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Renewable Energy Technologies in the Global South: Sub-Saharan Africa Trends and Perspectives

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***Abstract*— Sub Saharan Africa (SSA) and other parts of the Global South are richly endowed with renewable energy resources (RERs) that are grossly untapped. The integration of these resources, such as hydro, wind, solar, and biomass will facilitate the desired net zero-CO2-emissions economy. If these RERs are adequately harnessed, the perennial power supply challenges in the region will be resolved, and the negative power supply narrative changed. Presently, a greater percentage of the population without access to electricity live in the Global South with SSA having the highest share. This inadequacy has been attributed to many factors, which include lack of connection to the national grid; lack of adequate technical capacities to design and manufacture efficient power generation and transmission components and systems; insufficient funds; unreliable, limited, and poor energy data. A comprehensive study of the renewable energy potential (REP) and technologies in the Global South is imperative to the management, regulation, and policies concerning energy, in this era of energy transition (ET). This study presents - a summary of REP of SSA; statistical analysis of the proposed and installed RE capacity across the region; and discussion on the pressing need for renewable energy integration (REI) to mitigate climate change. In addition, to develop RE schemes to facilitate greater access to clean, affordable, and adequate energy supply. Actualization of the integration of RERs into the national portfolio will promote CO2 reduction and improve the socio-economic benefits to the populace in both rural and urban areas of SSA and the Global South generally.**

***Keywords*— Renewable energy system; Net-zero-CO2 emissions, renewable energy in Global South; hydro; wind; solar; biomass**

I. INTRODUCTION

Electricity in the global South, especially sub-Saharan Africa (SSA) is characterised by low quality, inadequate and unreliable power supply. This has socio-economic consequences on both rural and urban areas, but the impact is mostly felt in the rural areas. Electrical energy has been described in a study as a critical driver, and live wire of the economy and modern society [1].

Inadequacy of energy supply is an invitation to abject poverty, backwardness, and general underdevelopment. In 41 countries in SSA, only about 50% of the population have access to electricity, and only around 41 % is expected to have access to power by 2030 [2]. The region has been projected to accommodate 90% of the world's population without access to electricity by 2030. Despite the improvement in the energy use and GDP in the global South, about 750 million people will have no access to electricity in 2050, over 95% of these people will be in SSA. An estimated 1.5 billion people will continue to depend on the use of traditional bioenergy for cooking [3]. However, South Africa is exempted from the gross energy inaccessibility of SSA [4]; in 2019, the average access rate for SSA and South Africa was 46.75% and 85%, respectively. South Africa has been able to put in place and adopted successful access programmes, integrated policymaking, and the increasing presence of private investments in the renewable energy sector.

Despite the limited access to energy, human health and the environment are often traded off to provide the needed energy for socio-economic development. Globally, fossil fuels, such as coal, gasoline oil, diesel, fuel, biomass, and natural gas, are burnt for the needed energy to drive the economy. This practice comes with greenhouse gas (GHG) emissions, resulting in climate change, and morbidity and mortality increase. According to the World Health Organization (WHO) [5], an estimated 2.6 billion people globally, especially those in the Global South, are at risk of household air pollution; the burning of coal and biomass fuels for cooking and heating causes this; women and young children are mostly exposed to the pollution. In addition, about 3.8 million people die prematurely yearly from household air pollution-related illnesses, such as pneumonia (27%), stroke (18%), ischemic heart disease (27%), chronic obstructive pulmonary disease (20%), and lung cancer (8%).

Meeting the energy need for the growing industrialisation, population, and urbanisation in the Global South poses serious challenges. The situation in developing countries of SSA is very tense as the power need is by far greater than the power supply. The main source of power in the region is fossil fuels, such as oil, natural gas, and coal. These fuels are undoubted, reliable economic drivers responsible for the big economies globally. However, they are associated with negative environmental (CO_2 emissions), and human health consequences, and are continuously depleted [6-10]; and therefore, not sustainable. This led to a global outcry for energy transition- a shift from fossil fuel to a sustainable energy system that is adequate, affordable, secure, and clean [10-13]. In response, the United Nations (UN) resolved to tackle the issue of climate change attributed gas emissions, through the deployment of more renewable energy (RE) to reduce the consumption of fossil fuels [14].

