renewable energy sources accounted for only 19% of the total electricity generated in 2019, with hydroelectric power being the dominant source among solar, wind, tidal wave, and biofuels. According to the International Energy Agency (IEA), in 2019 Africa had a significant unexploited wind energy potential exceeding 300 GW, which is more than 30 per cent of its capacity. However, the investment costs for new projects in countries like South Africa, Kenya, and Morocco have ranged from USD 1600 to USD 3000 per installed kilowatt-hour (KWh), which is surprisingly higher than installation costs in other developed nations like China and India.

Although SSA has substantial potential for renewable energy, there is a lack of sustainable political will and commitment to establish the necessary regulatory framework and modern techniques for its utilization. Many urban areas in SSA have limited access to electricity due to the high costs of fossil fuel-based electricity and unregulated tariff structures. The urgency of transitioning to cleaner, sustainable and accessible energy sources cannot be emphasized enough. However, this transition is a formidable challenge. African nations grapple with many interconnected obstacles ranging from inadequate energy infrastructure and financial constraints to policy. Moreover, the energy transition is a nuanced process demanding customized solutions that consider each nation's unique circumstances, resources, and developmental priorities. Occasionally, it is feasible to combine traditional energy systems with renewable energy sources to reduce both the cost of producing electricity and emissions. This approach to providing energy to rural areas within power systems is referred to as a hybrid power system. Numerous studies on rural electrification have explored the practicality of utilizing single-energy sources as well as hybrid power systems.

Nevertheless, amidst these daunting challenges, Africa has seen significant progress. The continent has witnessed remarkable growth in renewable energy capacity with solar and wind projects emerging across various nations. This shift towards renewables aligns with global efforts to combat climate change and holds the potential for decentralized energy generation, particularly in rural areas where energy deficits are most acute. Africa's commitment to sustainable energy is underscored by initiatives like the African Union's Agenda 2063 and the United Nations Sustainable Development Goals [6]. These frameworks provide a roadmap for advancing energy access, environmental conservation, and social equity across the continent. They stress the importance of regional cooperation, good governance, and strategic investments in energy infrastructure to accelerate progress.

This research aims to update and provide the current trends of renewable energy resources in Africa for researchers in energy management systems and industry for their investments, especially since the previous review did not mention potentialities in marine-based energy and the recent data on renewable energy. It serves as a precursor to a comprehensive exploration of Africa's energy landscape. Through a deeper understanding of Africa's energy status, this review will lead to the right decisions on future projects by the decision-makers or by the private sector, which can provide a more prosperous and sustainable future for the continent and its people. This review is split into four main parts. Firstly, the review focuses on the energy landscape and electrification in Africa, which is stated in Section 2 where we highlight and discuss the electrification rate in some African countries and the way forward. Secondly, renewable energy technologies and their advancements are presented in Section 3. The discussion includes hydropower, bioenergy geothermal, solar energy, wind energy, and marine-based energy within Africa. Thirdly, the current status of renewable energy policies in Africa is presented and discussed in Section 4. Finally, the challenges facing renewable energy sectors and the way forward were also taken under review and are presented in Section 5.

2. Energy Landscape on Energy Access and Electrification in Africa

Energy is very important for economic progress of a country. Economic conditions vary widely across Africa, leading to differing economic situations within the continent. This diversity in economic conditions is a key reason for the significant disparity in electricity access between North Africa and the rest of the regions in SSA, which includes the eastern, southern, and western parts. This collective region of SSA faces particular challenges. A vast majority of Africa's population has lacked access to electricity; even in some rural regions, currently some people live without electricity. Within Africa, each country has his own challenges with accessing electricity. This can be easily shown by Figure 1, which indicates the disparities of accessing electricity in some African countries. Looking at Figure 1, more than 80% of people in North Africa have access to electricity. However, in SSA countries less than 30% of people have access to electricity. Moreover, within the same countries in Africa we have a large gap between rural electrification and urban electrification. For example, Figure 2 shows the electrification rate in Africa between rural areas and urban cities. It shows that, except for Cape Verde where the rate is about the same in the countryside and cities, most countries have a higher rate of accessing electricity in the cities than in the countryside [13]. The average rate of accessing electricity in West Africa was less or equal to 58% in cities and 25% in rural areas [13]. In Africa, only Cape Verde was leading in terms of providing electrification in the whole country and as Figure 2 shows, it currently challenges America and Asia's electrification rates. This could be due to the small population of the country and its good governance. In contrast, Sierra Leone was the worst with only 2% and 52% of people having access to electricity in villages and cities, respectively. Furthermore, in most of the ECOWAS countries many people live in rural areas but not many of them have electricity, as shown in Figure 3, which compares the rural population rate against the rural electrification rate. Besides Ghana, where 70% of rural people have power, and Cape Verde with a high 95.9% rate, the other countries have less than half the rural population electrified [13–15]. Let us take Burkina Faso for example. Even though 70% of its people live in rural areas, only 4.7% of them have electricity [13]. Sierra Leone is another are of concern. They have a rural electrification rate of just 1.5%, but 58% of their people live in the countryside [13].

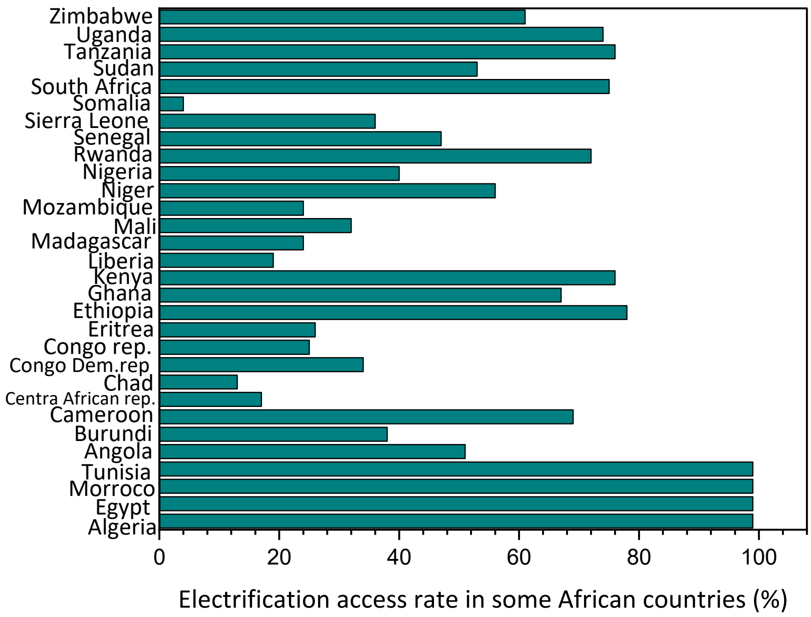

Figure 1. Status of electricity access in some African countries.

