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Functional Power Trade Key to Achieving Universal Access to Sustainable Energy Services in Sub-Saharan Africa Region

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ABSTRACT

Sub-Saharan Africa (SSA) is one of the most energy-poor regions in the world. Out of the about 1.1 billion people without access to electricity worldwide, about 621 million live in Sub-Saharan Africa (SSA). Fossil fuel accounts for approximately seventy percent of the power consumed in the region, particularly coal and gas. Yet, Sub-Saharan Africa has vast, diverse, and geographically distributed renewable energy resources. These resources include technical potentials of 1000 GW solar PV, 20 GW of geothermal resources, 350 GW of hydropower resources, 400 GW of gas resources, and an estimated 109 GW of wind resources. Currently, the SSA region faces the challenge of meeting the goal of achieving universal energy access while limiting greenhouse gas emissions. To achieve this goal, the SSA region needs to focus on accelerating the development of renewable energy resources, a move that will necessitate economic and environmental trade-offs. To harness renewable energy resources economically, the region requires to adopt a collaborative development approach through expanding cross-border power transmission lines and enhance regional power trade. The collaborative approach can be fast-tracked through the operationalization of the four existing regional power pools. The four power pools include the Eastern Africa Power Pool (EAPP), the Western Africa Power Pool (WAPP), the Central African Power Pool (CAPP) and the Southern Africa Power Pool (SAPP). The power pools will allow countries to aggregate resources and extend grids across national borders, capitalizing on regional diversity in renewable energy resources and demand. Currently, approximately 7% of electricity is traded in the SSA region, mainly through the Southern Africa Power Pool. Fully functional regional power pools have the potential to save the region an estimated value of US$50 billion in capital investment required to meet the current energy access gap.

1. INTRODUCTION

Universal access to modern energy services is critical in addressing some of the world´s development challenges. These challenges include poor health services, poor quality of education, high poverty levels, the risks associated with climate change, food insecurity, and gender disparities, among others (Bazilian et al., 2012). These challenges are most rampant in developing countries, where they are likely to persist if the current rate of annual increase to energy access remains unchecked. Some of the factors affecting the attainment of universal access to modern energy services in developing countries include ineffective government energy planning institutions, inappropriate legal and regulatory frameworks, inadequate technical and financial mechanisms, lack of transparent governance, and corruption, among others (Bazilian et al., 2012). Currently, there are 1.1 billion people in the world without access to modern energy services, particularly electricity. Out of this, approximately 621 million live in Sub-Saharan Africa (SSA).

Contrary to the high energy poverty levels experienced in the SSA region, the region has vast and geographically distributed renewable energy resources capable of meeting its population's current and future energy demands (Avila et al., 2017). The renewable energy resources potential is well documented in Cartwright (2015), Castellano et al. (2015), and Omenda (2018), among others. The SSA region lies between the tropics, hence, it is home to a vast amount of solar energy resource potential distributed in all the countries in the region. The long coastal shoreline of the SSA region and semi-arid conditions found in some of the countries in the region are the source of the region's wind energy resources, which are distributed across various countries. The SSA is home to the River Nile and the Congo River, hence, there is a high hydro energy resource potential mainly located in the Eastern, Western, and Central Africa. Geothermal resource potential is confined in countries through which the East Africa Rift Valley transects. Additionally, the region is endowed with fossil fuel energy resources, for example, gas and coal deposits in the Western, Eastern, and Southern Africa, which can be harnessed using clean technologies to leverage the full adoption of the variable renewable energy resources.

With the enactment and adoption of the Sustainable Development Goals (SDGs) and the United Nations Framework Convention on Climate Change (UNFCCC) by the United Nations, the SSA region faces the challenge of meeting its population´s energy demand while limiting the Green House Gas (GHG) emissions. To achieve this, the SSA energy decision-makers, stakeholders, and governments will need to make deliberate efforts to develop the existing renewable energy resources. Harnessing renewable energy resources requires substantial capital investment. In developed countries, integrated energy markets have proved the potential to substantially reduce the investment costs necessary to meet the energy demand and improve the quality of energy services (Oseni, 2014). Examples of such markets include the Energy Community of southeast Europe (ECSEE), the Single Energy Market (SEM) of Ireland, the Nord Pool, and the Pennsylvania New Jersey Maryland Interconnection (PJM) of the United States, among others. Currently, there are efforts to have integrated energy markets in the SSA region but with varying levels of commitment and effort.

