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CAN KENYA SUPPLY ENERGY WITH 100% RENEWABLE SOURCES?

Eliud Kiprop[1], Kenichi Matsui[2] and Nicholas Maundu[3]

[1]Graduate School of Life and Environmental Science, University of Tsukuba, Tsukuba City, Japan

[2]Faculty of Life and Environmental Science, University of Tsukuba, Tsukuba City, Japan
[3]Ministry of Energy and Petroleum, Nairobi City, Kenya
kipropkengu@gmail.com

Abstract — **Energy demand is rising rapidly in Kenya as a result of rapid population and economic growth. The energy sector faces frequent power outages, low access in rural areas and over-reliance on imported fossil fuels for power generation. The current energy policy emphasizes fossil fuels, but Kenya's Vision 2030 aims to enhance renewable energy generation and supply. Thus, the Kenya National Climate Change Action calls for investment in a low carbon climate resilient pathway. Here the question is: does Kenya have necessary technologies and resources to supply 100% renewable energy? We explore this potential by analyzing the current energy mix situation. We then look at current and projected demand. We found that the country has enough potential technologies and resources to meet its current and future power demands with renewable sources. Kenya is endowed with hydro, geothermal, wind, solar and biomass sources. Geothermal, hydro and wind resources in Kenya are estimated to contribute up to 10,000 MW, 4,750 MW and 30,000 MW respectively. The promotion and adoption of renewable energy can expedite the government's action plan of providing universal access to electric power by 2020. In so doing, the country can lead African countries in green energy policies.**

Keywords—renewable energy; Kenya; energy policy; energy demand; energy potential

I. INTRODUCTION

The energy demand is rising rapidly in Kenya as a result of rapid population and economic growth. With its Vision 2030 program, the Kenyan government has set ambitious goals for future economic growth of the nation, aiming at becoming a middle-income country by 2030 [1]. The main challenge the government faces are inadequate generation capacity arising from insufficient investment in power generation, and its dependence on hydroelectric generation. In a typical month, firms in Kenya experience an average of 6.3 power outages. Each outage lasts for about 5 hours. According to the World Bank, these interruptions cost firms 7.1% of their sales [2, 3]. Kenya Power runs a portal dubbed Power Alert to notify the public about expected shutdowns [4].

In case of power outage or shortage, the public utility buys supplies from Emergency Power Producers (EPPs). EPPs power generators are either medium-speed diesel (MSD) plants (running on heavy fuel oil) or high-speed diesel plants (running on automotive gas oil). The cost of these private energy supplies is high. EPPs currently contribute to more than 30% of the effective capacity with the cost of energy generated from these plants ranging from US 26-36 cents per unit [5, 6].

To address power demand and supply gap and as a solution to the challenges facing the energy sector, the Kenyan government, in 2013, launched an ambitious plan to increase the effective power generation capacity from 1,664 MW to more than 5,000 MW by the end of 2017. Although this goal has not been attained yet, when fully implemented the share of electric power from renewable energy sources will decline from 66% in 2017 to less than 50%. The rest will be supplied mainly from natural gas, thermal and coal power plants [5]. This plan works against Kenya's Intended National Determined Contributions (INDCs) and the Kenya National Climate Change Action Plan. The Plan intends to expand the power generation from geothermal, solar and wind sources [7].

Here the question is: does Kenya have required technologies and resources to supply 100% of its energy from renewable sources? In other words, can Kenya's Vision 2030 program be attained by solely depending on renewable energy? We explore this potential and analyze the current energy mix situation. We then look at current and projected demand and if the available potential can meet the demand. This analysis is limited to the electricity generation sector and does not consider electrification of transport and other sectors.

II. KENYA'S ENERGY MIX

A. Current Energy Mix

Today, Kenya's installed generation capacity remains at 2,336 MW, while the total effective capacity is 2,261 MW, provided that all existing plants are fully available. The effective interconnected capacity is 2,243 MW. The proportion of geothermal capacity increased from 14.8% in 2013 to 28.5% in 2017. This has significantly reduced dependence on hydropower plants. The installed capacity includes 4.65 MW of new capacity in off-grid stations. However, it does not include off-grid capacities decommissioned following grid extension to Mpeketoni, Lamu, Garissa and Hola [6]. The contribution of renewable energy sources in the current energy mix is 67% (Table 1).