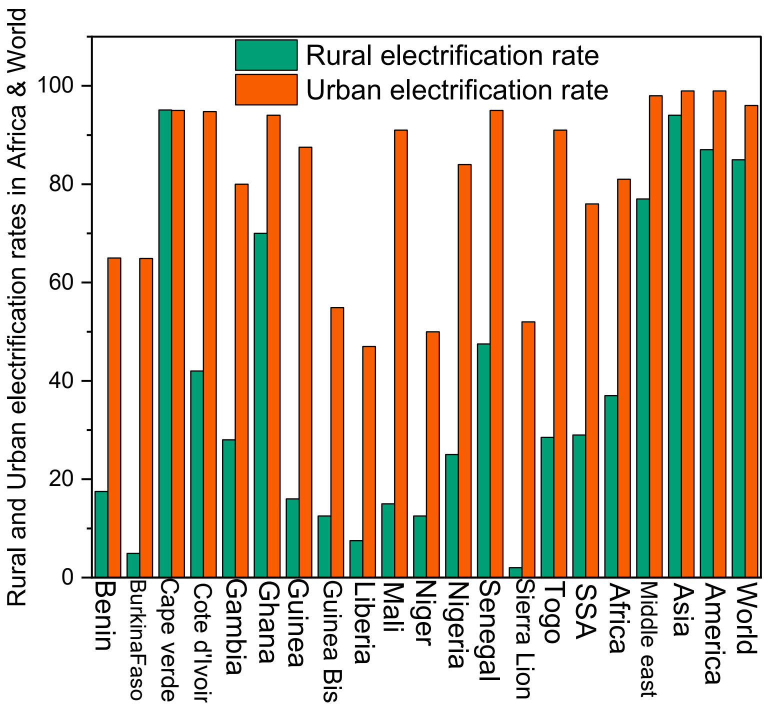

Figure 2. Rural and urban electrification rates of some African countries compared to others regions in the world.

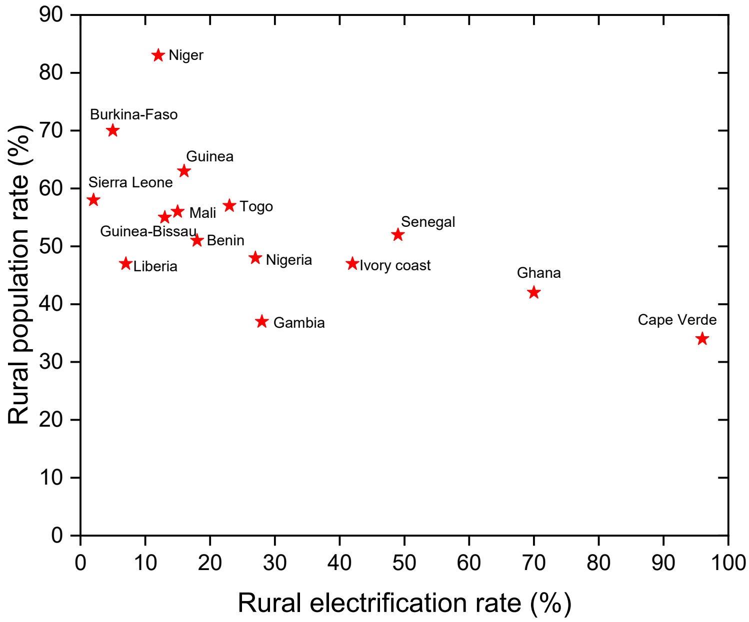

Figure 3. Share of rural population against rural electrification rate [13].

Consequently, the overall rate of electrification in Africa remains comparatively low when compared to other developing nations [15], as depicted in Figure 2. It is important to note that the demand for electricity in SSA is expected to continue growing due to population increases and the desire for socioeconomic progress aimed at enhancing the quality of life in the region.

One prominent challenge is the urban–rural divide where urban areas typically enjoy better access to electricity than rural communities. This inequality reflects historical underinvestment in rural electrification infrastructure. Energy poverty is another pressing issue, with many Africans relying on inefficient and costly energy sources limiting their access to modern energy services [2,3]. Furthermore, inadequate infrastructure including power generation, transmission and distribution, results in frequent power outages and reduced reliability of energy supply. The high cost of energy also contributes to affordability concerns with a significant portion of household income being spent on energy expenses.

On the positive side, there have been notable efforts and initiatives to address these challenges. Rural electrification programs, supported by governments and international organizations, aim to extend electricity access to remote areas through off-grid solutions like solar mini-grids and solar home systems [16,17]. The adoption of renewable energy sources, especially solar power, has gained momentum and proven effective in providing clean and affordable electricity. Public–private partnerships have emerged as a strategy to mobilize investments in the energy sector, facilitating the development and operation of energy infrastructure [2,6]. International support in the form of financial aid technical assistance and knowledge-sharing plays a crucial role in advancing energy access goals [6,17].

The development of smart grids and advanced energy storage systems can improve energy reliability and distribution. Innovative financing mechanisms like net metering and feed-in tariffs encourage investments in renewable energy technologies. The potential for decentralized and distributed power systems, particularly in remote regions, offers a promising solution for energy access [1]. However, significant challenges remain, including the need for substantial investments in energy infrastructure to meet the growing demand. African countries are actively seeking foreign investments to support their power generation sector offering opportunities for collaboration [1]. Regulatory reforms and favorable procedures within these countries are crucial to attract investments [1]. Despite these challenges, Africa's rich mineral resources, young and growing population, and potential for a robust manufacturing sector hold promise for economic development and energy advancement.

3. Renewable Energy in Africa and Its Advancements

The adoption of renewable energy technologies is not only a response to the global call for environmental responsibility but also a means to address energy access challenges and promote economic growth across the continent. Africa's renewable energy sector is marked by innovation, investment, and a commitment to reducing carbon emissions while providing clean, affordable, and reliable energy to its people. As shown in Figure 4, the social Clean Energy Access (Social CEA) Index of 35 SSA countries is discussed in detail in Ref. [18]. This index was created to identify the most suitable countries for funding and implementing decentralized renewable energy for improving social conditions through clean electrification. It shows clearly that in SSA, South Africa is moving well in terms of renewable energy consumption. In contrast, Chad is the country farthest behind in terms of renewable energy consumption.

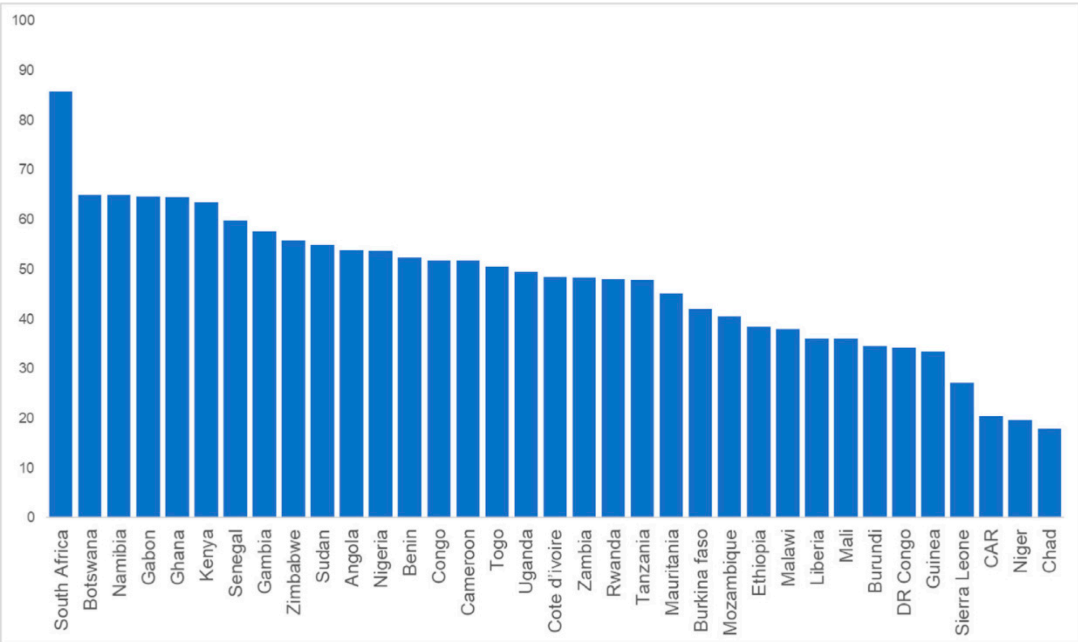

Figure 4. Final Social CEA Index scores [19].

