

ASFAP Energy

Robinson J. Musembi¹, Djouma Kobor², Eric Ofosu³

¹Department of Physics, University of Nairobi, Kenya

²Doctoral School of Science, Technology and Engineering, Senegal

³University of Energy and Natural Resources, Ghana

Africa Energy Needs

1. Introduction

Access to modern energy services is essential to achieving basic social needs by promoting economic development. Modern energy services, particularly electricity and gas, affect productivity, health, education, safe water, and communication [1]. Energy has a significant impact on socioeconomic development in any country because it encourages investment, innovation, and the formation of new businesses that promote the creation of jobs, inclusive growth, and shared prosperity throughout the entire economy [2]. This fact, along with the strong links between energy and the Millennium Development Goals (MDGs), makes it even more important to address the challenges and prospects of energy service provision in Africa. Developing countries' decisions on the growth of their energy sectors will have a significant impact on future energy consumption trends, fuel preferences, trade patterns, and other relevant aspects in addition to their development.

Over the past two decades, Africa has exhibited a significant increase in energy consumption, with a reported 45% increase [3]. However, the energy infrastructure in many areas remains underdeveloped, leaving the demands of the population unmet. Despite the wealth of energy resources available to cater to domestic needs, many countries continue to lack access to modern energy services. Approximately 620 million Africans, which account for two-thirds of the population, do not consume electricity, and a further 730 million rely on traditional biomass for cooking. Even for those with access to energy, the quality and cost of supply are often found to be subpar [3].

The energy sources used in Africa vary from country to country. However, the most commonly utilised energy sources on the continent are oil, coal, natural gas, hydroelectricity, and renewable sources, such as solar, wind, and geothermal power. It is worth noting that the International Energy Agency (IEA) states that Africa possesses 60% of the world's best solar resources, yet only 1% of the installed solar PV capacity. Furthermore, the IEA predicts that solar PV will be the most cost-effective power source in many regions of Africa by 2030.

Affordable and dependable energy are key factors in Africa's economic and social progress. The COVID-19 pandemic has highlighted the importance of a stable energy supply. Without electricity, the measures put in place by the government to contain the virus would have been unbearable. Access to electricity allowed people to work from home, schools continued functioning through online classes, and governments continued their operations (e.g. through virtual court systems). Electricity also facilitated water utilities to continue supplying clean water for handwashing, which was an essential guideline for reducing the spread of the virus[4], [5]. Increased access to affordable and dependable energy can play a significant role in mitigating economic disruptions caused by the pandemic. As countries prepare for economic recovery, African governments must focus on creating more job opportunities and stimulating economic growth. Investing in energy access can help achieve both goals[6].

The transition towards clean energy on a global scale presents promising prospects for the economic and social growth of Africa. As of May 2022, countries committed to achieving net zero emissions

accounted for more than 70% of the century. This includes 12 African nations that contribute to over 40% of the continent's total CO₂ emissions[7]. The commitment of these nations to achieve net zero emissions contributes to the transformation of the global energy sector due to the declining costs of clean technology and shifting global investments. African nations, the majority of which are signatories to the Paris Agreement on Climate Change, are well positioned to benefit from technological advancements and attract increasing amounts of climate finance[6].

For the African government to ensure greater energy access to its population, diversification of energy sources will play a key role, which will include investing in new sources of energy, especially renewables such as wind and solar energy, as well as pooling them together to ensure sufficient supply.

2. Africa energy challenges

Africa faces significant energy challenges, with millions lacking access to reliable electricity. Key points to consider: 1. Energy poverty: Over 600 million people in sub-Saharan Africa lack access to electricity. 2. Renewable potential: The continent has vast untapped renewable energy resources, including solar, wind, and hydroelectric power. 3. Infrastructure gaps: Inadequate power generation and distribution infrastructure hinder economic development. 4. Rural electrification: Off-grid and mini-grid solutions are crucial for reaching remote areas. 5. Energy mix: Many countries rely heavily on fossil fuels, but there's a growing shift towards cleaner energy sources. 6. Investment needs: Substantial funding is required to meet Africa's energy demands and achieve universal access. 7. Policy challenges: Regulatory frameworks and governance issues can impede energy sector development. 8. Regional cooperation: Cross-border energy projects and power pools can enhance energy security and efficiency. 9. Technology adoption: Embracing innovative technologies can accelerate energy access and improve sustainability. 10. Climate considerations: Balancing energy needs with climate change mitigation is a key challenge for the continent. Addressing these issues requires a multi-faceted approach involving governments, international organizations, and private sector investments to ensure sustainable and accessible energy for all Africans.

