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Review Paper

Strategies for sustainable development of the power sectors of Sub-Saharan African Nations

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Abstract

The achievement of sustainable development goals by the Sub-Saharan Africa region depends on access to modern and efficient renewable energy technologies. The Sub-Saharan Africa Nations have been unsuccessful in fully utilizing renewable energy resources for sustainable development of the power sector. Also, developing countries in this region are susceptible to the negative health and environmental effects of fossil fuels. The goal of all countries is sustainable development of the power sector using renewable energy sources with zero greenhouse gas emissions. Though, there are a lot of problems that arise in efficient utilization of renewable energy sources in Sub-Saharan Africa. This paper studies challenges that hamper the power sector and identifies strategies for sustainable development of the power sectors in Sub-Saharan African countries. Achieving net-zero emissions is a critical cross-sector climate-action goal, yet a complex undertaking with many significant but surmountable obstacles by switching to clean energy sources, changing the way you travel, and reducing your consumption by recycling and reusing everything. In conclusion, the paper recommends the adoption of the 2050 Net Zero Agenda, local production of power plant components in Africa and the consideration of natural gas as a key transitional fuel due to its lower carbon footprint compared to other fossil fuels.

Keywords: *Power sector, Sustainable development, Renewable energy, Sub-Saharan Africa, 2050 Net Zero*

1. Introduction

Energy production and supply are one of the key factors for socioeconomic and political development in the world. About 85 percent of our energy comes from nonrenewable fossil fuels-oil, natural gas, coal. The energy sector is dynamic, and energy producers need to develop new and modern technologies to generate, store and transport energy to other socioeconomic sectors [1,2]. The increased demand in global energy impacts world economies and the environment particularly energy security [3]. Energy security links the national security and availability of natural resources for energy consumption of a nation. Energy resources are classified as renewable or non-renewable sources. Though, non-renewable energy sources dominate global energy demand [4, 5]. Some studies [6, 7] have reported that fossil fuels contribute to over 60% of the global CO_2 emissions. Global emissions from fossil fuel combustion were primarily by coal (45%), oil (33%) and natural gas (22%) [8] respectively. The greenhouse gases are harmful therefore causing an increase in climate change. Currently, due to new technologies, a strong political will

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and reviewed government economic policy there is a rapid growth of renewable energy production and supply [8]. Previously, renewable energy sources were mainly produced from biomass and hydropower, but currently, wind and solar power are gradually emerging as cost-effective sources of renewable energy [9]. The African continent is rich in natural resources and renewable energy, but the continent has been unsuccessful in fully utilizing these resources to achieving sustainable development [10]. The Sub-Saharan Africa region is reported as the most energy deficient region in the world. Some studies [11, 12, 13] reported that only 24% of the population has access to electricity even though the Sub-Saharan Africa region has the highest renewable energy potential among all regions. However, 800 million people in this region depend on solid biomass, such as fuelwood, charcoal, agricultural waste, crop residue wood processing residues, municipal waste and animal dung, as their main source of energy for cooking [14]. While Sub-Saharan Africa (SSA) makes up about 15% of the total population of the world, it accounts for about 80% of the world population without electricity access. About 680 million people in SSA (about 60% of SSA's population and 51% of Africa's population) still lack access to electricity.

2. Energy Access in Africa

2.1 Resources

Africa today is the continent with the highest energy poverty with about 680 million Africans living without access to electricity. While currently the world average electricity consumption per capita is about 2,600 kWh that of sub-Saharan Africa is only 500 kWh [16]. The electricity access of some selected developing and sub-Saharan African countries are shown in Figure 1. It can be observed that Brazil, China and Russia have 100% access to electricity while the electricity access of sub-Saharan Africa and Nigeria are approximately 42% and 53% respectively [17].

