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Challenges and Prospects of Electricity Generation and Usage in Sub-Saharan Africa

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Abstract
Electricity production and consumption play a crucial role in the development trajectory of countries, especially in Africa, where challenges related to affordability and sustainability persist. Despite the abundance of renewable and non-renewable energy sources, achieving universal access to electricity remains a significant challenge. A reliable and affordable energy system is still far from being achieved in many African countries, hampering economic and social progress. This paper analyses the specific challenges faced by sub-Saharan Africa, particularly in Angola, the Democratic Republic of Congo (DRC), and Mozambique, in achieving clean energy goals electricity assess to all. Through a comprehensive analysis of current conditions in the electricity sector, the study identifies the main obstacles and discusses potential solutions. Based on a critical review of existing literature, the paper describes the motivations, objectives and provides information on the electricity sector in the selected countries. The findings reveal that while access to electricity remains extremely low in these countries, particularly in rural areas, there is a remarkable disparity between them. Our findings emphasize the vital role of access to electricity in poverty reduction and economic growth in the region, but access rates remain below 51%, with rural areas being disproportionately poor.

Keywords
Sub-Saharan Africa, Electricity, Sustainable Development

Introduction

Access to electricity is crucial for socio-economic development in Africa, yet it remains a pressing challenge. The continent grapples with issues ranging from energy scarcity to inadequate energy policies. Energy scarcity often arises not solely from a deficiency in energy resources but also from inadequate or non-existent energy policies [1]. Access to electricity services is a prerequisite for sustainable development and a fundamental source of poverty alleviation. However, in 2015, over than 1.1 billion, individuals globally lucked access to electricity, with nearly 97% residing in sub-Saharan Africa and developing Asia. Sub-Saharan Africa had an electrification rate of just 43%, significantly lower than the global average of 82%, thus indicating its status as the region with the lowest electrification rate worldwide [2].

Following Africa, developing Asia boasts an electrification rate of 83%, with the Middle East at 93% and Latin America at 95%. It is worth mentioning that rural areas exhibit the lowest electrification rates across all regions [3]. African countries and their leaders have expressed enormous concerns about the issues of sustainable development at the center of their policies. In terms of development indices, energy consumption is a recognized indicator [4].

Most African regions suffer from the main challenges facing developing countries and require critical attention including poverty, uneven distribution of national income, and several social problems [5]. Currently, nearly 600 million people in Africa lack access to electricity, and approximately one billion Africans do not have access to clean cooking energy [2]. Unfortunately, most African countries lack a large part of the basic infrastructure of the electrical energy network from its production, transportation

and distribution. In this context 1 renewable energy (RE) emerges as a promising avenue for African countries to bridge their electricity gap [6]. However, despite the continent's abundant RE resources, investment in RE has remained relatively low in recent decades, primarily due to funding and financing challenges [7].

The African continent, particularly West Africa, requires an electricity forecast plan, as approximately 171 million people lack access to electricity, with 18% residing in urban areas and 82% in rural areas. On the other hand, people with access to electricity suffer frequent unplanned power blackouts due to insufficient generation capacity [8].

This research adopts a multiple case study approach to analyze three different sub-Saharan African countries, namely Angola, the Democratic Republic of Congo (DRC), and Mozambique, all of them economies designated by the United Nations as least developed countries. The study aims to assess the potential for using RE in these countries and to compare electricity rates between rural and urban areas. This comparative analysis enables the identification of strategies, such as leveraging renewable sources, to enhance electricity access in both rural and urban areas, thereby addressing key sustainable development challenges related to healthcare and education across the three countries. The primary research questions addressed in this study are:

- How do electricity access rates and renewable energy potential vary across Angola, the DRC, and Mozambique? and what are the implications for the lack of access to electricity sustainable energy development in Sub-Saharan Africa? To answer these research questions, bibliographic and documentary research procedures were considered, based on sources such as books, published documents, websites, and papers published in scientific journals, and on the current situation of renewable energy use in the world and the three countries under study.
- The paper is organized as follows. Following this introduction, the next section provides in-depth case studies of Angola, the DRC, and Mozambique, augmented with country-specific data. Then, the methodology employed and data collected are described, followed by the main results derived from the analysis. A discussion of these results follows, focusing on their implications from a sustainable development perspective. Finally, the paper concludes with a summary of the key findings and conclusions drawn from the study.