This study, therefore, examines renewable energy potentials (REP) and technologies available in the Global South, their present development at both regional and national levels; statistical analysis of the proposed and installed RE capacity across SSA; analysis on the pressing need for renewable energy integration (REI) concerning climate change. In addition, it suggests RE policies and schemes facilitate greater access to clean, affordable, and adequate energy supply. Furthermore, the study targets the promotion of RE deployment to reduce CO_2 emissions and improve socio-economic growth in both rural and urban areas of SSA and the Global South in general.

II. METHODOLOGY

This study is based on current issues concerning energy access in the Global South, with a special focus on SSA. A wide review was carried out, considering published literature, mostly in the last five years that are relevant to this study. The following approach was adopted in this study: use of secondary data on power issues and RE in SSA from reliable platforms. These sources are ScienceDirect, Scopus, verified official websites of published feasibilities, investigations, and energy policies, power issues in SSA, and reports by global organisations on RE. Others are energy investments, the World Bank, climate change – Inter-governmental Panel on Climate Change (IPCC), and the United Nations (UN), International Energy Agency (IEA), International Renewable Energy Agency (IRENE), and World Energy Council (WEC).

III. ELECTRICITY DEMAND

The estimated electricity installed capacity in SSA (excluding South Africa) is 80 GW in 2018, which is about three times less than that of France [15]. Africa generated only 804 TWh of net electricity in 2019, which is about 20% of the total in the United States that same year. Africa experienced about a 2.5% decline in the electricity generated in 2020 (from 863 TWh in 2019 to 844 TWh in 2020) [16], due to the pandemic – COVID-19. Eleven countries accounted for three-quarters of the energy demand and gross domestic product (GDP) of SSA in 2018 [17]. The share of the primary energy sources and the eleven countries that accounted for three-quarters of energy demand is presented in Fig 1 (a) and (b), respectively.

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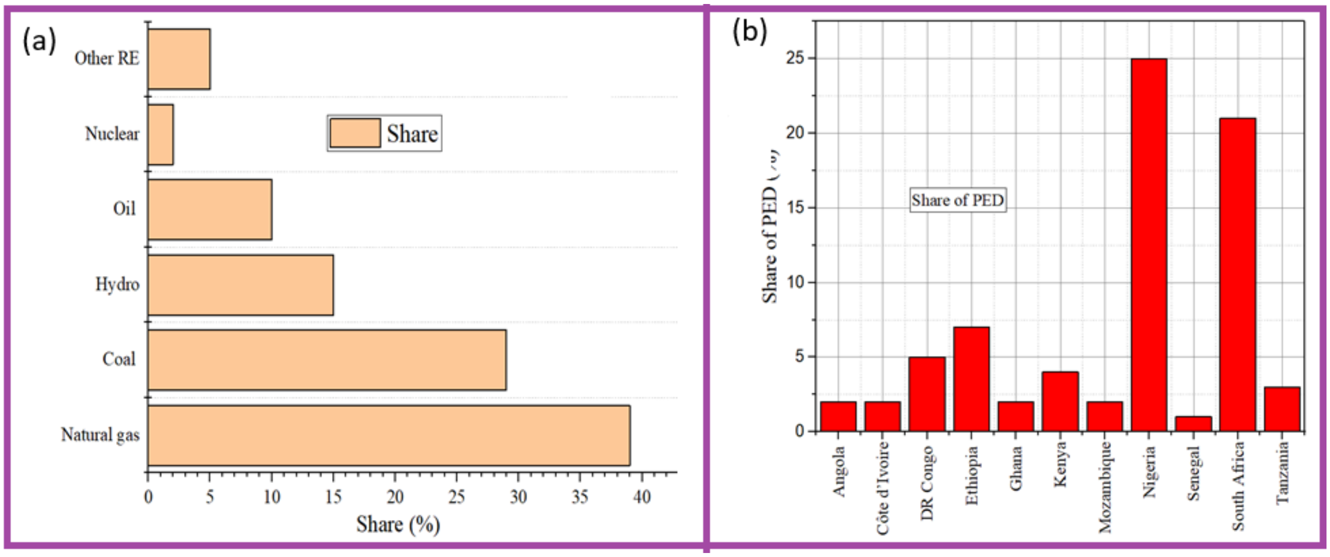

Fig 1: Shares of SSA primary energy demand (PED) by countries; (b) SSA countries that accounted for the three-quarters in 2018.