TABLE 1. GENERATION MIX- DECEMBER 2017

Generation Type	December 2017		
	Installed MW	*Effective MW*	*% contribution (effective)*
Hydro	826.23	805.02	35.6%
Geothermal	652.00	644.00	28.5%
Thermal (MSD)	716.32	690.12	30.5%
Thermal (Gas Turbines)	60.00	55.00	2.4%
Wind	25.50	25.50	1.128%
Biomass	28.00	23.50	1.0%
Interconnected System	**2,308**	**2,243**	**99.2%**
Off grid thermal	26.24	17.05	0.8%
Off grid wind	0.55	0.52	0.0%
Off grid solar	0.66	0.49	0.0%
Total Capacity MW	**2,336**	**2,261**	**100.0%**

B. *Energy Mix after Completion of 5000+ MW Project*

In the government's formulated generation expansion plan, 5,098 MW of new generation capacity was to be built from July 2013 to December 2016 [5]. However, this delayed and now to be completed by 2020-2021 financial year. Total system generation capacity is targeted to reach 6,670 MW in 2021 if there are no slippages in completion dates of committed projects. After completion of this project, renewable sources will supply less than 50% of energy (Table 2).

III. CURRENT AND PROJECTED POWER DEMAND

Vision 2030 identifies energy and electricity as a key element of Kenya's sustained economic growth and transformation [8]. Development projects recommended under Vision 2030 will increase energy demand [1]. The peak demand reached 1,754 MW on 5th December 2017 against an effective interconnected capacity of 2,243 MW. In particular, Kenya promotes energy intensive activities such as mining, iron and steel production, large-scale irrigation projects, petroleum pipeline operation for both crude and refined fuel oils, and petrochemical production. Furthermore, there are plans to supply electricity to designated rail lines, build shopping malls and airports, and establish new economic zones [5].

From the Model for Analysis of Energy Demand, the peak demand in 2030 will grow to 11,318 MW in low scenario, 21,075 MW in medium scenario, and 31,237 MW in high scenario. The current peak load is expected to grow 10 times by 2030 [9]. From the same model, the projected demand for 2017 was 2,410 MW, 2,676 MW and 2,849 MW for low, medium and high scenarios respectively. In December 2017, the installed capacity was 2,336 MW while the actual peak demand was 1,754 MW [6]. This implies that the low scenario gives a better power demand projection for Kenya. However, in the Kenyan

TABLE 2. ENERGY MIX AFTER COMPLETION OF 5000+ MW PROJECT

Generation Type	*Capacity*	*Percentage*
Hydro	794	12%
Geothermal	1887	28%
Thermal	432	6%
Wind	635	9%
Coal	1920	28%
Liquefied natural gas (LNG)	1050	16%
Co-generation	44	1%
Total	**6762**	**100%**

system, a suppressed demand of about 100 MW has been assumed in recent years [9].

Therefore, accounting for the suppressed demand reference scenario gives a better estimation of peak demand, which will be 21,075 MW in 2030. Between 2010 and 2017, the highest peak demand growth rate was 9.5%. Considering this growth rate the power demand in 2030 will be way lower than 21,075 MW, which was projected by the government.

IV. RENEWABLE ENERGY RESOURCE POTENTIAL

This section reviews the available energy potential of Kenya's renewable energy sources for electricity generation. According to the government's energy plan, the contribution of biomass in Kenya's future energy mix will be less than 1%. So, the focus is on hydropower, geothermal, wind and solar energy sources. Considering the variable nature of renewable energy sources, it also examines power transmission and distance from the national grid as well as potential site locations.

A. *Hydropower energy potential*

In December 2014, the installed hydropower generation capacity was 821 MW, equivalent to 38% of the total installed capacity. The hydroelectric power (above 10 MW) potential was estimated to be at least 5,605 GWh/yr. This hydropower potential is located in five geographical regions, representing Kenya's major drainage basins: Lake Victoria (295 MW), the Rift Valley (345 MW), the Athi River (84 MW), the Tana River (800 MW) and the Ewaso Ng'iro North River (146 MW) [8]. Fig. 1 shows the major drainage basins and principal centers of population in Kenya.