3. Sources of energy and resources in Africa

Africa is endowed with various resources which meet the energy needs of different countries. Different countries in Africa have different energy mixes as their sources of energy, including

- i. Hydroelectric energy: in Africa, several countries are tapping hydroelectric as part of the source of utility energy, the following are some of the biggest in Africa
 - a. The Grand Ethiopian Renaissance Dam (GERD) – 6,450 MW: Previously known as the Millennium Dam, the Grand Renaissance Dam in Ethiopia–has been under construction since 2011 and is set to become the largest dam on the continent upon completion. Located on the Blue Nile, the dam will generate an estimated 6, 450 MW per year in the Benishangul–Gumuz region near Ethiopia’s border with Sudan.
 - b. Aswan High Dam – 2,100 MW: Located near the city of the same name in southern Egypt, the Aswan High Dam ranks as the continent’s second-largest dam. Built across the Nile, the dam is the largest embankment dam in the world, with a height of 111 m and length of 4,000 m. By powering 12 generators, each at a rate of 175 MW, the dam has a total generation capacity of 2,100 MW.
 - c. Cahora Basa Dam – 2,070 MW: One of the two major dams on the Zambezi River, the Cahora Bassa Dam in Mozambique is the largest hydropower plant in southern Africa. Power was generated through five 415 MW turbines with a combined capacity of 2,070 MW. Most of the power generated by the Cahora Bassa Dam is exported to South Africa through the Cahora Bassa high-voltage direct current (HVDC) line system, with two conversion stations located in Songo, Mozambique, and Apollo, South Africa.

- d. **Gilgel Gibe III Dam – 1,870 MW:** The Gilgel Gibe III Dam located southwest of Ethiopia’s capital, Addis Abeba, is a roller-compacted concrete dam and hydroelectric power plant built on the Omo River. The Gibe III power station forms part of a cascade of dams, including the Gibe I dam, with a capacity of 184 MW, and the Gibe II power station, with a capacity of 420 MW. Plans are currently underway to add Gibe IV and V dams with capacities of 1,472 MW and 560 MW, respectively, to the Gibe Cascade. Currently, during its commissioning process, the future electricity generated by the plant is expected to provide half of its capacity to Ethiopia, with the other half expected to be exported to Kenya (500 MW), Sudan (200 MW), and Djibouti (200 MW). Under the country’s current development plans, Ethiopia has pledged to generate 95% of its energy generation from hydropower.
 - e. **Inga Dams – 1,775 MW:** Comprised of two single dams, the Inga 1 (351 MW) and Inga II (1,424 MW), Dams in the Democratic Republic of Congo (DRC) currently operate at a combined capacity of 1,775 MW. Built on Inga Falls, one of the largest waterfalls in the world, hydroelectric dams currently work at merely half of their potential capacity. The expansion of the dam has generated interest from nations and power companies all over Africa that have expressed interest in the pursuit of a Grand Inga project estimated to cost \$80 billion, which would become the largest power station in the world with a capacity of up to 70 GW.
 - f. **The Kariba Dam, 1,626 MW,** is located between Zimbabwe and Zambia. It is 128 m tall and 579 m long and is the largest man-made dam in the world. Currently, with a total installed capacity of 1,626 MW, the dam is under expansion to increase its yield. Power stations located on the north and south banks of the dam provide Zambia and Zimbabwe with their respective energy sources.
 - g. **Merowe Dam – 1,250 MW:** In terms of its size, with a length of 7km and height of up to 67 meters, the Merowe Dam in northern Sudan is the largest contemporary hydropower project in Africa by size. Situated on the Nile, the hydropower dam consists of 10 turbines, each with a capacity to produce 125 MW for a combined total of 1,250 MW.
 - h. **Tekezé Dam – 1,200 MW:** With a height of 188 meters, the Tekezé Dam in Ethiopia is the tallest dam on the continent. Situated on the Tekezé River, a tributary of the Nile, the \$360 million dam is one of the largest public works projects in the country. The dam’s powerhouse contains four 75 MW turbines, each generating 300 MW of electricity for a combined total of 1,200 MW.
 - i. **Akosombo Dam – 1,020 MW:** Located at the base of Lake Volta, the Akosombo Hydroelectric Dam in southeastern Ghana draws its hydropower from the world’s largest person-made lake in the world, with a surface area of 8,502km². Initially constructed to provide electricity for the country’s aluminum industry, the power plant currently has an installed capacity of 1,020 MW, and provides electricity to Ghana, Togo, and Benin.
 - j. **Kainji Dam – 760 MW:** Built on the Niger River in Nigeria, the Kainji Dam provides electricity to all of the west-African country’s major cities. Despite the intention of designing a dam with an installed capacity of 960 MW, only eight of the proposed twelve turbines have been installed, reducing the capacity of the plant to 760 MW. The Kainji Dam, with a length of 10km, is one of the longest dams in the world.
- ii. **Thermal energy**
Several African countries have thermal energy sources as part of their electricity energy mix. Electricity from thermal energy can be sourced from burning oil, gas, or coal. Here, a few countries are highlighted, where thermal energy as a source of electricity forms a large percentage of their energy source.