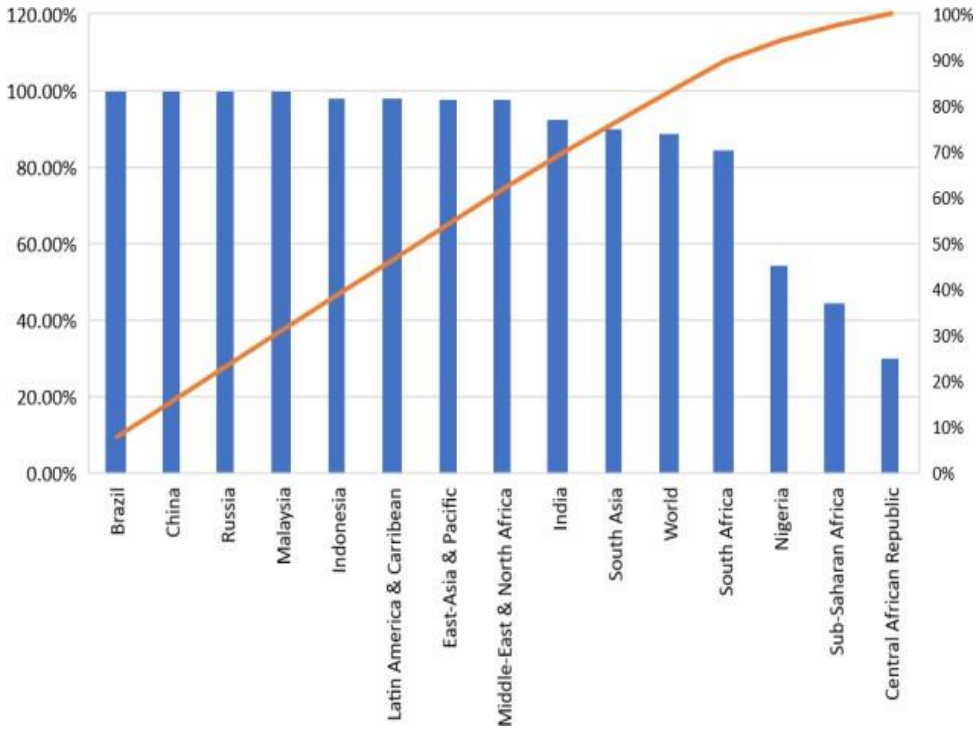

Figure 1: Access to Electricity of some Regions and Countries [17].

Africa is endowed with energy resources of oil, natural gas, coal, hydropower, solar, wind,

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geothermal, biomass, tidal and wave energy in its territorial waters, which are unevenly distributed. For example, as shown in Figure 2, oil and gas mainly in North Africa and the Gulf of Guinea; hydropower in Central and Eastern Africa; coal in Southern Africa; Geothermal energy mainly in East Africa; and highest winds in North and Southern Africa. While 18 out of the 55 African nations are endowed with commercial quantities of oil and gas, half a dozen have significant quantities of coal and about 4 are endowed with noticeable uranium deposits. Others are Solar energy is exploitable in all the 55 African States. Wind energy is most viable along the coastal areas of the continent. Geothermal energy is along the East African Rift Valley [18].

