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Reliability and Availability of Renewable Energy Sources in Kenya: A Review

Keter Amos Kiprono[1] & Hoseah Kiplagat[2]

[1]Rift Valley Technical Training Institute
[2] University of Eldoret, Eldoret, Kenya

Abstract

The research sought to evaluate the reliability and availability of renewable energy sources in Kenya by examining the available literature regarding the state of energy production and consumption of the renewable energy sources. Several studies have been conducted to establish the capacity of the renewable electrical power sources including hydroelectric power, geothermal sources, wind power, solar energy and biofuels. Regarding production of electricity, the existing capacity is barely able to keep up with demand. The research used systematic review as the methodology of collecting relevant data for analysis. Given that more than 38% (2021) of Kenya's electricity comes from hydropower, the situation is particularly difficult during the dry months of the year when water levels are low. Capacity gaps are then compensated by expensive thermal generation based on fossil fuels. Geothermal power has the capacity to be the most significant source of renewable energy with a potential of up to 7000MW. The reliability indices of the renewable energy sources, based on System Average Interruption Frequency Index (SAIFI) are at 1.98 (SAIFI) and at 4.37, based on the Customer Average Interruption Duration Index (CAIDI), which are below the international global standards. The research concluded that increased consumption of electricity, availability of alternate energy sources, amount of restoration time and number of planned interruptions have a significance influence on the reliability of a renewable energy source, with restoration time being the most significant. It is therefore recommended that new technologies and innovations that lead to reduced power interruptions and greenhouse gas emission be adopted.

Keywords: ***Reliability, availability, renewable energy, alternate***

Introduction

Reliability and availability are important factors taken into consideration when evaluating the feasibility of renewable energy resources as a replacement for fossil fuels. Research on these topics helps to identify any limitations or challenges associated with the integration of renewable energy into the power grid, and can inform the development of policies and technologies to address these issues. Research on the reliability and availability of renewable energy resources is crucial for understanding the potential of these resources as a replacement for fossil fuels and for developing strategies to effectively integrate them into the power grid (Lu et al, 2018).

Evaluating the renewable energy scenario in Kenya, several studies have been conducted to establish the capacity of the renewable electrical power sources including hydroelectric power, Geothermal sources, wind power, solar energy and Bio-fuels. In regard to production of electricity, the existing capacity is barely able to keep up with demand. Given that more than 38% (KNBS, 2021) of Kenya's electricity comes from hydropower, the situation is particularly difficult during the dry months of the year when water levels are low. Capacity gaps are then compensated by expensive thermal generation based on fossil fuels. Increasing economic activities and a rising national population lead to a higher domestic energy demand in Kenya,

which is mostly satisfied by imports of foreign energy, mainly hydro power from Ethiopia (KNBS, 2021).

Literature Review

The high cost of energy imports significantly slows economic growth in the country. The problem of high energy costs is supplemented by the unreliability of energy supply infrastructure. On average, Kenyan companies lose nearly 10% of their production because of power outages and fluctuations. Sustainable, affordable and reliable domestic energy for all citizens is, therefore, declared a priority factor in national policy (IEA, 2019a).

Accessing energy is crucial for the development of industries since it gives important services that are necessary in enhancing the quality of life. Ensuring adequate, affordable, and reliable service in energy sector with less negative effects on the environment has not only been important for Kenya but also vital for a lot of countries especially in Africa that are struggling to achieve their daily demand of energy (Castro et al., 2019).

Currently Kenya is among the countries in the Sub-Saharan Africa (SSA) that are still in energy crisis and socio-economic deficit that cannot be disputed. Accessibility to modern and renewable energy for a long time has been considered to be a privilege in Kenya. Furthermore, Kenya is among countries in SSA that are ranked least in relation to annual growth of Gross Domestic Product (GDP) as well as contemporary developmental strides. Globally, SSA region is the most undeveloped among the sub-regions in the world and has huge number of rural settlements which is scattered. Because of the nature of rural settlement which is scattered, it results in the region being weak technologically and economically to the development of its power sector of which Kenya cannot be left out (George, 2019).