These efforts are being made through the four power pools, which include the South African Power Pool (SAPP), West African Power Pool (WAPP), Central African Power Pool (CAPP) and the East African Power Pool (EAPP). SAPP is the oldest power pool, while CAPP is the most recently formed power pool. Despite the existence of these power pools, there is very little integration of the transmission network across countries. The existing integration is limited to the old bi-lateral agreements done between countries. Considerable efforts have been made to integrate the SAPP transmission network and enhance power trade yet, only 7% of electricity is traded in this power pool (Avila et al., 2017).

The diversity, vastness, and geographical distribution of the renewable energy resources in SSA provide an excellent opportunity for an integrated regional electricity market. The SSA region´s energy decision-makers and governments should leverage this opportunity and fast track the expansion of integrated transmission networks to enhance regional power trade. Regional power trade can be implemented through the adoption of a collaborated development plan by the countries of the region. The collaborative development can be modeled within the objectives of the existing four regional power pools. A collaborative development approach has the potential to reduce the capital investment required to meet the current and future electricity demand. Furthermore, it has the potential to increase the share of renewable resources in the regional energy mix, reduce regional carbon emissions, enhance the region´s power system stability and improve the quality of energy services (Oseni, 2014). This paper seeks to review how the SSA region can leverage on the power trade to attain universal to modern energy services for its population. The rest of the article is divided into three sections. Section 2 will review the energy challenges facing the SSA region. Section 3 presents the available energy resource potential for the SSA region, Section 4 shall discuss the SSA region´s power pools, discussion and conclusion will be in Section 5 and 6, respectively.

2. ENERGY CHALLENGES FACING SUB-SAHARAN REGION

Various researchers have highlighted the energy challenges that plague SSA, for example, Musonye et al., (2020) Carvallo et al., (2017), Avila et al., (2017), Onyeji et al., (2012), Hancock, (2015), Brew-Hammond, (2010) and Prasad, (2011), among others. These challenges are highlighted as low access rates, demand-supply mismatch, overreliance on fossil fuel, technical inefficiencies and inadequate financial investment, inefficient policy framework, and poor planning, among other challenges. These challenges have had the effect of slowing down economic growth, hence an increase in poverty levels in the region (Szabó et al., 2013).

2.1 Low access rate

There is a glaring disparity in levels of energy access rates among SSA countries, as well as between the urban and rural areas in a country. Some countries, for example, South Sudan and Burundi, have access rates in single digits, whereas the small island states of Mauritius and Seychelles have energy access rates of 100 percent (Morrissey, 2017). Secondly, rural areas in the SSA region are associated with a low average access rate of 15% as compared to the urban average access rates of about 43% (IEA, 2017). Approximately 70% of the SSA population lives in distributed remote rural communities. The majority of this population mainly practice subsistence farming and live on less than a dollar per day. The high electricity connection fee and tariff costs are unfordable for a majority of this population. Hence, the grid extension to the rural communities is uneconomical for the utilities **(**Murenzi & Ustun, 2015 & Azoumah et al., 2011). Furthermore, the SSA region has a high inequality in wealth distribution, with more than half of the population living on less than 2 US dollars per day. With such low income, electricity is regarded as a luxury. Hence, families do not strive to pay for the connectivity fee, which is generally high. In some countries, for example, Kenya, the government has initiated various programs to enhance connectivity to low-income families (MoEP, 2020). However, those low-income families connected through government programs do not consume electricity due to the high electricity prices. They prefer to use cheap biomass and kerosene for cooking and lighting (Taneja, 2018). On the contrary, consumers who are connected and are capable of paying are subjected to load shedding, epileptic supply, and constant blackouts. This relates to inadequate generation capacity, which fails to meet grid demand, and the absence of proper grid infrastructure to efficiently deliver generated power to the consumers (Avila et al., 2017). The low levels of annual investments in power generation expansion, which is outpaced by the rate of population growth in the region, have further exacerbated the challenge of inadequate capacity (Brew-Hammond, 2010).