- a. Egypt: Egypt is a country in Africa which has achieved remarkable electricity access and distribution in both urban and rural areas. Egypt generates almost all its electricity from fossil fuels, gas, and oil (almost 90% in 2022). This was distributed as 34% from oil, 58% from natural gas, and 7% from coal.

b. Morocco

Morocco has been investing in thermal electricity power generation to meet its growing energy demands. The country relies on a mix of fossil fuel-based thermal power plants, including:

1. Coal-fired power plants: These form a significant portion of Morocco's thermal electricity generation, with major facilities like the Jorf Lasfar power station.
2. Natural gas power plants: Morocco has been expanding its natural gas infrastructure to increase the use of this cleaner fossil fuel for electricity generation.
3. Oil-fired power plants: While less common, some older plants still use oil for power generation.

Key aspects of thermal electricity generation in Morocco:

1. Capacity expansion: The country has been increasing its thermal power capacity to meet rising electricity demand and reduce dependence on imports.
2. Efficiency improvements: Morocco is working on upgrading existing thermal plants to improve efficiency and reduce emissions.
3. Transition to cleaner fuels: There is a gradual shift towards natural gas and renewable energy sources to reduce the environmental impact of thermal power generation.
4. Regional variations: Thermal power plants are strategically located near industrial centres and areas with high electricity demand.
5. Integration with renewables: Morocco is developing a balanced energy mix, combining thermal power with renewable sources like solar and wind.
6. Environmental considerations: The country is implementing measures to mitigate the environmental impact of thermal power generation, including emissions control technologies. While thermal electricity generation remains crucial for Morocco's energy security, the country is also actively pursuing renewable energy projects to diversify its power sources and reduce carbon emissions.

c. Tunisia

Tunisia's thermal electricity power generation primarily relies on natural gas and oil-fired power plants. The country has been working to diversify its energy mix and reduce dependence on fossil fuels. Key points about thermal electricity generation in Tunisia:

1. Dominant energy source: Natural gas accounts for the majority of thermal power generation, followed by oil.
2. Major power plants: El Bibane, Rades, and Sousse are among the largest thermal power plants in Tunisia.
3. Challenges: - Increasing energy demand - Aging infrastructure - Reliance on imported fossil fuels - Environmental concerns
4. Efforts to improve efficiency: - Upgrading existing power plants - Implementing combined-cycle technology - Exploring cogeneration options
5. Transition towards renewable energy: - Tunisia aims to increase renewable energy share to 30% by 2030 - Developing solar and wind power projects to complement thermal generation
6. Regional cooperation: - Participating in the Mediterranean Electricity Ring (MEDRING) project - Exploring potential electricity exchanges with neighboring countries
7. Future outlook: - Gradual shift towards cleaner energy sources - Continued investment in modernizing thermal power infrastructure - Integration of smart grid technologies for improved efficiency and management

d. South Africa

Thermal electricity generation plays a crucial role in South Africa's power sector, with coal as the primary fuel source. The following are the key points regarding thermal power generation in South Africa.