In 2019, natural gas has the highest share in Africa's electricity generation mix, followed by coal, hydro, oil, nuclear, and other renewables, as presented in Fig 1(a). The region depends largely on conventional fuels, accounting for around 78% of the energy generated, as observed in Fig 1(a). This significant role of traditional fuels in increasing the energy access level will continue. The renewable component of the power supplied came from solar, wind, and geothermal power systems. These RE technologies are continually increasing in the region, having installed capacities of about 17.4% (geothermal), 26.1% (wind), and 60.2% (solar) between 2010 and 2019. In 2019, Africa possessed 7,236 MW, 5,748 MW, and 830 MW as installed capacities for solar, wind, and geothermal, respectively [18].

IV. SUB-SAHARAN AFRICAN RENEWABLE ENERGY POTENTIAL (REP)

Renewable energy sources, such as wind, solar, hydropower, and biomass are important technology options for increasing energy access and decarbonisation. They are sources of stable electricity supply and are expected to play a vital role in the future sustainable energy system. Sub-Saharan Africa is endowed with RE resources, such as wind, solar, hydropower, and geothermal, as presented in Fig 2. These resources are spread across the region, and the exploitable generating capacity is estimated as 11,000 gigawatts (GW) [19], which is adequate to meet the present and future energy needs of the region. Fig 2 presents the different potential energy resources their estimated power generation capacity and their distribution in the region.

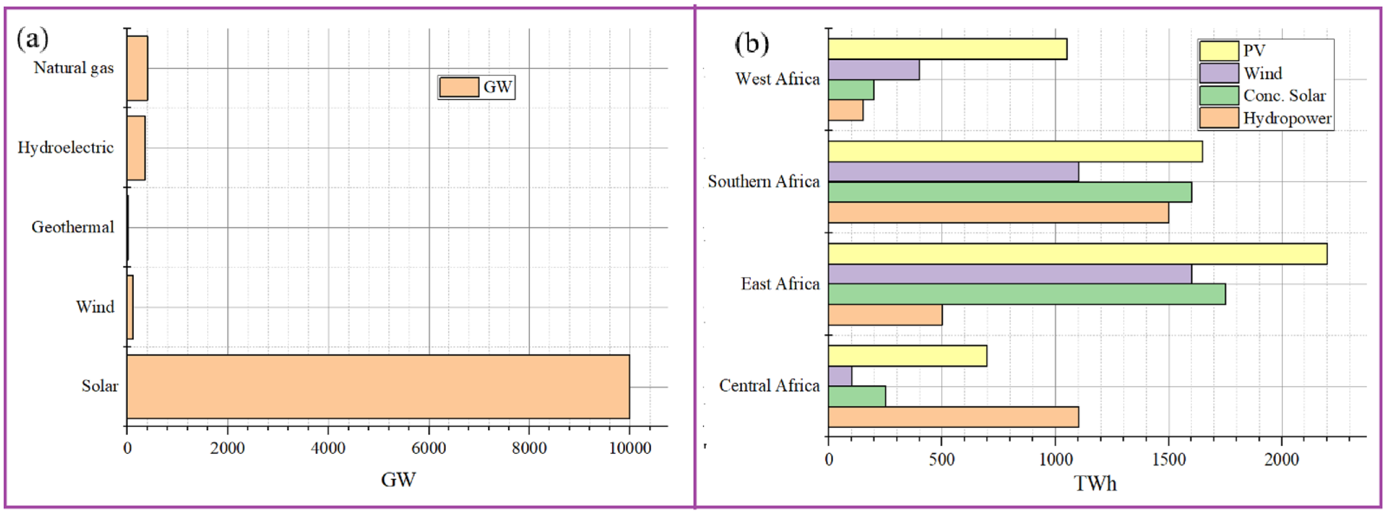

Fig 2: SSA renewable energy potential (a) Generation capacities of the energy resources available; (b) RE potential across the region

Generally, SSA is rich in energy resources but has a low useable energy supply. This statement looks contradictory, but this is a stark reality. The region is rich in natural energy resource that is grossly undeveloped into useable energy, such as electricity, despite the rapidly growing population, and urbanisation.

The distribution of the three most dominant RE sources and the distribution pattern across Africa is shown in Fig 3. The present SSA power capacity is about 147 GW [20].

Fig 3: The distribution of renewable energy in Africa [21, 22]

A. Hydropower

Currently, hydropower is the dominant RE source in terms of installed capacity, accounting for 18% of the total global electricity supply. In addition, hydropower is an economically competitive and technically mature energy source option that helps to balance electricity supply and demand.