The energy potential in African countries remains largely untapped despite abundant renewable resources. According to the African Development Bank, estimates indicate a massive power generation capacity within the continent. As shown in Figure 5, the different renewable energies used and their distribution in some African countries was randomly selected and covered each region of Africa. The analysis from Figure 5 indicates that Egypt is leading in total renewable energy used in Africa with a current (2021) capacity of more than 25,000 GWh. Mostly wind energy and solar energy are used in southern and northern parts compared to other regions. However, compared to other continents for the total renewable energy used, Africa is far behind. Figure 6 shows the current trend of renewable energy used in Africa, Asia, America, Europe, etc. From the analysis of the data, Asia stands as a leader in the field of renewable energy. This could be explained by the fact that China has become the second-biggest economy after the USA, and has many projects ongoing in that field. The need for transitioning to alternative power sources, including solar, wind, biomass, and geothermal is growing, aligning with increasing global awareness of climate change and commitments under the Paris Agreement 2019. All countries are focusing on climate change and working hard to keep the promises they have made and signed for in the Paris Agreement of 2019.

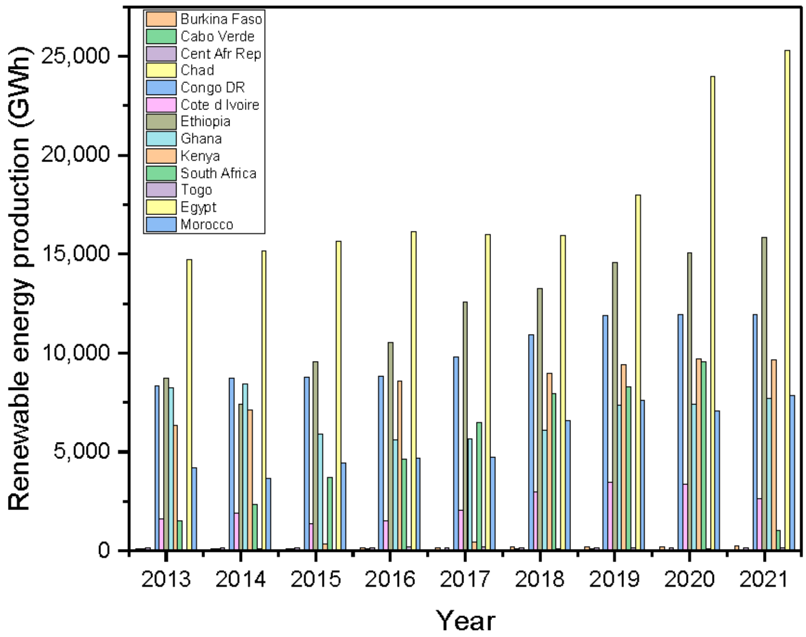

Figure 5. Total renewable energy distribution in some countries in Africa.

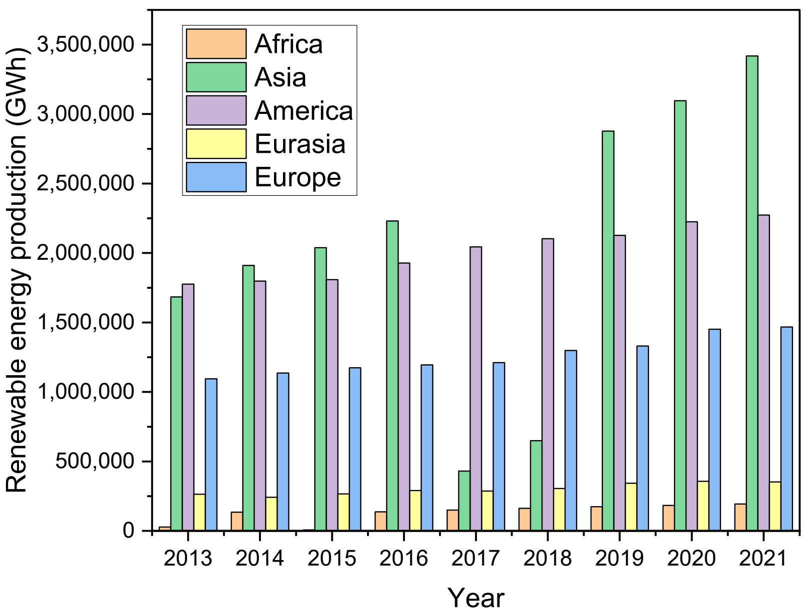

Figure 6. Total renewable energy production in Africa compared to other continents.

Solar energy in particular holds significant promise for Africa with regions in North and Southern Africa experiencing extended sunny days. Both photovoltaic (PV) and concentrating solar power (CSP) technologies have been exploited, with more than 6 GW of CSP and 14 GW of solar PV capacity in Africa IRENA-2015 [1,9]. Countries like South Africa have attracted foreign investments initiating large solar farm projects and expanding grid connectivity to millions of unconnected individuals. Furthermore, there is a rising trend in off-grid solutions facilitated by pay-as-you-go (PAYG) solar companies, such as Off-Grid Electric, M-Kopa, Bboxx, d.light, Mobisol, and Nova-lumos [1]. Several African nations like Kenya have successfully attracted private organizations and leveraged their capital to drive solar energy development. Recent advancements in Togo, Nigeria, and Ghana also indicate progress in the solar energy sector in West Africa.

Despite these opportunities and progress made, governments in African countries need to demonstrate full-fledged commitment to harnessing renewable energy sources.

Power generation capacity is gradually increasing but still falls short of meeting the growing demand, leading to frequent blackouts in significant countries. Addressing challenges such as limited financing and infrastructural deficits requires policy rectifications and government support. The investment gap in the power generation sector remains substantial, necessitating increased spending to meet future demands. Africa has the potential to capitalize on its vast hydropower resources, particularly in regions surrounding the Congo, Niger, Zambezi, and Nile rivers. A notable example is the Grand Inga Hydro Power Plant on the Congo River, which is poised to become a massive power generation facility once fully established. Hydropower currently accounts for only a small percentage of Africa's electricity generation, with substantial untapped potential. All the types of renewable energy resources and their trend from 2013 to 2022 are clearly mentioned in Figure 7.