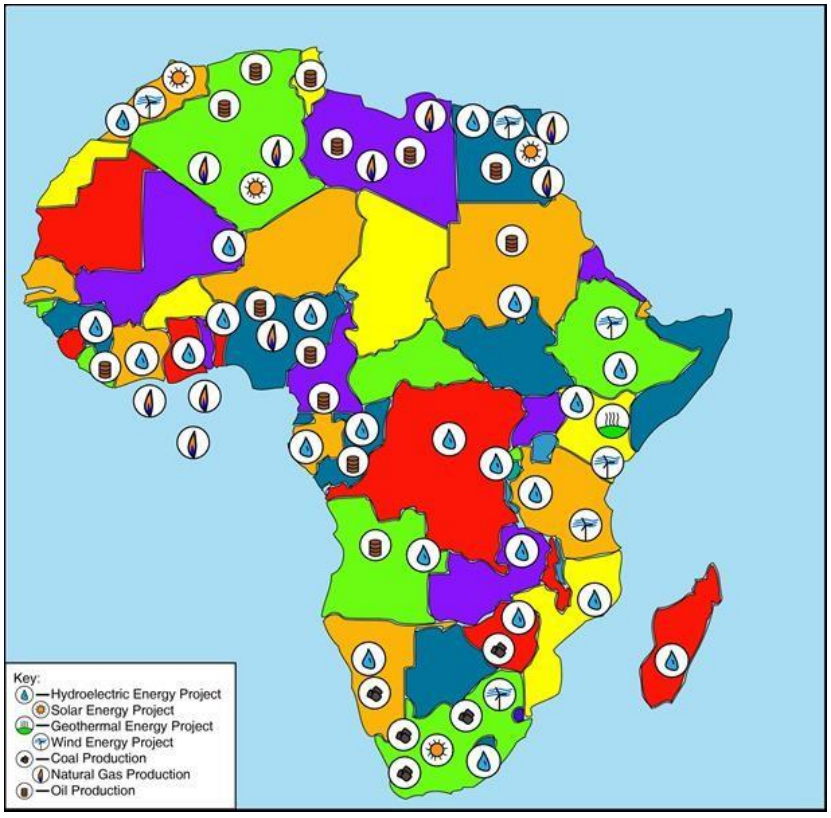

Figure 2: Energy Resources and Renewable Energy Projects in African Countries [18].

2.2 Challenges

Nigeria participated in the United Nations Climate Change Conference (COP28) summit held in Dubai in 2023 and made a commitment to transition away from fossil fuels to renewable fuels in a just orderly and equitable manner so as to achieve net-zero emissions by 2050. In addition, Nigeria pledged to support the European Union global initiative made at COP28 to triple the installed capacity of renewable energy and double the rate of global energy efficiency by 2030 [19]. Consequently, in 2021, Nigeria became the first African country to officially launch a detailed Energy Transition Plan to address the problems of energy poverty and climate change and deliver universal access to affordable energy, Sustainable Development Goal 7 (SDG7) by 2030 and net-zero emissions by 2060 [20]. Nevertheless, when Nigeria like other developing countries gradually plans to transit to zero-carbon energy sources, the Energy Transition Plan has many challenges.

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- Financial cost challenges: The cost of transiting from present fossil fuel energy sources is high and will require reportedly by the Nigerian government about $410 billion dollars to achieve net-zero by 2060. The financial investment required in new technologies for a successful energy transition and its sustainability is capital intensive.
- Technical skills challenges: There are also inadequate technologically skilled personnel required to completely transit to new net-zero carbon emission technologies. The energy transition requires new technological development particularly in electric vehicles and Nigeria has a shortage of the required technological skills in this area. There is a need for human capacity building and skills development to support the roll out of new net-zero carbon technologies.
- Policy regulation challenges: Inconsistent government policy regulations such as policies to reduce climate change, global warming, electrification and marketing may hinder the energy transition plan. There is a need for consistent government policy and regulatory change mainly aimed at creating a favorable environment for businesses to invest in the energy transition.

2.3 Opportunities

Africa with a huge population of more than 1 billion people is a very large market for energy developers. Demand for energy would continue to rise due to demand for improved energy services in Africa. This would require heavy financial investments in energy infrastructure. Opportunities for businesses in the energy sector are and would therefore abound. Opportunities exist for national and regional cooperation. Algeria, Nigeria, and Egypt currently lead other African countries in having the highest Liquefied Natural Gas (LNG) export capacity on the continent. Figure 3 shows Africa's current LNG projects and gas reserves. Also, Africa has the world's highest solar energy potential as shown in Figure 4 ahead of Europe, Asia, North America, Central and South America, Russia and Oceania.