The major problem facing the country is the lack of investment in power production and its reliance on hydroelectric power. Kenyan companies are faced with power outage, which amounts to loss of an average of 6.3 million Kenyan shillings in a single month (Maende & Alwanga, 2020). Every downtime takes around five hours. Per the World Bank estimates, such distractions cost businesses 7.1% decrease in overall sales. Kenya Power and Lighting Company maintains a website called Power Alert which alerts users during the expected shutdowns (Kimani et al, 2019).

The aim of this research was to evaluate the reliability and availability of renewable energy and to examine the potential energy resources from renewable sources and their present state of exploitation in Kenya. Since the demand for energy in Kenya is on the rise alongside the increase in population, the country spends a lot of funds on importation of energy. This review therefore also seeks to explore other sustainable sources of renewable energies which are available in Kenya including biofuel, wind, solar, geothermal, and their reliability.

Methodology

The research broadly followed the guidelines of reviews. A systematic review is a type of research methodology that involves a comprehensive and rigorous search, critical appraisal, and synthesis of existing research on a specific topic. It is considered a high-level form of evidence, and is often used to inform clinical practice guidelines and policy decisions (Moher et al, 2009).

The review procedure included literature collection and analysis. Potentially relevant literature was identified through multiple mechanisms, including searches in major bibliographic databases using a variety of search algorithms and combinations of key words, review of reference lists of relevant literature, and specialized searches on websites of known studies

series. All collected literature was first categorized by content and added to a bibliographic database. The literature collection methods described here apply to all classes of electricity generation technologies reviewed in this report.

Findings

Kenya Renewable Energy Scenario

According to the Ministry of Energy and Petroleum in Kenya, published reports from the Energy and Petroleum Regulatory Authority (EPRA, 2020) shows that the country has an installed capacity for renewable energy of 2179 MW, with the majority coming from hydroelectric power at 837 MW, followed by geothermal at 823 MW, wind at 336 MW, solar at 95 MW and Bioenergy at 88 MW.

In terms of actual energy production, hydroelectric power accounts for the most at 38%, followed by geothermal at 37%, wind at 15.4%, solar at 4.4% and bioenergy at 4.0%. These figures were reported in the Kenya Economic Survey 2021, which is published by the Kenya National Bureau of Statistics. It's worth noting that Kenya is also making significant investments in renewable energy, with plans to increase the country's installed capacity to 5,000 MW by 2030 through a mix of hydro, geothermal, wind, and solar power (KNBS, 2021).

Renewable Energy Potential in Kenya

According to a study by the International Renewable Energy Agency (IRENA, 2019), Kenya has the potential to increase the share of renewable energy in its power mix to 60% by 2030. This can be achieved through the expansion of hydroelectric, geothermal, and wind power, as well as the development of solar power.

Geothermal power is one of the most significant sources of renewable energy in Kenya, with an estimated potential capacity of 7,000 MW. The country has several geothermal power plants in operation, including the Ol-Karia Geothermal Power Station, which is the largest geothermal power plant in Africa. Hydroelectric power is also a significant source of renewable energy in Kenya, with an estimated potential capacity of 5,000 MW. The country has several hydroelectric power plants in operation, including the Seven Forks Hydroelectric Power Station, which is the largest hydroelectric power station in East Africa.

Wind power is also an important source of renewable energy in Kenya, with an estimated potential capacity of 2,000 MW. The country has several wind power projects in operation or under development, including the Lake Turkana Wind Power Project, which is the largest wind power project in Africa. Solar power is also a growing source of renewable energy in Kenya, with an increasing number of solar power projects in operation or under development. The Kenyan government has set a target of generating 5,000 MW of solar power by 2030.

Kenya has significant potential for bio-energy production, particularly in the form of biomass from crops such as sugarcane and cassava. These crops can be used to produce electricity through cogeneration at sugar factories or used as feed stocks for bio-fuels. Additionally, Kenya has potential for the production of biogas from livestock waste and organic waste from urban areas (IRENA, 2017).

Municipal waste may be used in creation of methane gas that can generate electricity. Turning of waste to energy undergoes an advanced process which is applied in different regions of the globe. Nairobi which is Kenya's capital city generates a total of 803,000 tons of solid waste which is produced and dumped annually at the Dandora dump site. Mombasa, Nakuru and Kisumu are the main cities after Nairobi and they generate 1124 million tonnes of waste. An

overall of 5.26 million tons per year are estimated to be produced in urban areas across Kenya (Kirumba, 2014). Municipal waste hasn't been used for electricity storage and is instead disposed by open burning.