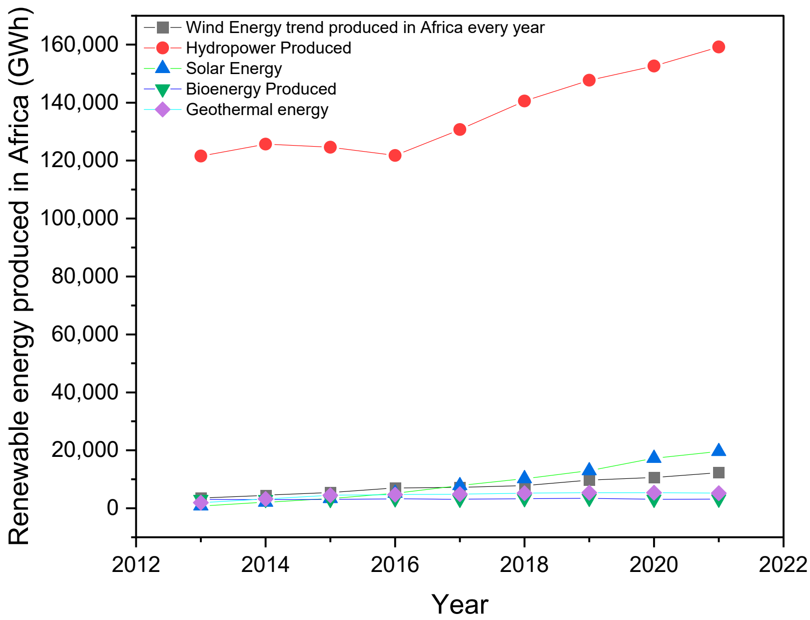

Figure 7. Different types of renewable energy resources used in Africa and their evolutions from 2013 to 2022.

3.1. Hydropower

Hydroelectricity is a clean and renewable energy source generated by transforming the energy of flowing water from higher to lower elevations through turbines to produce electricity. This method is environmentally friendly and does not contribute to global warming. However, the construction of hydroelectric dams can have social consequences including the displacement of local communities, which may not always be fully compensated. In 2019, according to the International Energy Agency, several African nations made significant progress in exploiting their hydropower potential with countries like Cameroon, Senegal, Cote d'Ivoire, and Togo boasting impressive installed hydroelectric capacities of 1.292 GW, 0.2 GW, 0.8 GW, and 0.209 GW, respectively [11]. Kenya heavily relies on hydropower as its primary electricity generation source contributing at least 677 MW to the overall installed grid capacity. However, there is a notable concentration of hydropower generation in specific regions, with projects like Sondu Miriu and Turkwel Gorge playing significant roles [20]. A concern arises from this over-reliance on specific water sources, particularly the Tana River, which accounts for a substantial portion of the hydropower capacity, indicating the need for diversification.

Kenya's large-scale hydropower production capacity is expected to expand to 1500 MW with substantial potential for projects capable of generating a minimum of 30 MW. These capacity additions are distributed across various basins including Lake Victoria, Rift Valley, Athi River, Tana River, and Ewaso Ng'iro North River [21,22]. The existence of approximately 55 river sites suitable for rural electrification is seen as a promising commercial opportunity, with potential outputs ranging from 50 kW to 700 kW [23,24]. In December 2014, Kenya had already exploited 821 MW of its hydropower production potential, representing 38% of its total generation capacity [17]. The overall potential for hydropower, especially in the regions associated with major drainage basins, holds promise for addressing the country's energy needs and achieving a more diversified energy mix. Hydroelectric power generation is recognized for its ability to preserve the natural environment while converting the kinetic energy of flowing water into electrical energy. Sub-Saharan Africa has substantial unexplored hydropower potential, with both small and large hydroelectric systems scattered across the region. The potential for hydropower generation in each country within the region depends on factors like precipitation levels and seasonal variations in water resources, which influence the availability of runoff water and the potential hydropower output.

As Africa faces rising energy demands, many countries in the region have initiated investments in hydropower projects. Hydropower is a valuable and reliable energy source, especially since the water used is not subject to market price fluctuations like oil and gas. As shown in Figure 8, the hydropower used in all African countries from 2013 to 2022 is rising year to year. The fact that most of countries rely too much on this energy resource can be explained by the fact that its technology is well known and also due to the resources available in many countries. Therefore, the development of hydropower offers a promising solution to address the regional energy crisis and meet the growing energy needs of the continent while maintaining its commitment to environmental sustainability.

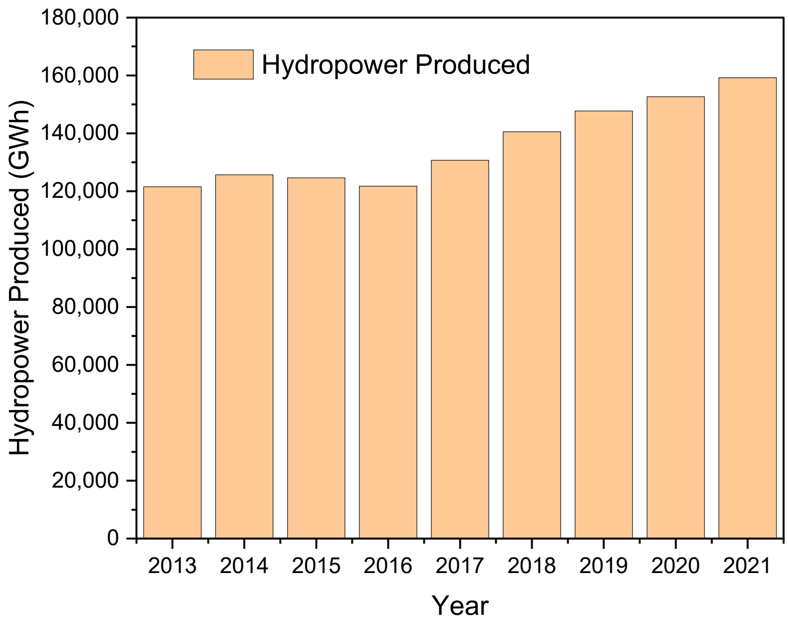

Figure 8. Trend of current hydroelectricity used.