2.2 Demand-Supply mismatch

A secure and reliable energy system must be able to respond to changing demand conditions to meet consumers´ energy needs in real-time and space (Golay, 2010). The demand-supply mismatch in SSA countries has adversely affected energy prices and reliability. With peak demand occurring for a few hours in the evening throughout the year (Avila et al., 2017), daytime is characterized by overcapacity, while a strain on the power system typifies evenings. Some of the previous studies have shown that idling capacity, particularly for power markets with PPA arrangements, leads to higher electricity tariffs, for example (CEC, 2020), (Simshauser, 2014) and (Denholm et al., 2015). This mismatch has forced most of the urban population, firms, and commercial enterprises to purchase emergency self-generation generators. The self-generation units have increased the cost of production as well as environmental degradation. Besides, the investment in diesel generators to meet the grid demand has rendered countries, for example, Kenya, Djibouti, Gabon, Nigeria, and South Africa, among others, with the high cost of energy (Carvallo et al., 2017); (Trollip et al., 2014) and (Aliyu et al., 2016). The generation of power from variable power sources has not helped matters. There is a mismatch between the peak generation from variable sources, such as solar and wind, and peak demand periods. The demand-supply mismatch with its repercussions is a common occurrence in most, if not all, of the SSA countries (Chakamera and Alagidede, 2018), (EXIM BANK, 2017) and (Avila et al., 2017).

2.3 Overreliance on fossil fuel

Over 70 percent of the SSA energy supply comes from fossil fuel, while 20 percent comes from renewable sources (Avila et al., 2017). The fossil fuels used for power generation include coal, natural gas, and oil. The diversity of the primary sources of an energy system is one of the significant aspects used to measure the energy security of a given energy system. An energy system that over depends on one mode of generation, mainly imported fossil fuels, is prone to energy security shocks. Fossil fuels are susceptible to international price variations and exhaustion. The fossil fuel price uncertainty has a significant impact on the economic viability of electricity production. Moreover, countries that are locked into fossil fuel-run electricity generation technologies for decades faces the risk of stranded assets whose operation is subject to affordable fuel envisioned during installation, and the availability of the fuel.

Additionally, studies, for example (Ngö & Natowitz, 2016) and (Richards, 2016), have shown that the burning of fossil fuel impacts negatively on the global climate. Negative climate impacts, for example, global warming, can result in the rise of sea-level, increase in exposure to disease, and exacerbate drought and flood events. Challenges of overreliance on fossil fuel for energy production by most of the SSA countries have been profoundly felt in countries such as Nigeria and South Africa, which are leading in the region in the use of fossil fuel for energy generation. Nigeria´s total installed capacity of 12,522 MW is dominated by fossil fuel, which consists of 86% of this generation. Out of this installed capacity, only 7,141 MW is available (Ayobami et al., 2018). Despite the country being among the major oil and gas producers in the world, the low net capacity relates to the inadequate supply of oil and gas (Aliyu et al., 2016). The inadequate supply is occasioned by attacks on pipelines and oil theft in the oil-producing Niger Delta region. The limited supply of oil has resulted in stranded generation assets hence, loss of revenue.

South Africa, on the other hand, has a total installed capacity of about 47,000 MW, of which more than 80% is from coal (Eskom, 2018). The purchase cost of electricity has been relatively inexpensive in the past as a result of South Africa‘s government subsidies on electricity generated by coal power plants (Dekker et al., 2012). In 2012, the government reduced the subsidies extended to the electricity generated from coal. Consequently, Eskom introduced an annual tariff review to carter for the escalating cost of production. Furthermore, Eskom has been facing challenges with coal stocks as the cost of coal production soars due to the aging of the mining sites (Jeffrey et al., 2017). The high coal production costs have resulted in an inadequate generation unable to meet South Africa’s growing demand. Accordingly, consumers have been subjected to load shedding, blackouts, and power rationing. Besides, the tariff review and escalating cost of coal production have resulted in an escalation of electricity prices. This situation has reduced power consumption as many consumers resort to the use of solar photovoltaic. Hence, exposing Eskom to losses and financial crisis (Pollet et al., 2015).