In 2020, the estimated global hydropower installed and generated electricity capacities is 1,330 GW and 4,370 TWh, respectively. According to a study [23], the total global gross and technical hydropower potentials are estimated to be about 128 pWh/year and 26 pWh/year, respectively.

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The range of economic potential is from 8 to 25 pWh/year with a cut-off cost between 0.05 $/kWh/year to 0.15 $/kWh/year while the range of exploitable potential is between 6 to 18 pWh/year.

The estimated regional hydropower generation potential and installed capacities are presented in Fig 3 based on the information obtained from a study [24].

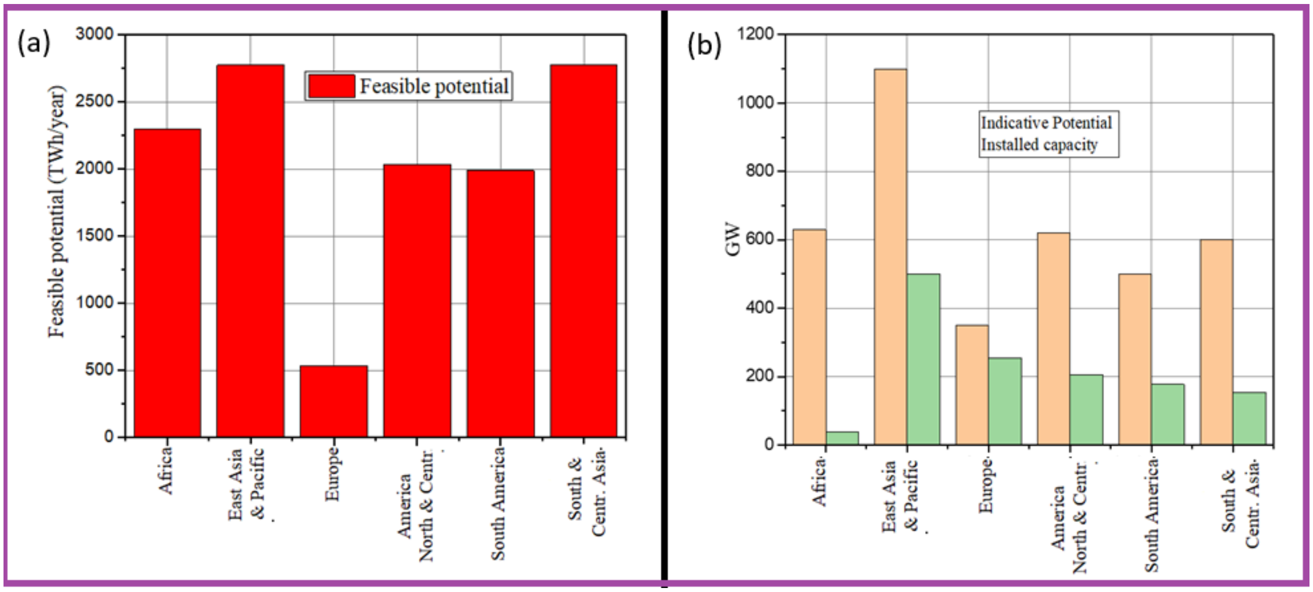

Fig 3: (a) Region estimated hydropower generation potential; (b) Indicative regional hydropower potential

In SSA, small hydropower (SHP) is considered econo-technically viable due to its widespread and huge potential across the region. The small-scale hydropower potential in this study is recognised as mini and SHP as 0.1 MW – 10 MW. Deploying the SHP scheme will increase access to clean electricity and reduce CO_2 emissions coming from energy generation and consumption. Hydropower is strategic and central to the socio-economic growth of the region, yet about 92% of the technical hydropower potential across Africa is untapped [25]. Other striking information about SHP in the region as obtained from a geospatial assessment study [26] are:

- ✓ SHP has been recognized as a modern energy system, suitable for standalone and rural electrification with attributes of clean electricity, affordability, and being environmentally friendly. The scheme produces relatively cheap electricity; costing between 0.02/kWh USD and 0.05/kWh USD [27, 28].
- ✓ Central and Southern Africa have the highest concentration of SHP and 15,599 sites were identified across the region, as shown in Fig 4.
- ✓ The estimated power capacity of SHP in SSA is 25,221 MW.