In terms of oceanic energy potential, Kenya has potential for the development of wave and tidal energy along its coastline. The Kenya Marine and Fisheries Research Institute (KMFRI, 2016) has identified several potential sites for the development of wave energy along the Kenyan coast.

Average Power Consumption in Kenya

According to the Energy and Petroleum Regulatory Authority (EPRA, 2019) of Kenya, the average electricity consumption per household in Kenya was approximately 200 kilowatt hours (kWh) per month in 2019. According to Kenya National Bureau of Statistics (KNBS) report of 2020, the total electricity consumption in Kenya in 2019 was 12, 564 GWh (Giga-watt hours). The report also indicates that the commercial sector consumed the highest percentage of electricity (42.2%) followed by the industrial sector (35.9%), and the household sector accounted for 21.9% of the total electricity consumption.

The Production and consumption data is illustrated in tabular form from research publications made by EPRA and IEA as illustrated in table 1. As utility-scale projects face a lengthy planning process, developers have started to target captive generation projects. The approval process for on-site power generation up to 1MW is far simpler and all projects below 3MW do not require a generation permit, which can be a lengthy process to obtain. The generation technology of choice is typically solar, although small hydro has been favoured in some regions, especially by the Kenya Tea Development Agency.

Table 1

Average Renewable Energy Production in Kenya, (EPRA, 2020)

Generation Type	MW	% Contribution
Hydro-Electric	837	38.4
Geothermal	823	37.8
Solar	95	4.4
Wind	336	15.4
Bioenergy	88	4.01
Oceanic/Tidal Wave	0	0

Reliability Indices of Renewable Energy Sources

A report from the Energy and Petroleum Regulatory Authority (EPRA, 2020), shows that the reliability indices of Renewable energy sources are below the international best practices. The Authority used the System Average Interruption Frequency Index (SAIFI) and Customer Average Interruption Duration Index (CAIDI) to measure the reliability of power supply in the country.

$$SAIFI = \frac{Total\ Number\ of\ Customer\ Interruptions\ per\ Reporting\ Period}{Total\ Number\ of\ Customers\ Served\ per\ Reporting\ Period}$$

SAIFI (System Average Interruption Frequency Index) is a reliability index that measures the frequency of power outages experienced by customers of a power distribution system. It is defined as the total number of customer interruptions (or power outages) during a specific period of time, divided by the total number of customers served by the system during that period of time. SAIFI is commonly used by utilities and regulators to evaluate the performance of power distribution systems and to identify areas that need improvement (IEEE, 1998).

According to Lee and Billiton (1992), the CAIDI (Customer Average Interruption Duration Index) reliability index is a measure of the average duration of power outages experienced by customers of an electric utility. It is typically expressed in minutes/year. This index is commonly used in the electric utility industry to evaluate the reliability of power supply to customers.

$$CAIDI = \frac{Sum\ of\ Customer\ Interruption\ Durations\ per\ Reporting\ Period}{Total\ Number\ of\ Customers\ Interrupted\ per\ Reporting\ Period}$$

Statistically, the country has enjoyed reliable power supply by the single power distributor, Kenya Power and Lighting Company. In the period of January 2019 to June 2020 the average SAIFI was 1.98, while CAIDI was 4.37 over the same period. The Low SAIFI and CAIDI recorded over the period is a manifestation of the vast upgrade of the transmission and distribution system by the government. The performance is still below the international best practices of less 1 and 2.5 respectively. The high rate of power loss is a clear indication that much more needs to be done to improve on reliability of supply to customers (EPRA, 2020).