Adding the total run of river potential, pump back station at Suguta Valley at the southern tip of Lake Turkana, and, subtracting the potential occasioned by constraints in protected areas it is estimated that a total of approximately 2,670.27 MW exists [11]. This figure is near to 3,000 MW reported by other researchers and the government [5, 8, 12]. 25 MW of this potential has been developed with the Government running schemes totaling 15 MW while the private developers run about 10 MW [8].

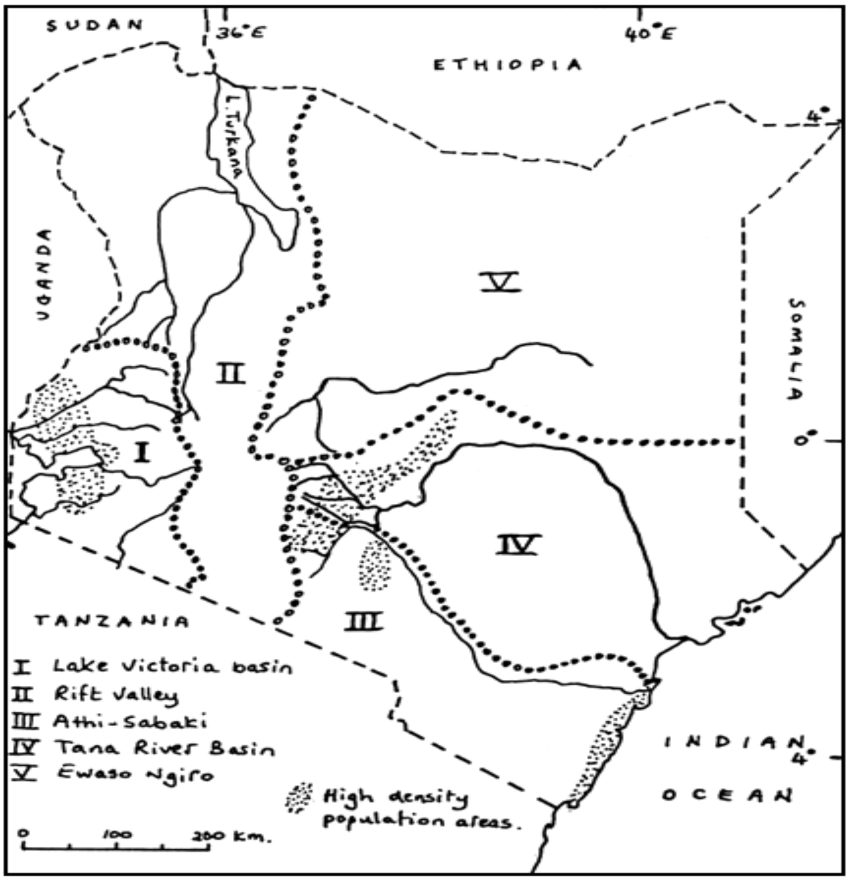

Fig. 1. The major drainage basins and principal centers of population in Kenya

The combined total potential of small and large hydro power is approximately 4,750 MW which is lower than the estimates of 1991 that amounted to approximately 30,000 GWh/yr, representing 6,000 MW of installed capacity [10, 12]. Current installed capacity is 826 MW constituting 35.6% of effective capacity [6].

B. *Geothermal energy potential*

Geothermal is abundant in Kenya [13]. Large potential sources exist along the Kenyan Rift valley that traverse the country from north to south (Fig. 2). The central part of Kenyan Rift Valley has a potential of generating between 7,000 MW and 10,000 MW. The areas examined include Suswa, Longonot, Olkaria, Eburru, Menengai, Lakes Bogoria and Baringo, Korosi and Paka [5, 13, 14].

Under the 5,000+ MW program, it is intended to develop 887 MW of geothermal energy from Olkaria, Menengai, Baringo, Suswa, Longonot and Akiira areas. Proposed projects entail drilling of a total of 400 geothermal wells by different companies like KenGen, the Geothermal Development Company (GDC), African Geothermal International Limited (AGIL) and Marine Power Generation (MPG) [5]. Between 2013 and 2017, Kenya gained 411 MW of geothermal power to the national grid. As of today, it generates 652 MW of geothermal energy in total [6].