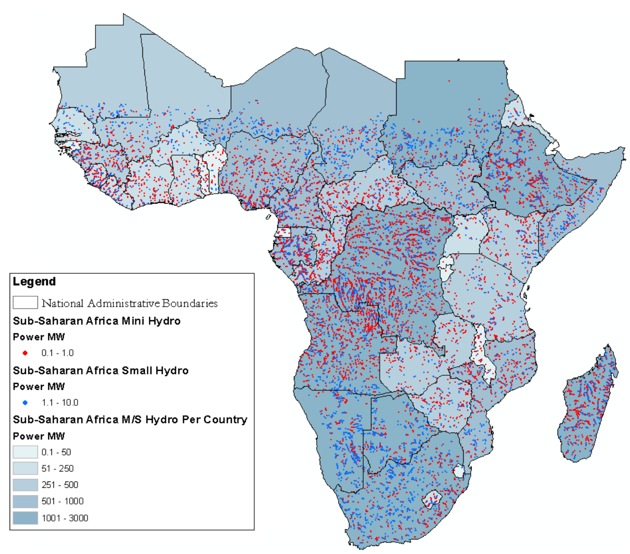

Fig 4. The identified hydropower potential sites for capacities between 0.1 and 10 MW in SSA [26]

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There are recognized restricted areas, designated as unsuitable for hydropower deployment. These areas cover about 45.3% of the total area in SSA. Eastern and Western African regions have the highest share of the restricted land. The regional based SHP potential and size of the restricted lands as shown in Fig 5.

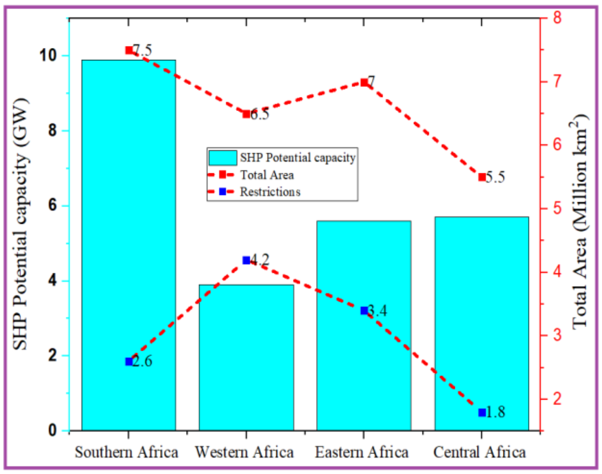

Fig 5. Small hydropower potential per African power pool and the restricted lands

B. Solar PV

Because of the triple and inter-connected effects of improved technology, reduction in photovoltaic PV module cost and policy initiatives, solar energy is expected to contribute substantially to the future global energy supply. Geographically, the location of SSA places it to contribute to the global energy supply significantly by deploying solar energy but at the moment no adequate infrastructure to achieve this. The region Africa receives an excess of global solar radiation annually estimated as 2000 kWh and this has not been transformed into useable and needed energy forms adequately. The average daily potential of solar PV in Africa is 4.49kWh/kWp with an installed capacity of only 4878.1MW in 2018 [29]. This installed capacity is relatively low considering the power inadequate supply in SSA and the installed capacities in other regions, even in a region with lesser potential, as shown in Fig 6.

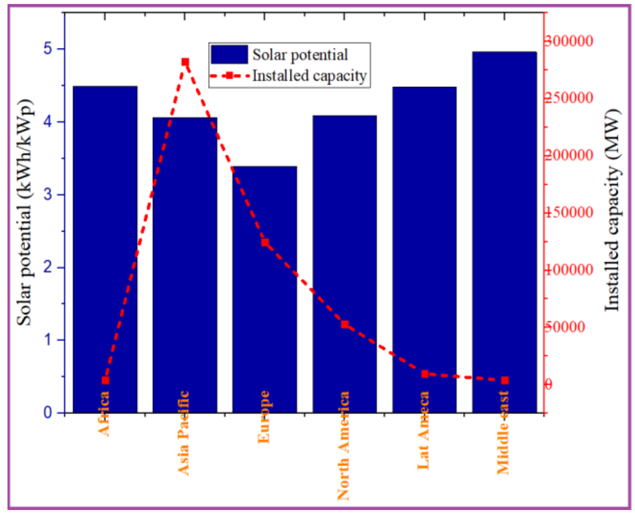

Fig 6: Regional solar potential and installed capacity

C. Wind energy

Wind power is among the three most dominant electricity sources in SSA and stands out among the promising RE options in the region for the following reasons [30, 31]:

i. It is abundant in SSA, especially in highlands and coastal regions, with an onshore wind estimation of about 109 GW capacity. These are five top countries that make up 66% of the wind energy in SSA - Angola, Somalia, South Africa, Chad, and Sudan. Along the Rift Valley and the south and east coasts are the most promising locations for wind energy in SSA with a speed of more than 9 m/s and more than 8.5 m/s in Kenya
ii. Wind farms are quicker to build and less controversial compared to large hydropower dams, they are environmentally friendly.
iii. Wind power technology is relatively cheap, as the price has drastically declined in the past decade. The Levelized costs of energy (LCOE) are between 107 USD/MWh and 152 USD/MWh, depending on the wind speed.