2.4 Technical inefficiencies and inadequate financial investments

SSA still relies on an aging conventional power infrastructure inherited from the colonial governments. The energy infrastructure in SSA countries was constructed to serve the conventional, and centralized power generation system (Avila et al., 2017). The infrastructure lacks the modern capacity essential for handling efficient distant transmission, intermittent generation, and surges in power demand. The aging infrastructure has, therefore, subjected the population to constant power outages, load shedding, deployment of emergency diesel generators, increased the cost of production, and retarded economic growth (Eberhard & Shkaratan, 2012). The system loses in SSA, for instance, are double the world average with regions average transmission and distribution losses estimated at 20 percent (IEA, 2019). These losses increase the generation capacity required to meet load, exposing power utilities to financial risks, and increasing end-user tariffs (Castellano et al., 2015). The expansion and modernization of the power infrastructure require high capital investment. The SSA region has recorded the lowest annual investment in energy expansion program in the whole world. Only 0.5 percent of the region’s annual gross domestic product (GDP) goes to energy expansion (Zyl, 2015). This investment is quite dismal compared to the proposed 4 percent required if SSA is to achieve universal access to modern energy services by its population by 2050 (Panos et al., 2016).

2.5 Inefficient Policy Framework and poor planning

Well formulated policies and supporting institutions play a critical role in shaping the future of any sector of any given economy (Murenzi & Ustun, 2015). In SSA, energy policies have failed to address topical issues such as proper planning for demand, energy security, environmental protection, sustainability, power sector capacity management, financing of power expansion, and user protection through workable tariffs and monitoring schemes (Mohammed et al., 2013). This failure has had an overall impact of the low rate of access, the high cost of energy, unreliable supply, overall inefficient energy system and a generally negative effect on the economic growth of the region. As of 2016, countries such as DRC did not have an existing elaborate Energy White Paper, which outlined the policy framework for energy supply and demand (Lukamba-Muhiya & Uken, 2006). Consumers in countries such as Kenya have had to incur increased electricity charges as a result of inefficient power planning. For instance, Lake Turkana Wind Power generation plant saw the government-owned Kenya Power and Lighting Company (KPLC) pay for the Deemed Generation costs after delays in the completion of the transmission line. Furthermore, Lake Turkana wind power has resulted in the idling of diesel generators, which had earlier signed a pay-or-take PPA agreement with the government. Hence, the government is expected to pay for the diesel generation‘s idling capacity. All these costs are passed down to consumers through electricity tariff adjustments.

An optimal combination of supply, transmission, storage, and demand-supply efficiency of energy is critical for stimulating resource development and fueling economic growth. Such an optimal combination can only be achieved through the proper use of energy planning tools to evaluate the impact of policies on the cost of different generation expansion pathways and how these pathways fit in the future demand-supply forecast. Currently, SSA energy planning lacks proper and efficient application of energy planning tools, for example, policy simulation modeling platforms, demand-supply expansion optimization models, and the grid, off-grid integrated energy models, among others. Energy investment decisions are politically driven, and energy models are either not used, flawed, or non-transparent (Musonye et al., 2020). The lack of energy modeling tools application has resulted in constant energy accessibility challenges in the region.

3. ENERGY RESOURCE POTENTIAL FOR SUB-SAHARAN AFRICA REGION

Many researchers have documented the energy resources potential in the SSA, for example, (Cartwright, 2015), (Castellano et al., 2015), (WEC, 2016), (Avila et al., 2017), (U.S EIA, 2018) and (IEA, 2018), among others. The total energy resource potential in the SSA region is estimated to be 11 terawatts (Castellano et al., 2015). This includes both renewable and fossil fuel resource potential. Figure 1 shows the regional distribution of renewable resources potential in terawatt hours.