C. *Wind energy potential*

As Kenya is located within the equatorial region, it is not expected to have strong winds. However, many locations in Kenya actually possess substantial wind energy potentials due to its complex topographical features, varying surface terrains, and large inland lakes [16]. Kenya has one of the highest and most-studied wind power potentials in Africa [17]. In 2013, the Kenyan government, commissioned WinDForce to carry out wind assessment across the country. The result shows that over 73% of the country has more than 6 m/s of annual mean wind-speeds at 100 meters above ground level (m.a.g.l) (Fig.3). In particular, northern and eastern regions (e.g., Turkana, Marsabit) and the Coastal region can support large-scale wind power generation [18].

In August 2009, the first wind farm with the capacity of 5.1 MW started operation at Ngong Hills near Nairobi. This was financed by a Belgium government loan. It consists of six turbines (height 49 m) rated at 850 kW.

The current installed capacity connected to the grid stands at 25.5 MW and 0.55 MW off-grid. The construction of Lake Turkana Wind Power Plant, the biggest wind power plant in Africa, was completed and awaiting completion of transmission lines for connection to the national grid [6].

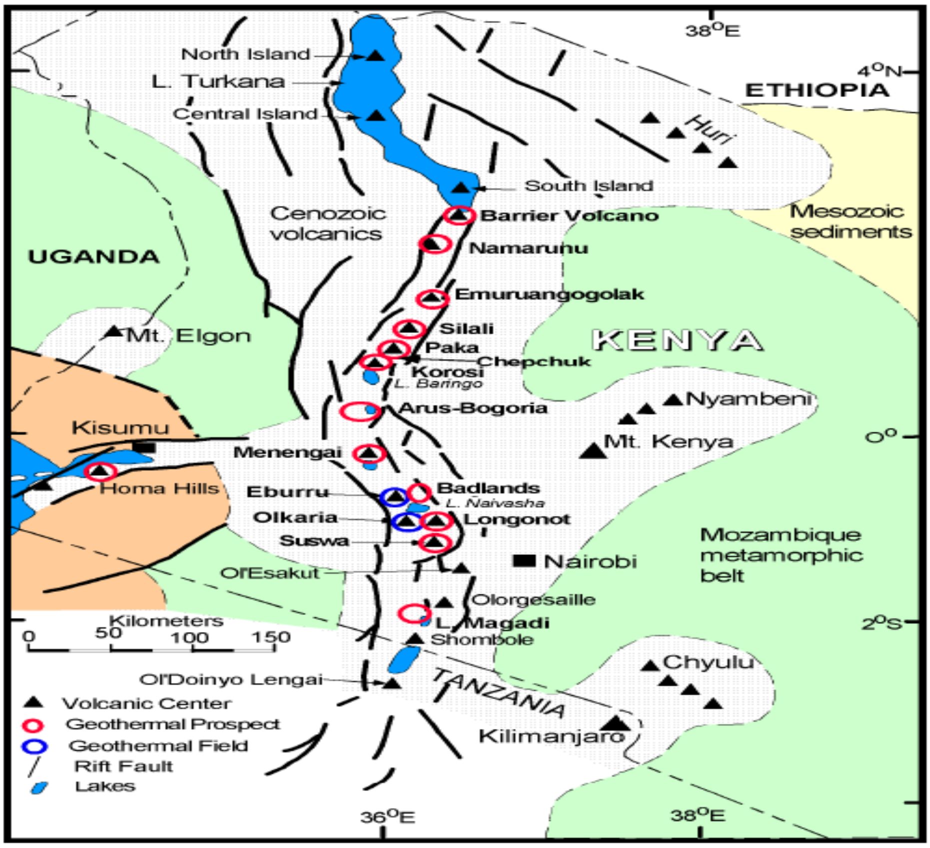

Fig. 2. Simplified geological map of Kenya showing locations of the geothermal fields and prospects

