Challenges and Planning in the Energy Sector in Africa

ISATA TEIXEIRA LEMBA [2], MARTA FERREIRA DIAS [1, 2] AND MARGARITA ROBAINA [1, 2]*

[1] GOVCOPP - Research Unit on Governance, Competitiveness and Public Policies
[2] DEGEIT - Department of Economics, Management, Industrial Engineering and Tourism
University of Aveiro
Campus Universitario de Santiago, 3810-193, Aveiro
PORTUGAL
*corresponding author: mrobaina@ua.pt

Abstract: - This article addresses recent literature contributions to current global energy challenges, in particular climate change, security of energy supply and volatile fossil fuel prices. It also describes the energy situation and prospects for energy sector development in some countries of the world and in Africa in particular. Africa, especially Sub-Saharan Africa, along with Southwest Asia, have very low rates of access to electricity. The African energy potential of both fossil energy resources and clean energy is abundant but it lacks the policies for the exploitation of these resources, in order to fulfill the persistent energy poverty. The predominant energy matrix on the African continent is based on fossil fuels, linked to emissions of greenhouse gases, with South Africa being the largest emitter. In the search of energy sources to balance the demand, Africa should select solutions less harmful to the environment, while ensuring security of supply, access to electricity and promoting socio-economic development.

Key-Words: Energy sector, Africa, renewable energy, electricity, sustainable planning, energy challenges.

1 Introduction

Electricity plays a key role in the socioeconomic development of any country. Successful development of the energy sector will be a crucial factor in determining the pace of economic and social development in Africa [1]. In many developing countries, especially those in Africa, the energy issue still embodies a huge challenge.

Energy sources used in Africa are not sustainable for the following reasons: (a) do not guarantee the security of supply, have little production capacity to meet the energy needs of the continent and do not have diversification of energy sources; (b) do not guarantee environmental protection, although the continent has abundant renewable energy resources, the energy mix is dominated by fossil fuel sources; (c) do not guarantee universal access to electricity, most of the African population have no access to electricity, the supply is very low, sources have limited capacity for energy generation, there are difficulties of energy infrastructure with regard to expansion of the transmission and distribution network; (d) do not guarantee the socioeconomic development of Africa, many locations are geographically dispersed and distant from the electricity grid, which reduces the development of any socioeconomic activity dependent on electricity services for those locations. Therefore, the lack of development of the energy sector represents an obstacle to Africa's development.

There is an absence of literature that exposes the energy problem in Africa and which, through successful examples from other regions of the world, questions what would be the sustainable path to energy and economic development on this continent. The objective of this research is to infer Africa's energy potential and to show guidelines for energy sector development, ensuring environmental protection, security of supply, universal access to electricity and socio-economic development. To this end, some practices for improving access to electricity in some African countries have been identified and are mentioned as possible examples for other countries in order to change the current energy structure for the better.

2 Energy situation in the world

The most widely source used for energy production energy is fossil fuel. However, the expansion of energy consumption in developed and emerging countries has raised two major concerns: the depletion of fossil energy resources, in this case oil and, consequently, the environmental concerns regarding the issue of global warming due to the increase of greenhouse gas (GHG) emissions, for which fossil fuels make a major contribution [2]. These two concerns are amplified by the volatility of prices to which fossil fuels are exposed on the world market. All of these may compromise the security of electricity supply. Consequently, developed countries want to keep up with the pace of achieved development, focusing on replacing fossil technologies with cleaner technologies, while for developing countries such as Africa, the concern is increasing their energy supply so that populations have more wide access to electricity.

This challenge requires good energy planning and good energy policy design. In face of these challenges, many countries are improving their energy models to ensure security of supply, socio-economic growth, environmental protection and increased access to electricity.

2.1 Environmental Issues

The effects of climate change and the need for a better quality of life have created a greater focus on accessibility, reliability and sustainability of modern energy systems, as well as on environmental awareness [3]. Environmental objectives are at the top of global, national and personal priorities as anthropic activities, especially those using fossil fuels, have been influencing climate change-related phenomena [4].

The energy sector is regarded as the largest emitter of GHG, followed by agriculture in smaller percentages [5]. Gases emitted from the use of fossil fuels intensify the greenhouse effect, modifying the way solar energy interacts with the atmosphere, affecting global warming with severe consequences, such as drought or flood frequency in some areas, rising sea levels, causing the disappearance of some animal species, and endangering human survival on Earth itself. It is noted that the poorest and least developed societies will be the most vulnerable [6]–[8].

Observations by climate scientists have shown that over the past century there has been a significant increase in atmospheric carbon dioxide (CO_2) concentrations, by 280 parts per million (ppm), compared with pre-industrial age values [5]. In 2015 there was a CO_2 concentration of around 399 ppm, which represented an average annual growth of 2 ppm over the last ten years, as well as an increase in concentration of other gases such as methane (CH_4) and nitrous oxide (N_2O) [5]. Since the Industrial Revolution, CO_2 emissions from fossil combustion have dramatically increased from almost zero to over 32 gigatonnes of carbon dioxide ($GtCO_2$) in 2014 [5].

Over the period 2014–2016 global CO_2 emissions reached about 32.1 gigatonnes (Gt), remaining stable over the three consecutive years [9]. CO_2 emissions decreased in the United States of America (US) and China, considered the largest energy consumers as well as the largest CO_2 emitters. Even if In Europe emissions remained stable, the CO_2 emissions increased in the rest of the world over the same period [9]. There is a tendency for developing countries to increase the levels of CO_2 emissions resulting from carbon oxidation in fuels during combustion in electricity production on account of their effort for developing.