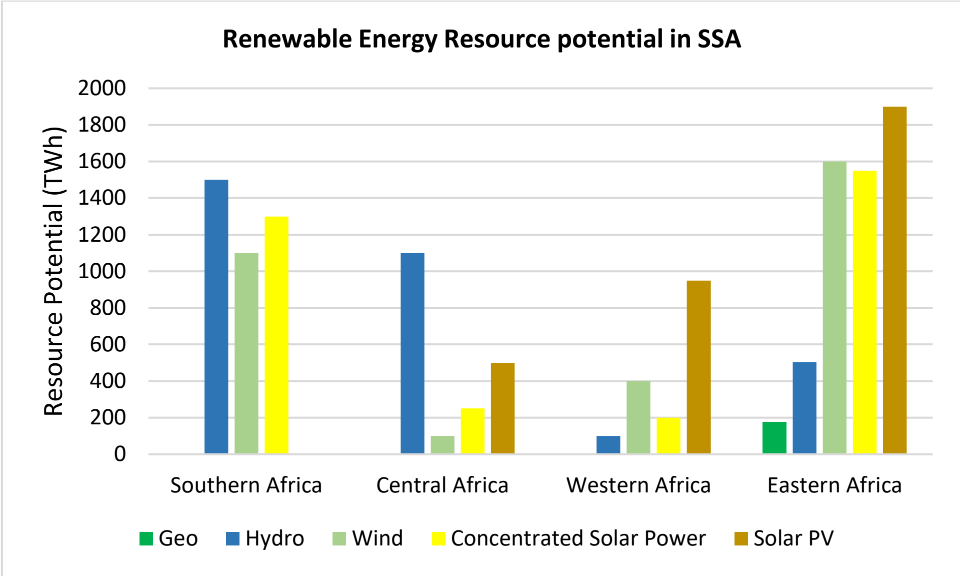

Figure 1: Distribution of renewable energy resource potential in SSA (Data from Cartwright, 2015; WEC, 2016; Hafner et al., 2018; Omenda, 2018 & IRENA, 2018. Analysis by the author).

3.1 Renewable energy resources

The renewable energy resources found in the SSA region include hydropower, geothermal, wind, and solar. The SSA region has a feasible technical hydropower potential of 350 GW. The hydropower potential is found in Ethiopia, the Democratic Republic of Congo, Angola, Cameroon, and Gabon (Castellano et al., 2015). This resource is located within the two main regional drainage basins, that is, the Nile basin, which is drained by the River Nile with its tributaries, and the Congo River basin drained by the Congo River and its tributaries. The technical solar resource potential is estimated at 525 GW for solar photovoltaic (solar PV) and 475 GW for concentrated solar power (CSP) (Hafner et al., 2018). The solar resource potential is distributed in all countries across the SSA region. The SSA region has a long coastal shoreline and semi-arid conditions found in some of the countries in the region. As a result, the technical wind resource potential is 109 GW. This resource is distributed in various countries across the region. There is an estimated technical geothermal potential of 20 GW (Omenda, 2018). This potential is confined in countries through which the East Africa Rift Valley transects. The Kenyan Rift Valley is a host to 10 GW of this potential, and the Ethiopian Rift Valley is a host to 7 GW, the Tanzanian and Ugandan Rift Valleys are hosts to an estimated potential of 650 MW and 450 MW, respectively (Mnjokava et al., 2015 & Omenda, 2018). The rest of the geothermal resource potential is distributed in Djibouti, Eritrea, Rwanda, Comoros, Zambia, and Burundi (Omenda, 2018). Out of the total technical renewable energy resource potential existing in the SSA region, only 9% hydro, 4% geothermal, 4% wind, and 0.5% of wind power resources have been harnessed for power generation as of December 2018. The percentage installed solar capacity might be higher since most of the installed solar stand-alone systems' capacity is not documented.

3.2 Fossil fuel energy resources

Apart from renewable energy resources, SSA is endowed with fossil fuel resources, some of which can be harnessed using clean technology to leverage the abundant variable renewable energy resources found in the region. The estimated technical coal reserve potential is 300 GW. The coal reserves are located in South Africa, Botswana, and Mozambique (Castellano et al., 2015). Natural gas has an estimated technical reserve potential of 400 GW and is mainly distributed in Mozambique, Tanzania, Nigeria, South Africa, and Mauritania (WEC, 2016; U.S EIA, 2018 & IEA, 2018). Out of this total reserve potential, very little has been harnessed to generate electricity. By the end of 2018, out of the sum available technical gas and coal potential, only 2% and 17%, is used to generate electricity, respectively. The SSA region has a substantial amount of oil reserves. Nigeria, Angola, and Congo Brazzaville are among the world's top oil producers. In 2016, Nigeria was ranked the 13th largest oil-producing country in the world, with 2.35 million barrels per day. In the same year, Angola´s oil production was 1.82 million barrels per day, while Congo Brazzaville had 277,000 barrels per day (OPEC, 2017).

4. REGIONAL POWER POOLS

Currently, the SSA region has four power pools that link states in Eastern, Western, Southern, and Central Africa, respectively (Saadi et al., 2015). They include the Southern Africa Power Pool (SAPP), the West African Power Pool (WAPP), the East African Power Pool (EAPP), and the Central African Power Pool (CAPP). These power pools were established through the signing of respective Inter-government Memoranda of Understanding. The power pools are tasked with the creation of an integrated regional energy market to balance supply and demand (Sebitosi & Okou, 2010). The regional energy market within the power pools is expected to reduce the capital and operating costs through a coordinated generation and transmission expansion, improve power system reliability through increased inter-country electricity exchange, enhance the security of supply through mutual assistance, and optimize the limited financial resources dedicated for generation expansion by each country through collaborative construction of bigger generation units.