1. Coal dominance: South Africa relies heavily on coal-fired power plants, which account for approximately 80% of its electricity generation.
2. Major power stations: Eskom, a state-owned utility, operates several large coal-fired power plants, including Medupi, Kusile, and Matimba.
- 3.

Environmental concerns: Heavy reliance on coal has led to significant environmental challenges, including high carbon emissions and air pollution. 4. Aging infrastructure: Many of South Africa's thermal power plants are aging, which leads to maintenance issues and reduced efficiency. 5. Energy crisis: South Africa has experienced frequent power shortages and load shedding owing to insufficient generation capacity and maintenance problems. 6. Diversification efforts: The country is working to diversify its energy mix by incorporating more renewable sources such as solar and wind power. 7. Cleaner coal technologies: South Africa is exploring cleaner coal technologies including supercritical and ultra-supercritical power plants to reduce emissions. 8. Gas-to-power initiatives: There are plans to increase the use of natural gas for electricity generation to reduce the reliance on coal. 9. Independent Power Producers (IPPs): The government has introduced programs to encourage private sector participation in power generation, including thermal and renewable projects. 10. Just Energy Transition: South Africa is developing plans for a gradual transition from coal to cleaner energy sources while addressing socio-economic impacts on coal-dependent communities. 11. Grid stability: Thermal power plants play a crucial role in maintaining grid stability as South Africa integrates more variable renewable energy sources. 12. Water scarcity: Many thermal power plants in South Africa face challenges related to water availability because they require significant amounts of water for cooling. To address these challenges and promote sustainable energy development, South Africa is focusing on balancing thermal energy generation with renewable sources, improving energy efficiency, and modernising its power infrastructure.

e. Algeria

Algeria relies heavily on thermal electricity generation, primarily using natural gas as the main fuel source. The country's power sector is dominated by fossil fuels, with thermal power plants accounting for the majority of electricity production. Key points about thermal electricity generation in Algeria include: 1. Natural gas dominance: Algeria's abundant natural gas reserves are the primary fuel for thermal power plants, contributing to over 90% of the country's electricity generation. 2. Combined cycle plants: Many of Algeria's thermal power plants use combined cycle technology, which increases efficiency by utilizing both gas and steam turbines. 3. Geographical distribution: Thermal power plants are strategically located across the country to meet regional energy demands, with major facilities in cities like Algiers, Oran, and Annaba. 4. Capacity expansion: The Algerian government has been investing in expanding thermal power generation capacity to meet growing electricity demand and support economic development. 5. Environmental concerns: While thermal power generation has been crucial for Algeria's energy sector, it contributes to greenhouse gas emissions and air pollution, prompting discussions about diversifying the energy mix. 6. Modernization efforts: Algeria is working on upgrading and modernizing existing thermal power plants to improve efficiency and reduce environmental impact. 7. Integration with renewable energy: The country is exploring ways to integrate thermal power generation with renewable energy sources, such as solar and wind, to create a more balanced and sustainable energy portfolio. 8. Export potential: Algeria's thermal power generation capacity also supports its ability to export electricity to neighboring countries, contributing to regional energy security. To address future energy challenges, Algeria is considering diversifying its energy mix while continuing to leverage its natural gas resources for thermal electricity generation.