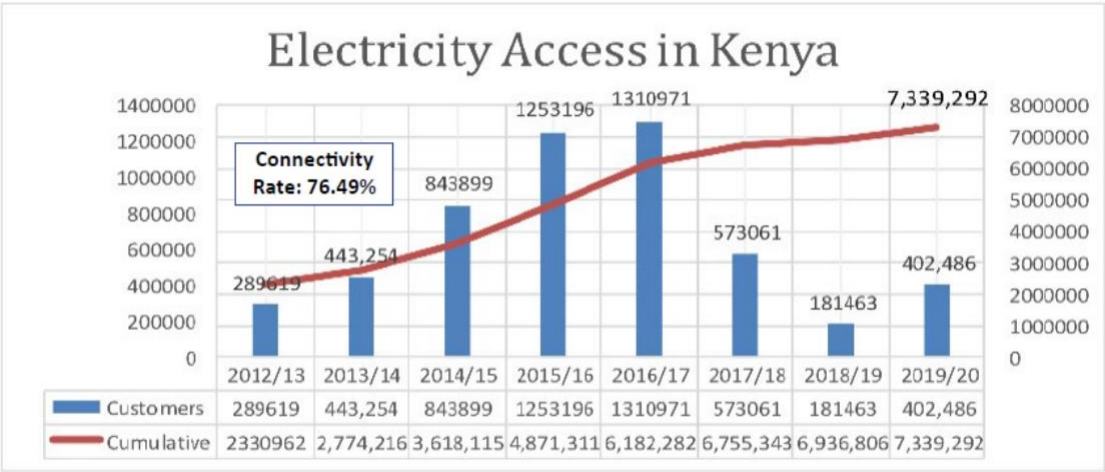
The reports by EPRA are corroborated by research done by Thuku (2017), that showed that increased consumption of electricity, availability of alternate energy sources, amount of restoration time and number of planned interruptions have a significance influence on the reliability of a renewable energy source, with restoration time being the most significant.

Accessibility of Renewable Energy Sources

The total number of connected customers increased from 2.3 million in 2013 to 7.3 million by the end of January 2020. The country has passed the 75% household connectivity threshold, establishing her as a regional leader in electricity access at 76.49%. Between January 2019 and January 2020, 402,486 customers were connected to the national grid; thus, leading to growth from 6,936,806 customers in January 2019 to 7,339,202 power consumers in January 2020. Kenya is currently the only East African country with electricity access of over 75% of her population, as illustrated by the Figure 1 (EPRA, 2020).

Figure 1

Electricity Access in Kenya (EPRA, 2020)



Source: EPRA and Kenya Power

Contribution of Renewable Energy

Renewable energy has positive contribution through addressing the issue of the climate and problems which are related to the environment. For example, biodiesel has potential of reducing amount of greenhouse gases that are emitted to the atmosphere. This is because of the minimal emission of the greenhouses gases as compared to the fossil fuels. Biodiesel development also leads to creation of jobs which improved the standard of living. This is because in Kenya and in Africa in general, women have responsibility to secure energy as well as the water in their households in addition to doing majority of the work in the farm. Commercializing some of the energy form such as biodiesel can help liberate women from the economic burdens and labour which are toilsome. And hence making them financially independent (Diogenes et al., 2018).

Conclusion

Kenya has a stable and expanding energy supply, which is central to its ambition to establish itself as an industrialized middle-income country, as set out in its Vision 2030 and the Big Four Agenda development strategies. The nation has a rich energy mix where renewable energy sources already play a significant role in power generation, particularly in the case of geothermal, solar and wind which have room for expansion. With renewable sources accounting for over 85% of power generated, Kenya continues to improve on her carbon footprint. The Energy Act 2019 and Petroleum Act 2019 will further strengthen the country's position in both electricity and renewable energy.

The country exhibits a great potential in the exploitation of the untapped areas of renewable energy especially Oceanic and Tidal wave energy sources. If the numbers of planned and unplanned interruptions are to be significantly reduced and the reliability index be improved to meet international global standards, then all possible renewable energy avenues have to be fully exploited.

Recommendations

i). EPRA should publish the Energy Statistics report annually to inform the public, consumers and investors on the key energy trends in the country.

ii). Expansion of renewable energy sources such as wind, solar and geothermal power generation can be achieved by providing incentives such as tax exemption, speedy

approval processes to the interested parties and provision of a framework for private sector investment.

iii). Further investment in expanding and modernizing the transmission network to reach more parts of the country and minimize losses

iv). Adaptation of new technologies and innovations that lead to reduced power interruptions and greenhouse gas emissions.

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