The Power trade in SSA began in the form of a bilateral agreement between Congo and Zambia in the 1950s (AfDB, 2013), followed by Zambia and Zimbabwe in the 1960s (Sebitosi & Okou, 2010). Other bilateral agreements followed in various parts of the region until the development of the first power pool in April 1995, that is, the Southern Africa Power Pool (SAPP) (AfDB, 2013). SAPP formation was necessitated by the increasing shortfalls in electricity supply in SSA countries in the mid-1980s, a situation that was impacting negatively on the cost of living and economic development (Sebitosi & Okou, 2010). The SAPP membership consists of power utilities and Independent Power Producers (IPPs) from the twelve member states that form the South African Development Community (SADC) (SAPP, 2018). The twelve-member countries include the Republic of South Africa, Swaziland, Tanzania, Zambia, Zimbabwe, Namibia, Mozambique, Malawi, Lesotho, Angola, Botswana and the Democratic Republic of Congo (see Figure 2). So far, SAPP is the only operational power pool in SSA under which there is active electricity trade among some of its member states. In 2009, SAPP initiated the competitive energy market in the form of a Day-Ahead Market (DAM) (ICA, 2016). In the year ending 2017, SAPP member total installed capacity stood at 67,190 MW (SAPP, 2019). The total operating capacity in the same year was 60,719 MW, while traded electricity on the SAPP market was 2,124 GWh for the financial year 2017/2018. There are various generation projects slated between 2018 to 2022 that will result in an additional 26,108 MW to the grid. Furthermore, there are several transmission projects at different levels of progress aimed at easing congestion and reducing technical losses (SAPP, 2019). To further enhance inter-regional power trade, SAPP sourced and secured funding from the World Bank to initiate studies for the SAPP-EAPP Transmission Integration. Currently, the project is still at the Impact Assessment stage.