f. Gabon

Gabon's thermal electricity power generation primarily relies on fossil fuels, particularly oil and natural gas. The country's electricity sector is dominated by thermal

power plants, which account for a significant portion of its total electricity production. Key points about thermal electricity generation in Gabon: 1. Fossil fuel dependency: Gabon heavily relies on oil and natural gas for its thermal power generation, leveraging its abundant hydrocarbon resources. 2. Main power plants: The country's largest thermal power plants are located in Libreville, Port-Gentil, and Franceville, supplying electricity to major urban areas and industrial zones. 3. Capacity: Thermal power plants contribute the majority of Gabon's installed electricity generation capacity, complementing hydroelectric sources. 4. Environmental impact: The reliance on fossil fuels for thermal power generation contributes to greenhouse gas emissions and environmental concerns. 5. Diversification efforts: Gabon is exploring ways to diversify its energy mix, including investments in renewable energy sources like solar and hydropower to reduce dependence on thermal generation. 6. Challenges: Aging infrastructure, limited transmission networks, and the need for increased capacity to meet growing demand are some challenges facing Gabon's thermal power sector. 7. Future outlook: The government is working on modernizing and expanding its thermal power generation capabilities while also promoting cleaner energy alternatives to ensure a more sustainable and reliable electricity supply. To improve energy security and reduce environmental impact, Gabon may need to consider further diversifying its energy mix and investing in more efficient thermal power technologies.

iii. Wind power

Wind power electricity generation in Africa has significant potential but remains largely untapped. Key points to consider: 1. Resource potential: Many African countries have favourable wind conditions, especially in coastal and mountainous regions. 2. Current status: Wind power capacity in Africa is growing but still limited compared to other continents. 3. Leading countries: Egypt, Morocco, and South Africa are at the forefront of wind energy development in Africa. 4. Challenges: - Limited infrastructure and grid connectivity - High initial investment costs - Lack of technical expertise and skilled workforce - Political and economic instability in some regions 5. Benefits: - Clean, renewable energy source - Potential for rural electrification - Job creation and economic development - Reduced dependence on fossil fuels 6. Future prospects: - Increasing government support and policies promoting renewable energy - Growing interest from international investors and development agencies - Technological advancements making wind power more cost-effective 7. Notable projects: - Lake Turkana Wind Power Project in Kenya - Tarfaya Wind Farm in Morocco - Jeffreys Bay Wind Farm in South Africa To fully realize the potential of wind power in Africa, continued investment, policy support, and capacity building will be crucial.

iv. Solar power

Solar farms for electricity generation in Africa present a promising solution to address energy needs across the continent. Key points to consider: 1. Abundant solar resources: Many African countries receive high levels of solar radiation year-round, making them ideal for solar power generation. 2. Scalability: Solar farms can be built to various sizes, from small community projects to large utility-scale installations. 3. Reduced reliance on fossil fuels: Solar power can help decrease dependence on imported fossil fuels and reduce greenhouse gas emissions. 4. Rural electrification: Off-grid solar solutions can bring electricity to remote areas without extensive infrastructure. 5. Economic benefits: Solar projects can create local jobs and stimulate economic growth. 6. Decreasing costs: The price of solar technology continues to fall, making it increasingly competitive with traditional energy sources. 7. Challenges: Initial investment costs, land availability, grid integration, and maintenance in harsh environments need to be addressed. 8. Policy support: Governments can encourage solar farm development through favorable regulations and incentives. 9. Technology transfer: Partnerships with

international organizations can facilitate knowledge and technology transfer. 10. Environmental considerations: Proper planning is necessary to minimize potential negative impacts on local ecosystems and land use. Implementing solar farms in Africa requires careful planning, investment, and collaboration between governments, private sector entities, and local communities to maximize benefits and overcome challenges.