Literature Review

Angola is the sixth largest African country with an area of 1,246,700 km2. Situated on the west coast of southern Africa, south of the equator, its main territory is bordered to the north and north-east and its current population is 36 million [9]. The country is included in the United Nations list of least-developed countries in the world. The country's Human Development Index (HDI) was 0.586 in 2022, placing it 148th out of 191 countries [10]. In Angola, the access to electricity is notably limited. One of the biggest challenges for the country is how to solve its energy needs for the coming decades. Angola's main sources of electricity are hydroelectric power, diesel and natural gas. Projects are underway to utilize solar resources, which are at an experimental stage and will operate in a hybrid system with diesel.

Angola has vast endogenous energy resources, encompassing significant oil and gas reserves, while the characteristics of its rivers place the country with one of the most significant potentials for hydroelectric power production on the African continent [11]. At the same time, the extent of its territory and strategic geographic location provides the country with significant solar potential. Nevertheless, despite these abundant resources, access to electricity remains a fundamental challenge in Angola [12].

The vast size of the country, the distribution of its population, together with high demographic growth rates, and difficult accessibility conditions collectively pose significant challenges to ensuring the complete electrification of the nation. In 2021, only around 48% of Angolans had access to electricity, 37.8% of which were connected to the national grid. Most of the electrified areas are located on the country's northern coast and near the capital, Luanda. The southern and central regions still have a very low electrification rate [10]. The large size of the territory, the dispersion of the population, the high rate of demographic growth and poor accessibility conditions, along with high costs, create difficulties in ensuring total electrification. Most of the electrified areas are concentrated along the country's northern coast, particularly near the capital, Luanda.

The Angolan electricity sector has been slowly increasing its generation capacity. Presently, the country relies on three main technologies for electricity production: large hydro, thermal and renewables. In 2021, the total installed capacity for electricity production amounted to 5880 MW. This capacity comprised 3676 MW of hydroelectric generation, 2169 MW of thermal generation, and 35 MW of hybrid production combining solar and diesel sources [13]. The Angolan state aims to achieve a national electrification rate of 60% by 2025, with at least 7.5% of the electricity generated in the country coming from non-large hydro renewable energy sources (biomass, solar, wind and mini hydro) by 2025 [14].

The DRC is in the center of sub-Saharan Africa and is the 11th largest country in the world covering a land mass equal to that of the United States east of the Mississippi, and second largest in Africa after Algeria. By the year 2023, the population of DRC was estimated to be 102 million, whereby 54% are rural dwellers DR Congo Population [15] Worldometer. The DRC's potential renewable energy sources include hydropower, biomass, solar, wind and geothermal. The United States Agency for International Development (USAID) reports the DRC generation capacity as follows: hydroelectric - 2792 MW, gas - 2.2 MW, solar - 1 MW, and other sources - 48.8 MW, totaling 2844 MW [16]. The International Water Activist Group called International Rivers [17] estimates that the Democratic Republic of Congo (DRC) possesses an untapped hydroelectric generation potential of 100,000 MW. However, this potential has not been utilized to meet the electricity needs of the country's population, as the government has directed its focus towards selling electricity to mines, foreign markets, and the affluent population, rather than prioritizing access for the impoverished. The DRC's rural access to electricity stands at 1% recorded in the SDG7 [18]. This country has one of the lowest rural electrification rates globally, resulting in 94% of the population relying on biomass for cooking and lighting purposes [19].

The Republic of Mozambique is a country located in the southeast of the African continent, a member of the Southern African Development Community (SADC), with around 32 million in-

habitants. In the Republic of Mozambique, around 68.51% of the population has no access to electricity, with an even lower access rate in rural areas, where around 66.6% of the population lives. For this rural population, access rates remain around 3.81% [20]. Despite these challenges, the country has significant potential for renewable and non-renewable energy sources. These resources, coupled with the commitments made to guarantee universal access to electricity, population growth projections and increased demand for electricity, present substantial investment and long-term business opportunities in the electricity sector. However, economic, social and cultural obstacles pose uncertainties that must be carefully considered in the decision-making process for investment in rural electrification infrastructure, both in Mozambique and throughout sub-Saharan Africa [21]. Security of supply remains however as a main problem to be solved, as it is well recognized that electricity unreliability and expenses negatively contribute to the generation of sustainable livelihoods and negatively influence the country's production and productive uses of electricity by enterprises [22].

Methods

This study addressed the evaluation of electricity rate in rural and urban areas of Angola, the DRC and Mozambique and the possible implementations of energy production through renewable sources to supply electricity in isolated locations without access to the electricity grid (off-grid systems). This research adopts a qualitative approach to investigate electricity access rates and renewable energy potential in Angola, the DRC, and Mozambique. The trends in electricity access rates over time were analyzed, and disparities between rural and urban areas were compared. By employing a comprehensive research methodology, this study endeavors to understand some of the energy challenges and opportunities in Sub-Saharan Africa while aiming to inform evidence-based policy interventions for sustainable energy development. The selection of case study countries is based on specific criteria including geographic diversity, urban-rural divide, and the level of development of energy infrastructure. The primary data sources comprise reports from esteemed international organizations, scholarly literature, and governmental reports.