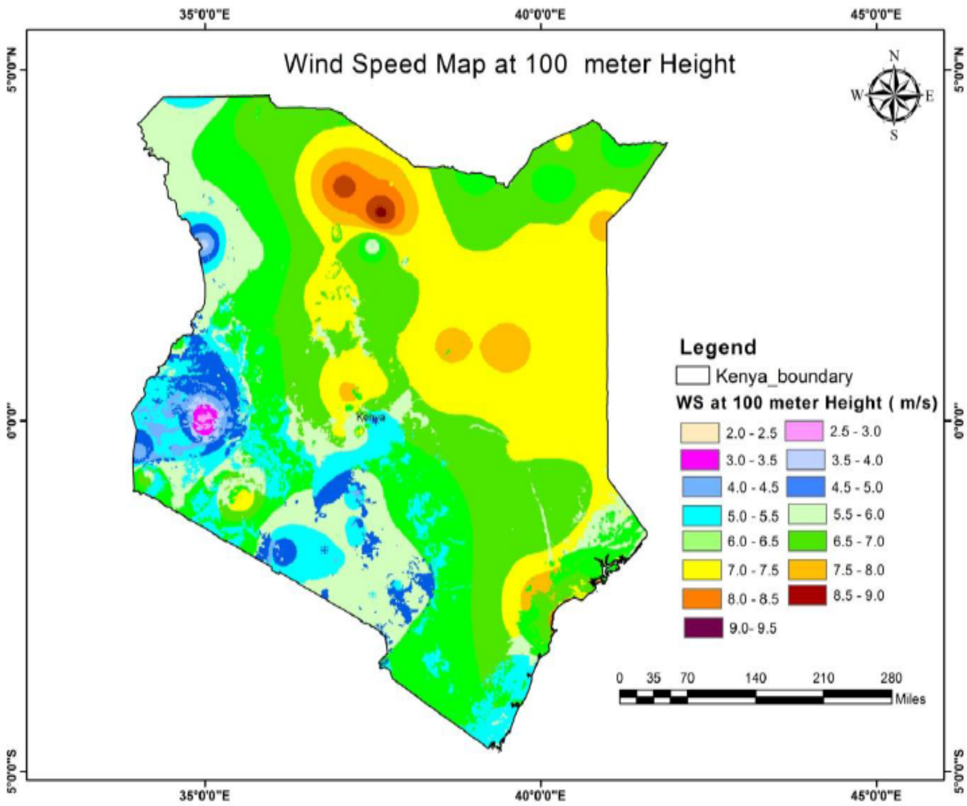

Fig. 3. Wind speed map of Kenya at 100 m height above ground level

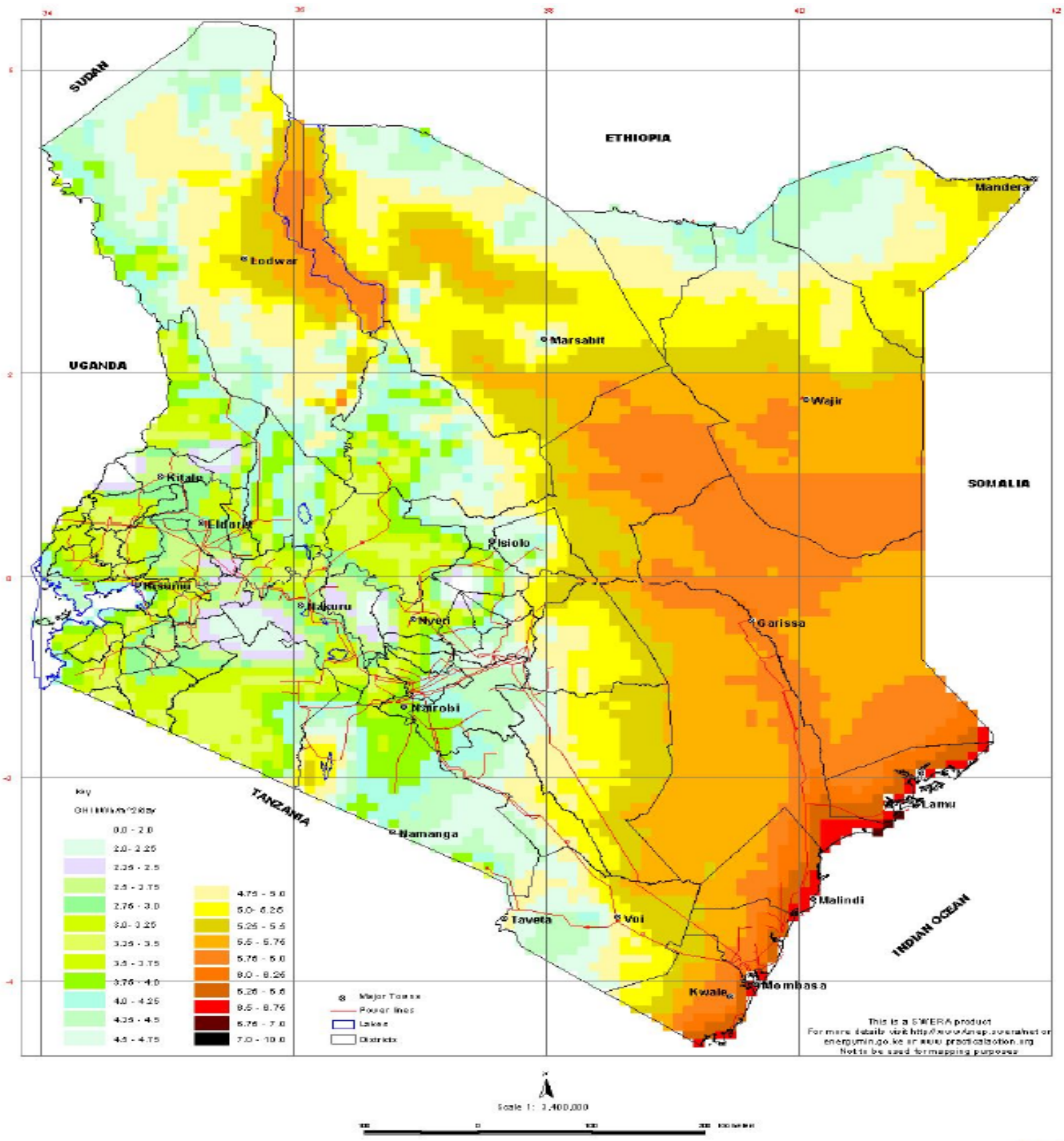

Fig. 4. Map showing 3 year (2000-2002) average Global Horizontal Irradiance for Kenya

D. *Solar energy potential*

Kenya receives high irradiance, and most of the northern and north eastern areas are solar energy hotspots. Kenya has a potential of 4-6 kWh/m^2/day of solar energy, equivalent to 250 million tons of oil per day [9, 12]. Kenya has high insolation rates with an average of 5 peak sunshine hours (The equivalent number of hours per day when solar irradiance averages at 1,000 W/m^2). The total amount of annual energy production ranges from 700 kWh in mountainous regions to 2,650 kWh in arid and semi-arid regions (Fig.4). Nevertheless, the solar PV systems are used mainly for telecommunication as well as the cathodic protection of pipelines, lighting and water pumping [15]. Kenya has high solar radiation energy potential with approximately 188,284 km^2 (32.4%) of the total land area predicted to receive between 5.0-5.5 kWh/m^2/day of solar radiation.

154,185 km^2 (26.5%) of the total land area is estimated to have a potential of receiving between 5.5-6.0 kWh/m^2/day. 58,800 km^2 (10.1%) of the total land area is estimated to receive between 6.0-6.5 kWh/m^2/day of solar radiation. In the highest solar energy potential class, approximately 4,230 km^2 (0.7%) of the land area was characterized to produce more than 6.5 kWh/m^2/day of solar radiation. In the lowest solar energy potential category, approximately 176,170 km^2 (30.3%) of the land area is estimated to receive less than 5 kWh/m^2/day [19, 20].

It is difficult to estimate the actual installed capacity of solar power since most of the installation is small-scale and household applications. Current off-grid solar installed capacity is estimated to be 0.66 MW [6].

V. CONCLUSION

A substantial proportion of renewable energy resources are unexploited. Of the potential renewable sources, Kenya has harnessed only less than 20% of its hydropower sources, approximately 7% of the potential geothermal resources and much smaller proportions of proven wind and solar power potentials. The main challenge seems to lie on the policies and priorities of the government. In conclusion, Kenya has sufficient renewable energy sources to meet the entire power demand projected for 2030 and beyond. At the same time, these 100% renewable energy help achieve Kenya's Vision 2030 in a sustainable way.

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