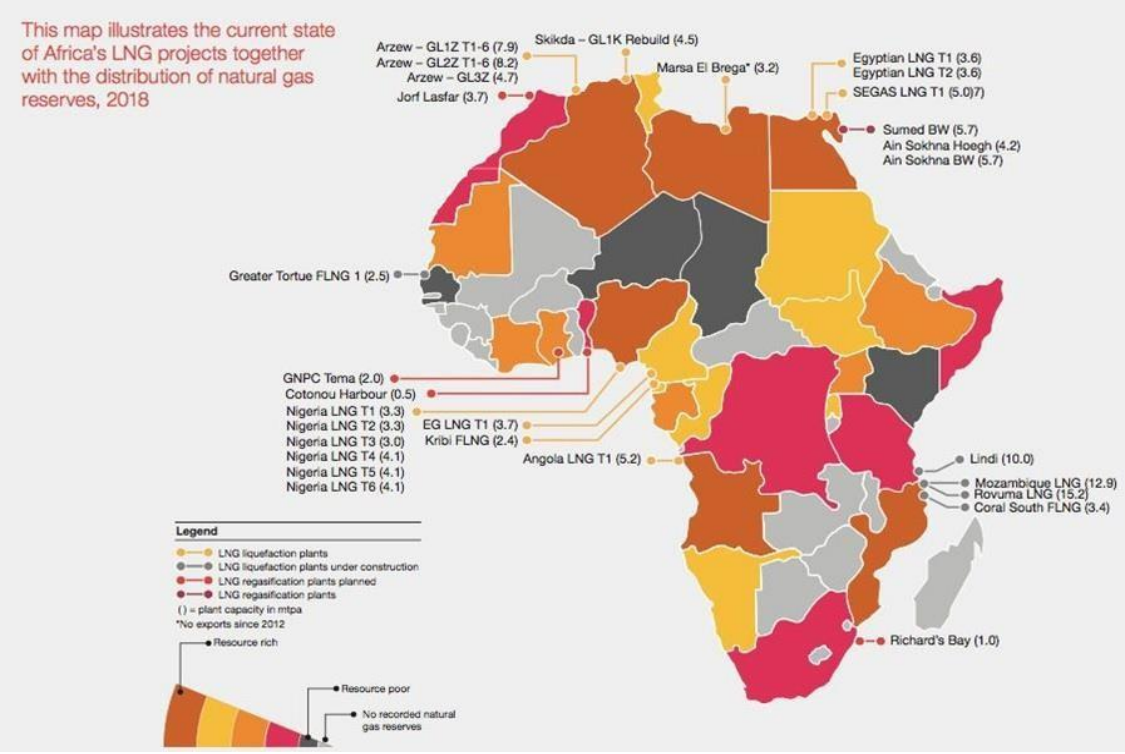

Figure 3: LNG projects and gas reserves in African countries [21].

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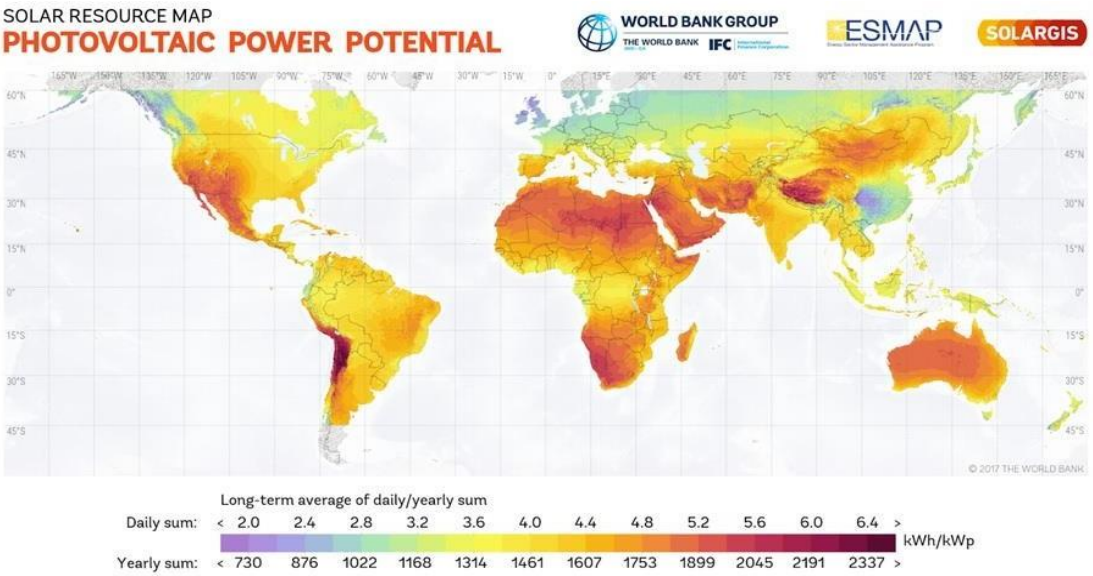