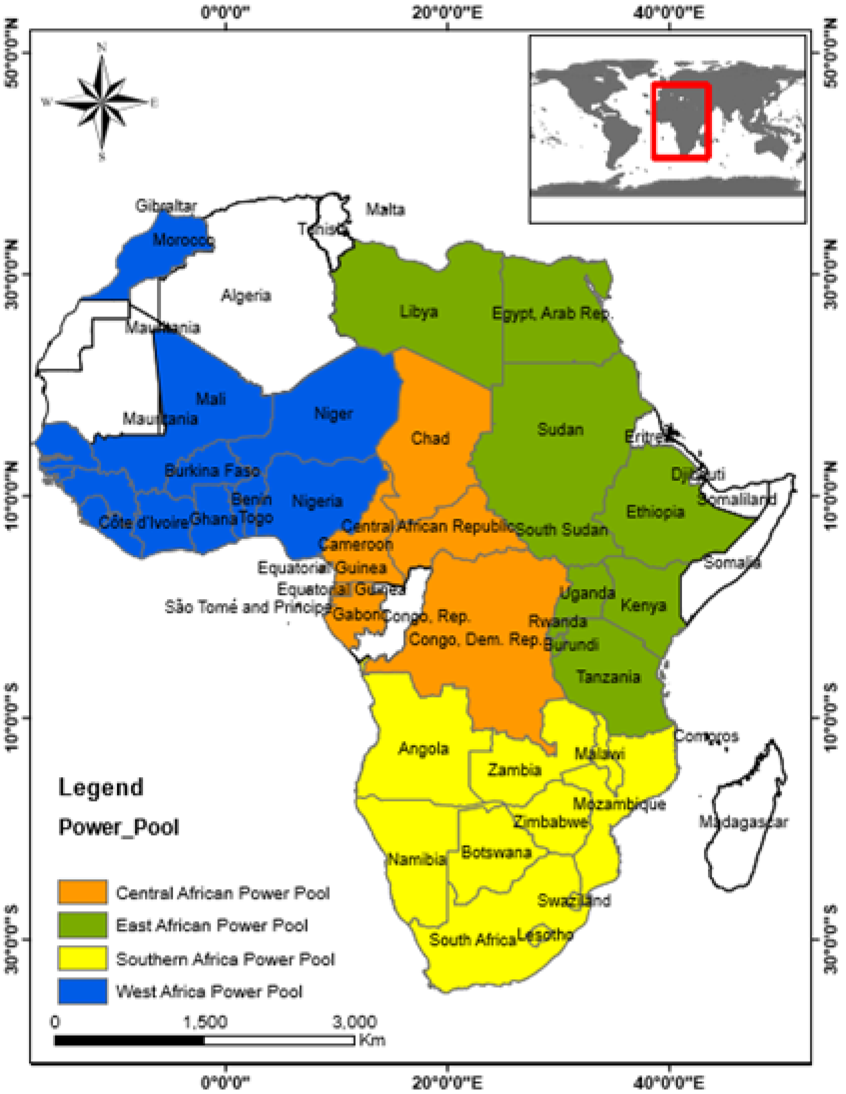

Figure 2: Member countries of the four Sub-Saharan Africa Power Pools. NB: Tanzania is also a member of the Southern Africa Power Pool, while DRC is also a member of the East and Southern Africa Power Pools.

On the other hand, the EAPP was established in 2005 by seven Eastern Africa countries namely; Burundi, the Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, and Sudan (see Figure 2). Between 2010-2012, Tanzania, Libya, and Uganda joined the power pool bringing the number of countries to ten (Oduor, 2010). The EAPP was formed to optimize the use of energy resources in, reduce costs by pooling generation expansion resources together, provide efficient co-ordination for the various initiatives taken in the field of power production and, coordinate and facilitate the process of power trade and integration among member states (ICA, 2016). EAPP membership constitutes the power utilities from member countries, excluding IPPs (Deloitte, 2015). By the end of 2015, the EAPP's total installed capacity was 55,000 MW, while the generated electricity was 235,505 GWh (ICA, 2016). There is minimal power trading between the EAPP members states with a paltry 350 GWh of power traded between neighboring member states but based on the earlier existing bi-lateral agreements. However, the EAPP masterplan has outlaid plans to develop cross-border transmission lines to fast track power trade among member states (EPRA, 2018).

The WAPP is a cooperation of the national power utilities in Western Africa under the auspices of the Economic Community of West Africa States termed ECOWAS (WAPP, 2017). WAPP was created in 2000, and its membership consists of fourteen countries (WAPP, 2017). They include Benin, Burkina Faso, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo and the recently joined Morocco. WAPP's main aim is to integrate the national power systems into a unified regional electricity market, promote and develop power generation and transmission infrastructure and coordinate power exchange among member states. Even though power trade is yet to be fully operational among the WAPP member states, there is a master plan to enhance interconnectivity as well as construct a number of power plants through shared cost between member states (Admin_DEVCO, 2014). The total installed capacity by the WAPP member states as of 2015 was 19,648 MW, while the total consumption was 50,634 GWh (Kambanda, 2018). Power trade between member countries in the WAPP is still based on the bilateral agreements.

The Central Africa Power Pool (CAPP) is an eleven-member pool created in 2003 as a specialized agency of the Economic Community for Central African States (ECCAS). Like the other power pools, CAPP was created through Intergovernmental Memoranda of Understanding signed by ministers responsible for energy as well as the Chief Executive Officers of power utilities in ECCAS (ICA, 2016). CAPP is tasked with increasing the reliability of electricity supply in ECCAS, expanding the population´s access to electricity, improving the power systems performance, creating a regional forum for discussion of energy sector problems, and establishing a liberalized energy market within ECCAS. Central Africa region is the region with the least rates of energy access by its population in the whole of the SSA region (Kappiah, 2016). The CAPP Member countries include Angola, Burundi, Cameroon, Central Africa Republic, Chad, Congo, DRC, Equatorial Guinea, Gabon, Sao Tome, and Prince. The membership for WAPP comprises of power utilities from member countries (PEACE SIE, 2018). CAPP is still in the development stage; hence does not have an established power market (Avila et al., 2017). The total installed power capacity in CAPP as in 2013 was 6,299 MW, while total consumption was 24,744GWh (Kambanda, 2018).