3.2. Solar Energy

Solar power is derived from solar radiation and is exploited through specialized devices like photovoltaic panels to produce electricity. Solar irradiation in Africa exceeds daily electricity requirements offering applications such as water pumping, household lighting, traffic lights, community lighting, and limited urban street lighting in various African communities. SSA experiences high solar radiation intensity ranging from 4.0 to 7.0 KWh/m^2, which is capable of meeting domestic electricity needs as shown in Figure 9 [25]. For instance, Kenya and Togo possess significant solar energy potential receiving an average of 4–6 KWh/m^2/day, which is equivalent to 250 million tons of oil daily and 4.4–4.5 kWh/m^2/day [26], respectively. Presently, approximately 1.2% of Kenyan households utilize solar energy primarily for lighting and television charging. While solar energy is not yet economically prevalent, rising oil costs and environmental concerns are driving its adoption as a viable alternative addressing global energy demand. Kenya benefits from high solar insolation levels, particularly in the northern and northeastern regions, which serve as solar hot spots. With approximately 5 h of peak sunshine daily, Kenya's estimated annual energy generation varies from 700 kWh in mountainous regions to 2650 kWh in arid and semi-arid areas [26]. Additionally, solar-driven cooling systems are gaining traction, particularly in rural areas without grid electricity access exemplified by the installation of ISAAC photovoltaic-powered ice makers in coastal Kenyan villages [26]. Furthermore, solar thermal energy has been used in order to generate electricity or provide hot water in both rural and urban region in Africa. For example, the MICROSOL-UEMOA project, which aims to improve the living conditions of rural populations through the diversification of energy sources in the eight countries of UEMOA, which was started in 2018 in Togo and Senegal, shows how the potential energy can be transformed in Africa to fulfill the deficit [27]. From 2013 to 2022, the common technologies used for power generation were concentrated solar power (CSP) and photovoltaic (PV) modules, which are fabricated through multiple solar cells made from silicon, CI(G)S(Se), or Perovskite [28]. The produced solar power, PV power, and the CSP power are highlighted in Figure 10. It can be easily seen that the CSP was growing slowly up to now. This could be due to the fact that its technology is very expensive for African countries and it is not a well-known technology. Currently, the CSP technologies are only developed in Algeria, Egypt, Morocco, and South Africa, where South Africa and Morocco are the leaders in that field. Moreover, PV technology is still growing due to its simplest technological utilization in homes far from the grid and being less expensive than other renewable energy sources. The majority of SSA countries have already implemented PV technologies but they are still running behind North Africa and South Africa. Despite its abundant potential in Africa, solar energy remains underutilized for cooking purposes or power generation in the region compared to other regions in the world [29].

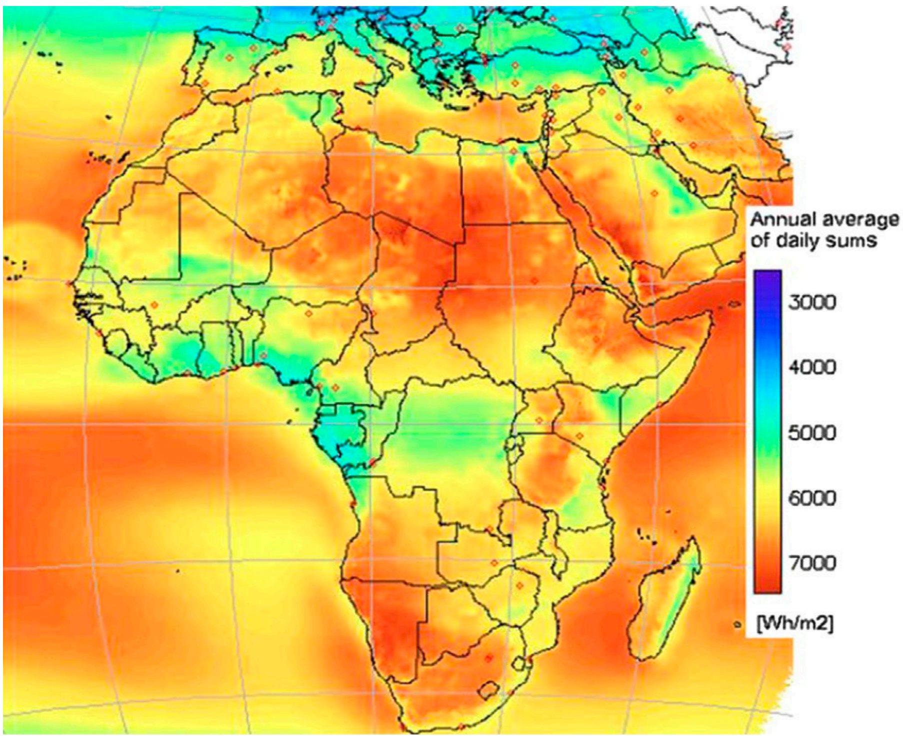

Figure 9. Solar map of Africa [15].

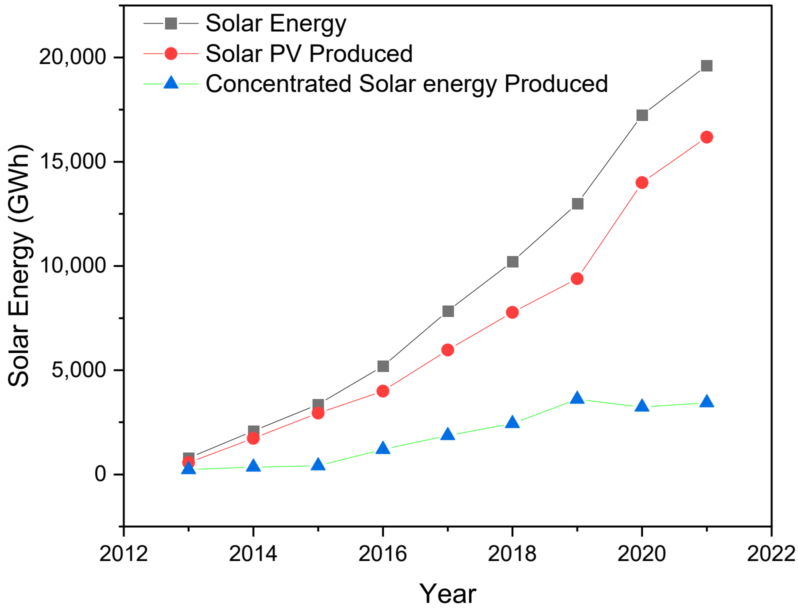

Figure 10. The produced solar power, PV power, and the CSP power in Africa.

3.3. Wind Energy

Wind energy is generated through the conversion of wind's kinetic energy into mechanical energy and further into electrical energy using wind generators. Wind turbines act as pivotal tools to actively capture this abundant wind-generated power. Presently, Africa possesses a wind energy capacity of 6.5 GW but these numbers could dramatically escalate to an impressive 85 GW by 2040 according to estimates from the World Wind Energy Council [11]. To facilitate this remarkable growth in wind energy, key factors such as the availability of suitable geographical locations, well-established grid infrastructure, and supportive legislation hold significance. These factors are crucial for African nations.

Wind power provides a clean energy but requires extensive investment for its installation. It helps to meet the global growing energy needs and it keeps the world's energy supply secure, especially in places that are notably dry or cold. Wind energy can provide a sustainable energy and is very suitable for implantation in any region in rural villages or urban areas in Africa, except regions with low wind. Around the world, more and more wind power has been set up. As shown in Figure 11, the capacity of wind power is still rising slowly in Africa. The progress of wind power worldwide relies heavily on strong government policies. However, in Sub-Saharan Africa, where policies for renewable energy are weak, this is slowing down the growth of wind energy in the region [15]. It is clear that renewable energy technologies are still in their early stages in SSA. Furthermore, the leaders in the field of wind power generation in Africa are respectively Egypt, Morocco, Ethiopia, Tunisia, and South Africa (IRENA, 2023). Right now, there is no robust support for developing wind power in the region. But, in some SSA countries small-scale use of wind power is happening in remote villages where they use it for things like pumping water. Moreover, a select few nations, including Ghana, South Africa, Nigeria, Kenya, and Mali have begun exploiting wind power to generate electricity to power domestic appliances [15]. The first wind generators in Kenya are shown in Figure 12. When it comes to developing bigger wind power systems for businesses, most SSA countries are weak in that manner and stand behind. Exploring how to make off-grid models for more sustainable energy generation, especially with mini-grid wind power systems, could be the way forward. So, there is much potential for wind power to help in these places.