Figure 4: Photovoltaic power potential in Africa and globally [22]

3. Results and Discussion

To energise Africa for meaningful socio-economic growth will require sub-Saharan African nations, in particular, to:

- Produce a comprehensive scenario-based energy demand projections using modern energy modeling tools.
- The tools should be used on short-, medium- and long-term time horizons covering the major economic sectors.
- An example of this is the 2050 Pathway Calculator which was recently used to determine the energy demand of Nigeria.

The Energy Commission of Nigeria (ECN) used the 2050 Pathway Calculator energy modeling tool initially developed by the UK's Department for Energy & Climate Change, modified with Nigerian socio-economic parameters. The nation's energy demand in MWyr is shown in Table 1 below.

Table 1: The 2050 Pathway Calculator of Nigeria's energy demand in MWyr by ECN.

Sector	2010	2015	2020	2025	2030	2035	2040	2045	2050
Transport	-	-	238	298	357	417	476	536	596
Industry	3,557	4,357	5,309	6,426	7,076	10,444	15,497	22,692	33,372
Cooling	5,156	8,255	11,526	14,984	18,641	22,513	26,615	30,964	35,579
Lighting, machines & cooking	4,345	8,053	13,979	25,706	36,979	49,129	60,008	70,837	82,405
Total	**13,159**	**20,665**	**31,053**	**47,413**	**63,054**	**82,503**	**102,597**	**125,030**	**151,951**

Produce comprehensive energy supply strategy based on the outcome of the scenario-based national energy demand projections on all the economic sectors namely: industrial, transport, services and household.

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The United Nation's Sustainable Energy for All Initiative launched in 2011 has three objectives to be achieved by 2030 that calls for:

- Universal access to modern energy services by 2030
- Doubling the share of renewable energy in the global energy mix by 2030
- Doubling the rate of energy efficiency thereby reducing energy intensity by 2030

To achieve the United Nation's Sustainable Energy for All Initiative, the Federal Government of Nigeria launched in 2022 the Nigeria Integrated Energy Planning Tool in collaboration with Sustainable Energy for All (SEforALL) to support the country's ambition of achieving universal energy access by 2030 and declared commitment to net-zero emissions by 2060.

3.1 The energy transition

Energy Transition can be defined as the global shift from fossil fuel-based energy systems to low-carbon renewable energy sources. The objectives of Energy Transition are to mitigate global climate change, reduce greenhouse gas emissions, promote sustainable development and improve energy security. In 2021, Nigeria's Energy Transition Plan was produced at the 2021 Conference of Parties (COP26) meeting, prompting Nigeria's net-zero commitment by 2060. African countries including Nigeria pledged their commitment at COP28 by aligning with the COP28 goal to triple renewable energy and double energy efficiency by 2030.

Having noted that the Sustainable Development Goals as agreed upon by the United Nations and Paris Climate Change Talks of 2015 were unlikely to limit global temperature rise to 1.5 °C, the International Energy Agency produced the roadmap to Net Zero carbon emissions by 2050. Global temperature rise arising largely from combustion of fossil fuels is the principal cause of global warming which if not curtailed will lead to devastating consequences with massive global floods, droughts, increased fire threats and disruption of agricultural productions along with scarcity of drinking water. African governments should faithfully implement the African Union's Agenda 2063 which was adopted in 2013, and which mandates African nations to produce and implement their Nationally Determined Contributions (NDCs) for abating Climate Change. Essentially, the NDCs should significantly focus more on renewable energy for electrification and electric vehicles in the entire transportation value chain.