v. **Geothermal energy**

Geothermal energy is one of the most reliable renewable energy sources and some countries have invested heavily in tapping this type of energy. Geothermal energy presents a promising renewable resource for electricity generation in Africa, particularly in countries along the East African Rift System. Key points to consider: 1. Potential: The East African Rift System offers significant geothermal potential, with countries like Kenya, Ethiopia, and Tanzania having substantial resources. 2. Current development: Kenya leads in geothermal electricity production in Africa, with the Olkaria geothermal field being a major contributor. 3. Advantages: - Clean, renewable energy source - Baseload power capability (24/7 operation) - Low operational costs after initial investment - Minimal land use compared to other renewable sources 4. Challenges: - High upfront costs for exploration and drilling - Technical expertise requirements - Environmental concerns (e.g., water usage, potential seismic activity) - Limited grid infrastructure in some areas 5. Future prospects: - Increased investment in geothermal projects across East Africa - Potential for power export to neighbouring countries - Technology transfer and capacity building initiatives 6. Policy considerations: - Government support through favourable policies and regulations - International partnerships for funding and technical assistance - Integration of geothermal energy into national energy strategies 7. Environmental impact: - Reduced greenhouse gas emissions compared to fossil fuels - Careful management of water resources and potential land subsidence 8. Economic benefits: - Job creation in construction, operation, and maintenance - Reduced reliance on imported fossil fuels - Potential for industrial applications (e.g., agriculture, manufacturing) To fully leverage geothermal resources for electricity generation in Africa, continued investment, capacity building, and supportive policies will be crucial.

4. Energy pooling in Africa

African countries have been endowed with different energy resources such as hydropower, geothermal energy, solar energy, and fossil fuels. African countries are collaborating to enhance energy access across borders by pooling their resources. Sub-Saharan Africa (SSA) faces substantial energy supply and distribution deficiencies while having access to both renewable and non-renewable energy sources. Approximately 600 million people, accounting for 57% of the total population, lack access to electricity, with 80% of them residing in rural regions (Grosse Puppenthal et al., 2017). This shortage increases the expenses of efficient economic endeavours, impeding sustainable and comprehensive growth. Moreover, individuals who have access to power frequently encounter expensive rates for unstable and inadequate provision (Woolfrey 2016). Consequently, people and businesses depend on costly, non-renewable, and fuel-consuming generators. This reliance can make entire industries and manufacturing sectors less competitive, impede job creation, and reduce yearly GDP growth by 1-3 percentage points (Woolfrey 2016:33). The main obstacles related to insufficient energy generation and ineffective distribution systems continue.

Enhancing electricity generation and transmission within African countries is necessary. Additionally, promoting cross-border trade in electric power can efficiently link surplus capacity in one area with high demand in another. Establishing a regional power market enables countries to engage in regional energy cooperation, theoretically.

African power pools are regional electricity networks that connect multiple countries to facilitate the sharing and trading of electricity across borders. These pools aim to improve energy security, reliability, and affordability by leveraging the diverse energy resources and generation capacities of participating nations. The main African power pools are: 1. Southern African Power Pool (SAPP): Established in 1995, it includes 12 countries in Southern Africa. 2. West African Power Pool (WAPP): Created in 2000, it comprises 14 countries in West Africa. 3. East African Power Pool (EAPP): Formed in 2005, it includes 11 countries in East Africa. 4. Central African Power Pool (CAPP): Established in 2003, it consists of 10 countries in Central Africa. 5. North African Power Pool (NAPP): Also known as COMELEC, it includes five countries in North Africa. These power pools offer several benefits: 1. Enhanced energy security through diversified power sources 2. Improved grid stability and reliability 3. Reduced overall system costs through economies of scale 4. Increased renewable energy integration 5. Promotion of regional cooperation and economic integration Challenges facing African power pools include: 1. Inadequate transmission infrastructure 2. Regulatory and policy harmonization across countries 3. Political instability and security concerns 4. Limited financial resources for large-scale projects 5. Technical capacity and skills gaps To address these challenges and maximize the potential of African power pools, stakeholders are focusing on: 1. Investing in cross-border transmission infrastructure 2. Harmonizing regulatory frameworks and policies 3. Strengthening institutional capacity and governance 4. Attracting private sector investment 5. Promoting renewable energy integration and regional energy planning As African power pools continue to develop, they have the potential to significantly improve energy access, affordability, and sustainability across the continent. African countries have established power pools to pool energy resources together for mutual benefits, these include: The south African Power Pool (SAPP), West African Power Pool (WAPP), East African Power Pool (EAPP), and Comité Maghrébin de l'Electricité (COMELEC- Maghreb Electricity Committee) for North Africa.

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