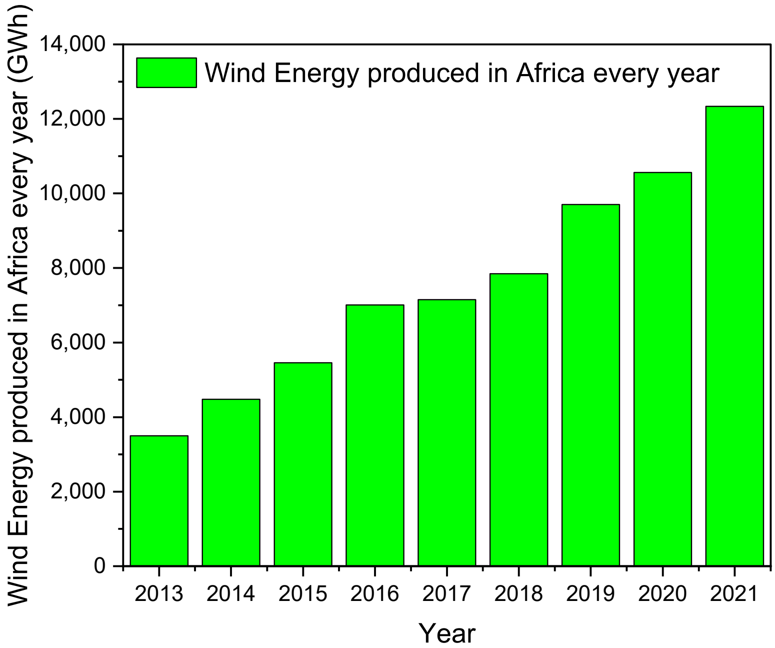

Figure 11. Installed wind energy in Africa.

Figure 12. Kenya's first wind farm in Ngong Hills [30].

3.4. Geothermal Energy

Geothermal power generation is a process that converts thermal energy from the Earth's geological structures into electrical energy. It closely resembles the operation of traditional fossil fuel thermal plants employing steam turbines. Geothermal energy, often referred to as "ground heat", represents a clean and sustainable thermal energy source generated by the Earth's internal heat and pressure. The process of extracting heat from geothermal reservoirs involves various methods including wells, which draw fluids with varying temperatures to the surface. These fluids can then be harnessed for electricity generation and various heat-related applications [31]. Moreover, geothermal power systems utilize naturally sourced steam from the Earth, eliminating the need for conventional boilers to produce steam for power generation. According to data collected from IRENA, 2023, currently, there are only two countries exploiting geothermal energy in Africa; they are Kenya and Tanzania. The prominent player in geothermal power in Africa is Kenya, producing 949 MW of electricity presently. Kenya's unique position in the volcanic center of the Rift Valley grants it a vast, untapped geothermal electricity potential, estimated at 4000 to 7000 MW [32]. This potential has incited collaborative efforts between private investors operating under independent power projects and the government to harness this valuable resource for electricity generation. Exploration activities are underway in various parts of the subregion, notably in Kenya where the significance of this renewable energy source is already evident in the national power sector. However, despite the abundance of high-quality geothermal resources, they do not match the scale of solar and wind energy sources. Although many other SSA nations are blessed with similar geothermal resources, they have not yet explored their potential for substantial renewable power generation.

Africa's estimated geothermal potential is approximately 15 GW, primarily concentrated in the Rift Valley, with countries like Kenya and Ethiopia holding significant shares. In 2016, Africa had a total installed geothermal capacity of 606–653 MW, with Kenya alone contributing 95% of this capacity [33,34]. Nonetheless, the development of geothermal power plants in Africa faces various limitations including substantial initial capital requirements and the need for a well-connected transmission line network [16]. The Eastern African Rift alone boasts a geothermal potential exceeding 20,000 MW [16,33]. As of 2018, Kenya stands as the sole African country with operational geothermal power stations. The ambitious plans aim to increase total geothermal installations in East Africa by over 4000 MW within the next decade [33]. However, multiple challenges hinder the progress of geothermal development, such as high upfront costs, insufficient grants for research and drilling, a lack of technological advancements, and a shortage of trained workers. Commercial banks' financial support, particularly during the drilling and exploration phases remains crucial [33]. As shown in Figure 13, the evolution of the geothermal production from 2013 to 2022, the power generation started dropping from 2019 up to now. This can be due to the lack of the investments in that domain. In contrast, from 2013 to 2019 the production was growing every year. This should be an example to base further development on for exploiting the resource since it is still unexploited. Despite these challenges, Africa possesses significant untapped geothermal potential, demanding support in areas like human capital development, technical assistance, and initial research and exploration grants.

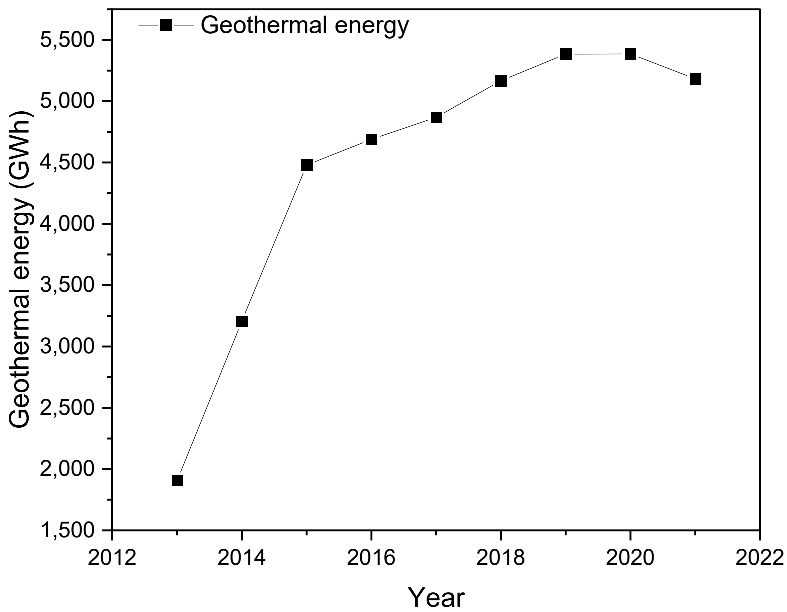

Figure 13. Total geothermal energy produced from 2013 to 2022.

3.5. Bioenergy

Bioenergy is sourced from biomass primarily consisting of recently living organisms, predominantly plants. This form of energy is derived from a variety of sources including wood, food crops such as corn, dedicated energy crops, and a range of waste from forests, yards, and farms. Among these sources, forest bio products like wood waste, agricultural leftovers such as sugar cane byproducts, and residues from animal husbandry like cow dung hold immense promise as fuels for bioenergy plants. The utilization of bioenergy presents numerous benefits not only serving as a renewable resource with the potential to fuel vehicles and heat homes but also for reducing greenhouse gas emissions and providing a sustainable fuel supply for the future. All the forms of bioenergy cited above can be regrouped into bagasse, solid biofuels, liquid biofuels, biogas, etc. The production of each from 2013 to 2022 is shown in Figure 14. It indicates and confirms that biomass (solid biofuel and bagasse) makes up most of the bioenergy used in Africa.