5. DISCUSSION

This paper reviews the importance of power pools in enhancing universal access to sustainable energy in the SSA region. Accordingly, the article discusses the challenges hindering SSA from achieving universal access to electricity for its population, energy resources found in the SSA region, and the status of the regional power pools in SSA. The review indicates that the SSA region has vast and geographically distributed renewable energy resources with the capacity to meet the region's current and future energy demand. Yet, SSA remains the world's region with the lowest access rates to modern energy services, particularly electricity (Hancock, 2015). Various challenges are hindering the attainment of universal access to modern energy services in the SSA region. Some of these challenges, for example, the low access rates, demand-supply mismatch, inadequate financing, and overreliance on fossil fuel, among others, can be solved through functional regional power trade.

The geographical distribution of renewable energy resources in the SSA region provides an excellent opportunity for the SSA governments to meet the region's energy demand while limiting carbon emission (EXIM BANK, 2017). However, the capital cost required to develop renewable energy resources is higher as compared to fossil fuel resources (Taliotis et al., 2016). Power pools fostered by regional cooperation and cross-border transmission networks could offer economies of scale for the development of renewable energy resources and reduce the cost that could be required by each country if they were to develop the resources unilaterally. Cross-border transmission networks can enhance access to clean energy for remote communities, which are located hundreds and thousands of kilometers from countries' central grids that are mainly based in urban centers, and along the main road networks. Shared cross-border transmission networks and resource development will reduce the average cost of generation by pooling countries' resources. Regional power trade can reduce the current cost required to meet 100% access rates for the SSA region by $50 billion (Castellano et al., 2015).

Through regional power trade, the demand-supply mismatch can be addressed by the trading of electricity between countries with more renewable energy resources and those with limited renewable resources. States can leverage intermittent generation from renewable sources with varying levels of demand per country per hour through cooperated and integrated transmission networks to meet the regional demand at various times of the day. Furthermore, regional power trade can help diversify countries´ energy portfolios and shield them from price shocks. For example, electricity generated from the abundant hydropower resources found in Central Africa can be exported to Western Africa, whose primary source of power is oil. Moreover, diversification of the energy portfolios will reduce overreliance on fossil fuel imports by enabling the diverse renewable energy resources to be shared among countries. For instance, electricity generated from geothermal resources in Eastern Africa can be transmitted to Southern Africa, which is mostly powered by coal. Accordingly, an increased share of renewable energy resources will reduce greenhouse gas emissions associated with electricity generation by the SSA region (Sanoh et al., 2014).

The SSA region is also endowed with fossil fuel resources. Through regional power trade, the SSA countries can leverage the geographical distribution of both renewable and fossil energy resources to synergistically address universal access to modern energy services while limiting GHG emissions. For example, clean technologies can be used to utilize the gas resources to built gas peaking plants to stabilize the system once the share of the intermittent renewable resources in the energy mix increases. On the other hand, fossil fuel resources, for example, coal and oil, can be utilized using clean technologies to provide the base loads supply.

Energy planning tools are critical in attaining an efficient integrated energy network at both national, regional, and global levels (Musonye et al., 2020). Currently, the SSA region suffers an inadequate technical capacity for the use of energy planning tools. The region mostly relies on expatriates for energy planning, which makes energy planning more expensive. Through power pools, a coordinated local technical capacity building can be done by pooling resources together from member states. The SSA region can tap into the already existing expertise in developed countries to built and retain a pool of experts. A local pool of experts can provide the required technical expertise at a relatively lower cost as compared to expatriates. Besides, a pool of energy modeling expertise at the power pools' level will facilitate an easily coordinated integrated regional energy model development. Such a pool will make it easy to infuse countries' plans into regional plans and vice versa, applying a cyclic approach.

6. CONCLUSION

This paper reviews the importance of power pools in enhancing universal access in the SSA region using renewable energy resources. The SSA region has vast and geographical distributed renewable energy resources with the capacity to meet the current and future energy demand for the region while limiting greenhouse gas emissions. Various challenges hinder universal access to energy services in the region. They include; low access rates, demand-supply mismatch, overreliance on fossil fuel, technical inefficiencies and inadequate financial investment and, inefficient policy framework, and poor planning. Some of these challenges can be addressed by the operationalization of the regional power trade through regional power pools. The regional power pools provide a platform for coordinated planning and approach to these challenges. Accordingly, operational power pools can reduce the investment cost required by each country to meet its electricity demand. Furthermore, improve the efficiency and delivery of energy services, increase the share of renewable energy resources in the region's energy mix, and limit greenhouse gas emissions.

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