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V. Significance Of RE Development In SSA

The development of power infrastructure in SSA is far below the power demand due to the rapid population, industrialisation, and urbanisation. Lack of adequate access to electricity is stagnating the socio-economic growth and leads to a denial of social justice to the poor people in the region. The region is a home for the highest population living in extreme poverty, without access to electricity, clean energy for cooking [32]. About 78% of the little power that is generated in the region is from fossil fuels, including oil, coal, and natural gas, which are economic drivers and biomass, used for cooking and heating. The burning of these fuels come with consequent greenhouse gases emissions, especially CO_2. The biomass has been invaded massively for lumbering and firewood business because of energy poverty and the high rate of unemployment in SSA. These practices accelerate CO_2 emissions, which facilitates climate change and respiratory diseases. Over 90% of households in about 25 countries in SSA depend on solid waste, wood, and charcoal for cooking. About 2.8 million premature deaths annually have been linked to the noxious fumes released during the burning of biomass [2]. Although SSA accounts for about only 0.55% of the global CO_2 emissions, in 2011, Africa accounted for 15% of CO_2 emissions from agriculture, and this is expected to rise by 18% and 30% in 2030 and 2050, respectively [33, 34]. Therefore, adequate development of the abundant renewables available in the region will:

i. Change the narrative of perennial power challenges that have bedevilled the region for decades.
ii. Prevent the CO2 emissions that come from the generation and consumption
iii. Create employments
iv. Boost developing economies
v. Create flexibility of generating system types and capacity

VI. Steps To Facilitate Re Exploitation In SSA

The development and deployment of the RE resources in SSA are subject to the following:

D. Political unpredictability

Some countries in SSA are politically volatile and this can influence smooth transitions and developments negatively. The regional leadership and national governments should work together to entrench the peace and political stability needed for development.

E. Institutional framework

Although some countries in the region have developed RE policies and frameworks, these need to be re-evaluated to ensure the deliverables and the goals are achieved. This involves implementation, monitoring and appraisal of the short and long-term frameworks. Policies should be used to address disagreements between the stakeholders in the sector for effective and enduring partnerships. The culture of transparency should be imbibed and ambiguity in the management and regulatory structure should be avoided.

F. Adaptation of global best practices in electricity supply

The region should take the advantage of the gross energy deficit to develop RE infrastructure and be the best in the world in the deployment of clean energy in all sectors. Innovation in terms of new technology should be exploited and imbibed and avoid obsolete energy systems.

G. Technical skills

At present, the capacity in terms of technical personnel and manufacturing infrastructure to design, manufacture, operate and maintain RE components and systems domestically is inadequate. Hence, a deliberate attempt should be made, nationally and regionally, to build the needed capacity through partnerships and formal training for self-reliance, and to reduce overdependence on foreign technologies.

VII. Conclusion

The decades of chronic power shortages and unreliable electricity supply have impeded socio-economic activities in SSA. More than 600 million of the 1.3 billion people that are without access to electricity live in SSA. The power inadequacy has manifested into high rate unemployment, hunger, extreme poverty, and health challenges. There is a mixed source of electricity in SSA with fossil fuels (coal, oil, and natural gas) providing over 78% and the rest from RE (wind, solar, and hydropower). The energy demand in the region is driven by an increase in population, urbanisation, and industrialisation and achieving adequate supply is compounded by the quest for a clean, accessible, and affordable energy system. The huge renewable potential in the region can provide the present and future energy needs of SSA if adequately harnessed. Substantial development of the renewables in SSA will:

- ✓ Change the narrative of perennial power challenges that have bedevilled the region for decades.

- ✓ Prevent the CO_2 emissions that come from the generation and consumption
- ✓ Create employments
- ✓ Boost developing economies
- ✓ Create flexibility of generating system types and capacity

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