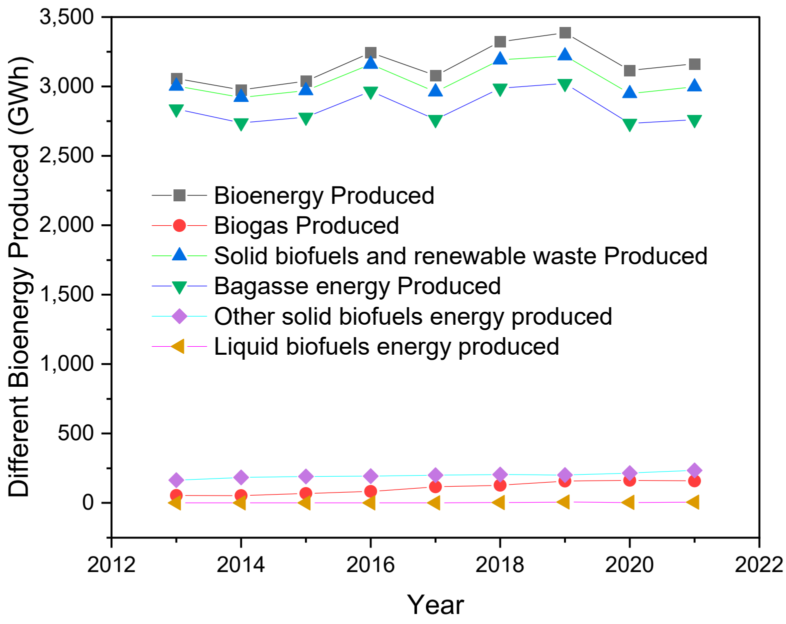

Figure 14. Bioenergy produced in Africa from 2013 to 2022.

Biomass is a prominent renewable energy in Africa, particularly catering to the needs of the economically challenged population. Its consumption patterns and significance across African countries are influenced by factors like access to electricity, available resources, and prevailing renewable energy policies. Despite the region's abundant biomass resources like domestic waste, forest resources, and crop residues, comprehensive data on its exploitable potential remains largely undocumented. The slow adoption of modern renewable energy development the population is often relying on traditional bioenergy exploitation methods. However, studies like that of Dasappa [35] indicated vast power potential. For instance, combining agricultural residues and forest wood could potentially yield up to 15,000 MW, which is equivalent to about 15% of SSA's current electrical capacity. Specific countries like Ghana and Nigeria have shown remarkable biomass potential with Tanzania heavily relying on biomass for its energy needs due to the prohibitive costs of modern energy resources [36]. The energy breakdown in Ghana in 2007 revealed a significant reliance on biomass, while in Uganda there is an unexplored potential from agricultural residues estimated to be around 2600 MW [36].

3.6. Marine-Based Energy

Marine-based energy is an emerging and alternative energy resource where electricity is produced from energy from the ocean, including offshore wind power, tidal energy (the movement of tides), wave energy (the movement of waves), ocean thermal energy (by exploiting the temperature difference between warm surface water and cold deep water), and salinity gradient power (energy from the difference in salinity between freshwater and saltwater). Indeed, offshore wind appears to be the closest-to-market of marine energy technology. According to Bernardino et al. 2017 [37], on Cape Verde island, coastal areas have a higher potential in terms of wave power resources. In the coastal areas neighboring the Cape Verde islands, the wave power is greater than 7 kW/ m. They found that significant differences can be noticed between the two seasons of winter and summer; in the summer time the wave power has a value of around half that in the winter. The potential of ocean energy is very large on island countries like the Union of the Comoros, Madagascar, Mauritius and Seychelles, Cabo Verde, and Democratic Republic of São Tomé and Príncipe. Furthermore, all coastal countries, for example present a potential for exploiting ocean energy. According to Surroop et al. 2018 [38], the southeastern part of Madagascar, Mauritius, and Seychelles is estimated to have a power potential of an average of 15–25 kW/m and at least 7 kW/m is expected in Cape Verde. However, policy mechanisms for enhancing marine energy uptake are nonexistent at this point.

According to Pisacane et al. 2018 [39], offshore wind farms likely represent the most advanced solution when considering the technological maturity of converters alone in the Mediterranean region. They can draw upon the expertise gained over several years from the exploitation of analogues and on the less disturbed winds that are available offshore compared to on-land. Offshore wind turbine technology has essentially followed that of its onshore analogues. Turbines usually consist of three blades rotating around a hub, with rotor diameter well above 100 m and hub height around 100 m, reaching a rotational speed of 10 rpm and nominal power production just below 10 MW, but rapidly increasing as development continues [39]. Their technology is in fact rapidly evolving, and it appears feasible to further upscale individual wind turbines, although problems might still arise from noise and blade erosion [40]. Compared to other forms of ocean energy, offshore wind energy seems to be comparatively more developed from both the technological and environmental point of view. However, offshore wind farms have been fully operative for a relatively short period, and the research on their potential environmental impacts is therefore also limited [39].

4. Renewable Energy Policy Status

The restructuring of electricity in Africa has led to the emergence of various national policy frameworks aimed at promoting distributed electricity generation, particularly in rural areas. These policies in African countries emphasize the adoption of renewable energy sources to enhance power supply reliability, security, and availability aligning with the region's growing population and the need for socioeconomic improvements. Strategies employed to promote renewable energy adoption include renewable energy portfolio standards, private sector involvement in renewable energy investments, and deregulation of the oil and gas sectors to make fossil fuel-based energy less competitive than renewables. Numerous regulatory agencies, private sector entities, and organizations such as the Energy Commission of Nigeria [41], Energy Commission of Ghana, Ghana Energy Development and Access Project, and Capacity Building Project in Energy Efficiency and Renewable Energy in South Africa actively advocate for renewable energy utilization with modern technologies.

However, the implementation of policy reforms in the region has been lacking, casting doubt on the feasibility of achieving universal electricity access by 2030. Despite commendable efforts by governments to diversify their energy resources for improved security and sustainable development, there remains a pressing need to reinforce existing energy policies and potentially introduce new ones to create a favorable environment for renewable energy investors. The region's political instability has hindered the implementation of several policies, which is becoming a significant barrier to financial access and energy market development. Moreover, the lack of well-established policies supporting collaboration between central and local governments further complicates renewable energy planning and execution in the decentralized administrative systems prevalent in many African countries. To overcome these challenges and make substantial progress in renewable energy development, the region must prioritize renewable energy policies implementation and foster cooperation among stakeholders at various levels of government. It is important to make proactive policies to avoid early problems. Waiting to act can make it harder to shift away from fossil fuels and limit chances for connecting different sectors. Policies that do not work well can create more obstacles like transitional or reputational barriers [41].