3.2 Renewable energy projects in Africa

There is a very visible increase in the uptake of renewable energy projects in Africa that are crucial for sustainable development and addressing energy security. Some renewable energy projects in Africa are:

- The Bethlehem Hydro Plant in South Africa
- George Airport Solar Plant in South Africa,
- The Lake Turkana wind park in Kenya
- The Olkaria IV Geothermal Project

These projects provide valuable insights into the varied approaches to renewable energy development in Africa.

From the foregoing the best strategies for renewable energy projects in Africa will involve local production of the components along with the auction-based financing scheme and as much as

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possible projects can be jointly developed, operated and maintained by two or more neighboring nations.

3.3 The place of gas

With intensive exploration activities over the past two decades about 14 sub-Saharan African nations are producers of oil and gas which contributes substantially to export earnings. Although the global energy transition initially being promoted by the United Nations Sustainable Development Goals (SDGs) and now by the 2050 Net Zero Agenda are strongly advocating the abandonment of fossil fuels nearly all the oil and gas rich African nations have vowed to continue using their gas. Taking Nigeria, which has gas reserves of more than 200 trillion cubic feet which is the largest in the region as example, it is as follows:

- Declared the years 2021-2030 as the decade of gas
- Declared that its reserve to production of 128 years imply that opportunities for development of gas infrastructure and gas-based industries are vast and untapped.
- Got the National Assembly to pass the Petroleum Industry Bill and which the President has just signed into law. It will harmonise and update the several petroleum Acts and make Nigerians to have more benefits from the sector.

The recent policy declaration of Nigeria also involved the following:

- Fossil fuels remain relevant, maximizing domestic utilization to power the economy.
- Government takes a proactive carbon-reduction position, driving massive uptake in renewables investments and facilitating the much-desired regulatory & policy reforms.
- Commercialization/elimination of gas flaring.
- Resilient gas demand, as it becomes the strongest–growing fossil fuel for the nation.
- Gas for Power
- Gas for Transport (Compressed Natural Gas, Autogas, etc.)
- Gas for Industry & Chemicals
- The other 13 sub-Saharan African nations are expected to take positions similar to what Nigeria has done.

The enhanced renewable energy based on the 2050 Pathway Calculator Demand tool is given in Table 2.

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Table 2: Power supply plan or Electricity Generation Expansion Plan (EGEP), in MWyr, with Enhanced Renewable Energy based on the 2050 Pathway Calculator Demand

Sector	2010	2015	2020	2025	2030	2035	2040	2045	2050
Natural gas	2,099	5,596	13,522	18,775	18,775	18,775	18,775	18,775	18,775
Coal	-	-	-	2,998	9,069	9,069	9,069	2,998	2,998
Self-Generation	12,641	18,085	14,267	16,347	12,768	2,115	-	-	-
Biomass	-	-	899	1,799	2,248	3,598	5,396	6,606	8,405
Nuclear	-	-	-	799	1,519	2,958	5,676	10,953	21,186
Wind	-	-	420	839	1,259	1,679	6,426	10,509	14,928
Hydropower	1,139	1,139	1,943	2,740	3,544	4,341	5,145	5,942	6,745
Small Hydropower	32	32	32	523	768	1,013	1,258	1,504	1,749
Grid Connected Solar PV	-	-	1,232	3,301	19,800	23,006	29,545	43,917	57,067
Concentrated Solar Power for the Grid	-	-	1,997	3,998	5,995	7,995	9,993	11,993	13,991
Off-Grid Solar PV	3	105	2,281	3,721	5,158	16,387	25,765	37,364	42,591
Electricity imports/export	(60)	(60)	(60)	(60)	1,378	2,816	4,254	5,692	7,130
Total	**15,854**	**24,897**	**36,533**	**55,780**	**74,181**	**93,754**	**121,302**	**155,253**	**195,565**

The government of Togo in June 2021 completed and commissioned a 50MW solar power plant shown in Figure 5 with the capacity to provide clean electricity to nearly 160,000 homes and small businesses. This renewable source of energy will reduce the country's dependence on fossil fuels for energy consumption. Also, Morocco constructed the World's Largest Concentrated Solar Power Plant (CSP) with a capacity of 580MW. The Noor Ouarzazate solar energy plant shown in Figure 6 is the country's first renewable energy project and was commissioned in February 2016.