Results

The study carried out in this paper points out that there are several renewable energy resources in Angola, the DRC and Mozambique, such as solar, wind and hydroelectric, which, if well exploited, would reduce the current high rate of energy shortages in these countries. Angola continues to grapple with a deficit in its electricity system, leading to inadequate access to electricity among the population, to address this pressing issue, there is a crucial need to explore new energy supply and planning models. Electricity planning emerges as a promising option for mitigating the current situation and ensuring more reliable and widespread access to electricity for Angolan citizens [23].

In the case of the DRC, the current electrification rate is very low, around 79.23% of the population has no access to electricity, and this rate could increase by 2030. The country has made a projection of energy demand until 2025, with residential loads expected to consume 77% of the DRC's electricity. The industrial sector is expected to account for 20.5% of consumption, while agriculture, transport and public services collectively consume around 2.5%. Regardless of these plans, the DRC continues to have a deficit in its electricity system and the population's access to electricity remains insufficient [24].

The DRC has a source of renewable hydroelectricity that could improve the current situation, as is the case of the Congo River, with its basin located along the Equator, with the mentioned potential of around 100,000 MW, could be explored in 780 locations in 145 territories and 76,000 villages. Unfortunately, most of the energy from this Congo River is unexploited, representing only 2.5% of total electricity in 2009, while biomass represented around 95% and the rest was thermal [10]. In addition to the Congo River, DRC has several other unexploited endogenous energy resources, that is, municipal solid waste (MSW) with the potential to generate 96 MWh of electricity from 200 metric tons of MSW [25]. Furthermore, the DRC boasts approximately 128,004,198 hectares (ha) of forestry, which covers 54% of the total area. Forest products could be harnessed to provide electricity if they were ecologically harnessed to ensure the continuation and survival of the forest [26].

In the case of Mozambique, access to energy in rural areas is at a considerable low rate, and the challenges are even greater for the country in terms of energy supply. The country continues to face a deficit in its electricity system, resulting in inadequate access to electricity for the population.

The African continent, particularly the sub-Saharan part, has a variety of energy resources and policies. What is common, however, is the availability of abundant renewable energy sources. Figure 1 illustrates the percentage of the population's access to electricity in Angola, DRC and Mozambique in 2021.

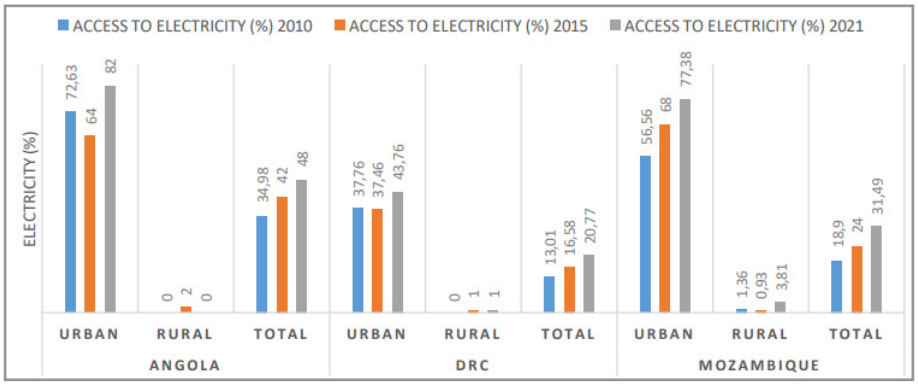

Figure 1: Electricity access rate in Angola, DRC and Mozambique. Data from (UNDP, 2021).

The electricity rate in the three countries studied remains notably low, as can be seen in Figure 1. Although there is a noticeable better scenario in urban areas of Angola in 2021, with access reaching 82%, the situation remains dire in rural regions, where access is nil. Overall, access for the total population stands at 48% which is insufficient for Angola with more than 34 million habitats (UNDP, 2021).

The DRC is considered the country with the lowest electricity rate in rural areas in the world 1% [26]. Total access to electricity for the population is low at 20.77%, with urban areas slightly higher at 43.76% in 2021. The energy supply situation in the DRC is critical, because despite the country's great potential, the national electricity company, called Societe Nationale Electricity (SNEL), has difficulties in supplying electricity to the provinces [27].