5. Energy Challenges in Africa and Perspective Recommendations

Core renewable energy technologies are often scarce or poorly sustained in many places in Africa, posing a challenge for sustainable energy adoption. According to Amir et al. (2021) [1], the access of energy in Africa faces many challenges, such as poor technologies and capacity building, unsustainable renewable energy policies, poor financial support and high interest on credit facilities, unstable economies, and low levels of foreign investment.

Addressing the energy needs of African communities requires a strong commitment to developing and continually improving energy generation technologies. While countries like China and India are advancing in renewable energy, Africa as a whole still lags behind in adoption and deployment. International organizations have advocated for reducing electricity access gaps, particularly in SSA, leading to the emergence of regional economic and development groups like ECOWAS, SADC, EAC, CEMAC, and UEMOA. Despite their potential, these regional communities have yet to make significant progress in expanding energy access. Collaboration is essential for disseminating existing renewable energy technologies and transferring emerging innovations. Some targets and projects were settled in many countries in order to boost the renewable energy as presented by Amir et al., 2021 in Table 1 [1].

In this regard, the recommendations are as follows. Africa should accommodate and lower the price of electricity by adding policies on renewable energy so that low-income people can easily access electricity. For lighting, the replacement of incandescent light bulbs with light-emitting diodes (LEDs) and other efficient lights can bring about large energy savings. Towards this end, the cost of LEDs and other efficient lights needs to be reduced to make them more affordable by promoting their large-scale manufacturing. Furthermore, there is a need to promote solar thermal energy for use in hot water applications in Africa. Households, hospitals, hotels, and schools use hot water for different purposes, especially for bathing. It is recommended that efforts already aimed at expanding the use of solar water heaters in the residential or commercial sectors be improved upon, which could be achieved through the provision of financial incentives and customized loans to promote renewables for direct use in Africa. Policies aimed at transport electrification and acceleration of the adoption of electric vehicles (EVs) should be put in place. They should also promote the adoption of solar heating technologies in large industries where there are available spaces to deploy them. It is recommended to improve the affordability of solar irrigation pumps. While solar irrigation pumps are already cheaper than diesel and gasoline pump sets in terms of levelized cost of energy, their initial capital outlay remains relatively higher in Africa [34,41,42]. For example, this scenario makes it challenging for Nigerian farmers, who are predominantly poor and peasant farmers, to purchase solar pump sets as they remain financially disadvantaged [41]. Furthermore, there can be improvement upon existing efforts to promote clean cooking. Around 80% of Nigerians still do not have access to clean cooking facilities [41]. Moreover, accelerating the electrification of end users and promoting policies that would support it could be the way forward. Modernizing the transmission and distribution infrastructure, promoting energy efficiency policies, improving the existing financing mechanisms, and exploring further regulatory options can lead more reliable system in Africa. Finally, the other recommendations are to improve and expand the regulatory framework for decentralized renewable energy solutions, develop a robust database for renewable energy potentials and invest in renewable energy over fossil energy.

Table 1. Targets, projects, and barriers in the energy sector through the process of development and generation in Togo, Ghana, Kenya, Nigeria, and South Africa.

Factor	Key Targets	Incentives Provided to Boost Renewable Energies	Barriers in the Energy Sector through the Process of Development and Generation
Togo	Increasing renewable energy consumption from 10% in 2013; 15% in 2020 to 20% in 2022 [26]	CIZO Project with Individual solar kits and PayGo payment.	No policy in renewable energy. Low technology and high price of PV modules
Ghana	Boosting renewable energy from 2% to 10% by 2020.	Large-scale boosts with help of government initiatives. NGO funds. ECOWAS and ECREE Program.	Slow adoption of solar system technology. No effective framework. Unavailability of fully fledged manufacturing sector.
Kenya	Enhancement of domestic market and indigenous production till 2024. Generating of estimate of 20 GW/year using home solar systems.	Policy framework from government: PPP model for further generation. Solar power use became mandatory for every newly built home. VAT on solar panels removed in 2007.	Low R & D capability to provide job opportunities and tax incentives in the field of renewable energy generation.
Nigeria	To achieve 20% of production using renewable energy by 2030. Target of accounting to 7% using renewable by 2025.	NGO funding. Feed-in tariffs to boost off-grid generation. Economic community of West States (ECOWS), ECREE program.	Lack of awareness among policy makers. Having limited capability to absorb imported technologies. Lack of strong framework and policies.
South Africa	To generate 14% of energy using solar photovoltaic systems till 2050. To achieve 8400 MW using PV systems by 2030.	Government initiatives like tax credits, feed-in tariffs, and capital subsidies. Various renewable energy programs.	Subsidized solar panels from various countries like China, USA, Germany, Spain, and Italy. Lack on return of investment in solar PV system. High initial cost and unavailability of enough schemes at consumer end. Indigenous products are facing huge competition in the market due to imports from China. Increment in wages and lack of skilled labor.

6. Conclusions

We examined the innovative solutions being implemented and emphasized the critical significance of sustainable pathways. The electrification rate in West Africa is less than 58% in urban areas and less than 25% in rural areas. Results show that 65% of the SSA population does not have access to electricity and 81% rely on wood and charcoal. In West Africa, only Ghana (70%) and Cape Verde (95.9%) have equitability access to electricity between rural and urban areas. The potential renewable energies used are hydropower, geothermal, bioenergy, solar power, wind power, and marine-based energy. The potentiality of solar irradiance ranges between 3 and 7 KWh/m^2/day. The wind speed ranges from 3 m/s to 10 m/s. Egypt, Morocco, Ethiopia, Tunisia, and South Africa are, respectively, countries leading in wind power technology. Solar energy technology was more advanced in North Africa and South Africa. Finally, geothermal energy has only been developed in Kenya and Tanzania. Kenya is the leader in that field. However, the rest of the continent is still on a small scale or has not yet implemented those renewable energies. These pathways prioritize not only expanded energy access but also environmental preservation and social inclusivity. Africa has seen significant growth in renewable energy capacity, particularly in solar and wind energy projects. This shift aligns with global efforts to combat climate change and offers the potential for decentralized energy generation. The continent has committed to sustainable energy development through initiatives like the African Union's Agenda 2063. However, the unique challenges faced by different regions were discussed and analyzed. The energy sector in Africa heavily depends on fossil fuels, contributing to environmental degradation indoor air pollution and carbon emissions.

While Africa possesses abundant renewable energy resources, the investment costs for renewable energy projects is relatively high compared to other developed nations. This has impeded the widespread adoption of renewable energy sources. Many African nations face obstacles related to inadequate energy infrastructure, financial constraints, and regulatory frameworks, hindering the transition to cleaner and more sustainable energy sources. Through this review, the recommendation is that Africa needs regional cooperation south–south and south–north, transferring innovations on existing renewable energy technologies through collaboration, prioritizing policy implementation, decentralizing energy systems, enabling electricity generation to have a commodity pricing, and diversifying their energy resources for improved security and sustainable development. Developing proper planning of renewable energy, good governance, strategic investments in energy infrastructure, proper design of mini on- or off-grid solar plants, wind plants, accurate and economical energy management system for different sources of energy, proper cooling of the solar plant, and fabrication of solar modules with better efficiency can be recommended to enhance the reliability and sustainability of energy generation.

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