Figure 5: Togo's 50MW Solar PV Plant [23].

The 580 MW CSP Solar Plant in Ouarzazate, Morocco Location has annual solar radiation intensity of 2,635 kWh/m^2 developed in 3 phases as Noor I, II and III covering an area of 2,500 hectares. The three phases were grid connected in 2018, and they offset 760,000 tonnes of carbon dioxide per annum.

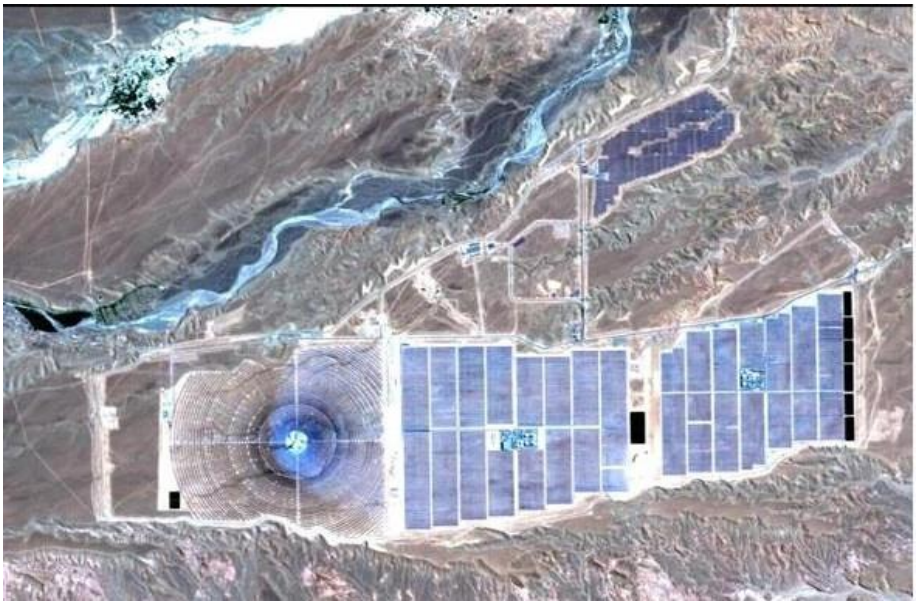

Figure 6: Morocco's CSP Solar Plant [24].

The 310 MW Lake Turkana Wind Energy Project in Kenya shown in Figure 7 below with 365 wind turbines each rated at 850 kW was commissioned in July 2019. The associated overhead electric grid distribution system and a high voltage sub-station are connected to the grid. Compare this with the 10 MW Wind Project in Katsina State.

Figure 7: The 310 MW Lake Turkana Wind Energy Project in Kenya [25].

4. Conclusion

Sub-Saharan African nations can significantly expand their electricity access and move to attain Goal no. 7 of the SDGs by adopting the 2050 Net Zero Agenda in line with their respective NDCs which they all agreed following African Union's decision in 2013. Sub-Saharan African nations should also ensure that their energy transition plans adequately cover their pledges at the UN Climate Change Conference in Glasgow (COP26), like Nigeria's commitment to attain Net Zero Emissions by 2060, and to prepare well for COP 29 at Baku, Azerbaijan in November 2024. In view of preponderance of renewable energy in the 2050 Net Zero Agenda there will be need for local production of the power plant components in Africa and the adoption of the most transparent funding scheme which should be in line with South Africa's Renewable Energy Independent Power Producer Procurement Programme (REIPPP). With about 30% of sub-Saharan Africa being producers of oil & gas and majority of them have vowed to continue using gas. Natural gas should continue to be considered as a key transitional fuel and be developed jointly with renewable energy sources. Since oil-rich nations like Nigeria will have some size-able carbon emitting power plants there is need for such countries to adopt effective carbon capture and sequestration methodologies along with forestry plantations that can serve as effective sinks of the emissions.

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