Among the countries examined, Mozambique stands out with the highest rural electricity access rate at 3.81% in 2021. However, the overall access to electricity for the population remains low at 31.49%, significantly lower than Angola's situation. Conversely, urban areas in Mozambique exhibit a relatively higher access rate at 77.38%. In comparison, the DRC fares the worst among the three countries, despite being the most populous and geographically expansive.

Given the low electricity rate in Angola, DRC, and Mozambique, several problems have been identified, and corresponding improvement measures can be proposed [28].

African governments need to prioritize the development of viable strategies that integrate energy and sustainable development concerns into decision-making processes across the continent.

An inclusive energy planning process should be established, involving local participation for the assessment and prioritization of energy needs in Angola, DRC, Mozambique.

It is essential to implement an integrated energy planning framework led by local and national leaders, focusing on rural populations' needs and ensuring access to a variety of suitable energy resources while considering environmental impacts.

Energy planning initiatives should be integrated with other rural development programs, including land reform, housing, healthcare, and education, to ensure comprehensive and sustainable development.

Several authors argue that the African continent faces many barriers to its sustainable development, such as extreme poverty, lack of health and education and environmental degradation [29]. However, the solution to these obstacles lies largely in the energy challenges that the continent faces in the first place, since a reliable and sustainable energy supply is the very basis for solving other socio-economic problems [30].

The implementation of decentralized renewable energy generation in these countries can contribute directly to the improvement of the health and education system, and the economy, but also to the improvement of air quality through the replacement of non-renewable sources. This should result in an overall reduction not only of greenhouse gas emissions but also of other pollutants caused by the excessive use of diesel in generating sets, especially in sensitive areas such as health facilities and schools.

The use of renewable energy generation can contribute to the achievement of several Sustainable Development Goals (SDGs) in these three countries. Primarily, SDG 7 (Affordable and Clean Energy), SDG 4 (Quality Education), SDG 3 (Health and Well-being), SDG 9 (Industry, Innovation and Infrastructure), but the systemic nature of these SDGs confirms that reliable access to energy is also a key enabler for achieving other goals, such as action against climate change, food security, zero hunger and freedom from poverty [31-34]. In addition, industrial development, improved working conditions and economic growth are also highly dependent on a reliable energy system, as well as a higher level of education among the population and their general health.

Conclusions

The African continent faces several problems in its socio-economic development, including the serious energy crisis. This crisis does not only result from the lack of energy resources, but rather the lack of infrastructure, appropriate technology to take advantage of these resources, especially renewable ones, and the lack of qualified human resources. It is necessary for the continent, the cradle of humanity, to address energy issues with utmost urgency so that there are no major delays in African countries. Furthermore, when analyzing the strategies that must be addressed to deal with these problems, we must ensure that the solutions are sustainable and that the alternatives to be provided must make economic sense for the rural user.

This paper delves into the energy sector of three Sub-Saharan African nations used as case studies to illustrate some of the main problems. In analyzing the electricity access rates in Angola, the Democratic Republic of Congo (DRC), and Mozambique, the incapacity to fulfill the electricity for all three cases. However, significant disparities emerge between rural and urban areas which highlight the existing asymmetries in the countries.

While Angola shows a notable improvement in urban access with 82 %, rural regions lag far behind, with only 2% in 2015, but in 2021 access was nil, resulting in an overall access rate of 48%, indicative of the country's significant electricity deficit. On the other hand, the DRC has an electrification rate of 43.76% in urban areas and in rural areas it has the lowest electrification rate in the world at just 1%, and overall access is 20.77% of the population with electricity, concentrated mainly in urban centres. Mozambique presents a contrasting scenario, with the highest rural access rate of the three countries at 3.81%, but overall access remains low at 31.49%, substantially below Angola's urban access rate. It should be noted that urban areas in Mozambique have a relatively higher access rate of 77.38%. Angola has demonstrated some progress in the use of renewable energy, which helps tackling Africa's energy crisis, but the country presents major challenges, as the current electricity rate does not meet the country's needs. The DRC stands out as one of the poorest countries in Africa concerning energy access rates in rural areas. This situation exemplifies the severity of the energy crisis in Africa and underscores the urgent need to strengthen and expedite the modest initiatives being undertaken in the country. On the other hand, the DRC boasts abundant energy resources, both conventional and renewable, yet their utilization

remains inadequate. The Republic of Mozambique has made a great effort to supply energy in rural areas, but the country needs to improve especially in urban areas.

These findings underscore the pressing need for comprehensive strategies to address the electricity challenges in Sub- Saharan Africa, encompassing integrated energy planning, local participation, and the prioritization of rural development initiatives. Moreover, the implementation of decentralized renewable energy generation emerges as a crucial solution to improve health, education, and economic prospects while mitigating environmental degradation and reducing reliance on harmful diesel generators.

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