Some commitments have been made to fight the current growth rate of GHG emissions in order to adapt and mitigate the environmental impacts due to climate change. The first commitment was the Kyoto Protocol, signed in 1997, which committed participating industrialized countries to reduce gas emissions by about 5% from 1990 levels during the period 2008-2012 [5]. That Protocol established three flexibility mechanisms, which should allow these countries to comply with the emission reduction requirements, which are (1) Emissions trading: Annex I Parties should trade a portion of their emission quotas, converting their emission share in tradable emission allowances; (2) Joint Implementation: established the possibility of transferring emission quotas between countries with quantified targets from Annex I through the implementation of public or private projects that should contribute to emission reductions in the other country; (3) Clean development mechanism: established the possibility of obtaining emission credits through the implementation of public or private projects that contribute to the reduction of emissions in developing countries. However, the same Protocol faced some barriers in its implementation. Although it had a largest participation and was signed by 192 parties, the US remained outside the jurisdiction of the Protocol, and developing countries had no emission targets [5]. This was the basis for the full non-compliance with the Kyoto Protocol.

Another important commitment on the international agenda was the Paris Agreement adopted at the 21st Conference of the Parties (COP21) on climate change in December 2015 by 196 nations [5], [10]. The Agreement aims, in the long term, to keep the global average temperature rise below 2°C above pre-industrial levels and to promote efforts to limit the temperature increase to 1.5°C above pre-industrial levels [5], [10]. To achieve this goal, global emissions from fossil fuel-based power generation must necessarily fall by the year 2050, from more than 13 current $GtCO_2$ to 1.4 $GtCO_2$ [10]. This will require changes in coal and gas-based power generation, namely [10]: (a) elimination of inefficient coal-fired power technologies beyond 2030; (b) reduction in off-balance-sheet gas generation for back-up gas generation for wind and solar generation; (c) acceleration and expansion of carbon capture and storage; (d) exploitation of efforts to reduce emissions from carbon capture and storage equipment as these operate with additional fossil fuels.

In December 2018, the 24th Conference of the Parties (COP24) of the United Nations Framework Convention on Climate Change was held in Katowice (Poland) to implement the 2015 Paris Agreement [11]. This Conference made it known through scientific and socio-economic knowledge that limiting global warming to 1.5 °C above pre-industrial levels would be the right bet, as it has clear benefits for humankind in terms of environmental protection. By this limitation it is intended that by 2030 at least 45% of carbon dioxide emissions will be reduced face to 2010 levels and by 2050 global carbon dioxide emissions will reach net zero (reduction 100%) [11]. But to do so, important transitions are required in various sectors, especially energy. Significant reductions in coal use to close to zero per cent in their share of electricity generation will be required, and therefore the choice of renewable energy sources with a share of 75 to 80% in worldwide electricity generation by 2050 [11].

In the African continent the most emitting country is South Africa, which emitted about 415.6 million tonnes of CO_2 in 2017 from combustion of oil, coal and gas [12]. But it has been decreasing compared to previous years, for example in 2008 its registration was 447.5 million tonnes of CO_2, an increase of about 7.68% compared to 2017 [12]. In other African countries, emissions have been rising for the same period (2008–2017), although with levels below South Africa: Egypt from 170.5 million tons of CO_2 to 217.3 million tonnes of CO_2 (+102%); Algeria from 90.8 million tons to 128.1 million tons of CO_2 (+41%); and Morocco from 48.6 million tons to 58.5 million tons of CO_2 (+ 20.4%) [12].

Renewable energy sources are commonly understood as a way to contribute to climate change mitigation, being a resource solution in face of CO_2 emissions from fossil resources. Moreover, they are seen as a promising industry that could be assumed as a driving force for reactivating and developing a country's economy [13].

2.2 Security of Supply

Sustainable energy supply is seen as a relevant factor for the continued economic growth of any society [14]. For this to happen, it is essential that each country, region or community adopts an energy policy focusing on security of electricity supply.

Security of supply is regarded as an indispensable aspect of global economic and security stability today [15]. The definitions assigned to energy security have varied depending on each researcher, but all focus on the absence, protection or adaptation of threats that are caused or impact on the energy supply chain [16].

In order to ensure security of energy supply, many countries have been focusing on diversifying energy sources with less environmental impacts [17], while others have been betting on diversifying the fossil energy supply market so that they can safely reach their power generation centers. Many fossil resources are acquired in countries with some political instability, which may also become a threat to energy security for importing countries.

For example, Japan imports about 96 percent of its national energy needs. Following the Tsunami and the Fukushima nuclear power plant accident in March 2011, associated with global issues on climate change and energy security, it has been forced to focus on the promotion of renewable energy sources, mainly on biomass, wind and solar [18]. Singapore has been focusing on importing natural gas and implementing renewable energy in order to ensure security of electricity supply and also to reduce carbon footprint and dependence on fossil fuel imports [19].

Brazil's electricity matrix is dominated by the strong share of hydroelectric power, representing two thirds of the installed capacity. In 2000 and 2001 and later in 2014 and 2015 extreme droughts hit Southeast, Midwest and Northeast of that country, causing an energy crisis and thus highlighting the insecurity of the hydroelectric source for Brazil [20]. Given this vulnerability and with the forecast of increased energy consumption, Brazil saw as a solution the diversification of energy sources, focusing on the development of renewable energy sources, such as solar, wind and biomass. However, to do these transformations, the adoption of policies that provide a favourable policy environment and public awareness of the development of emerging renewable technologies in ways that make them more competitive compared to conventional power sources is recommended. Another strategy is to support domestic manufacturers and investors in research and development considered crucial to the achievement of security of supply goals [20].

Another example is the case of China that wants to reduce its strong dependence on the Malacca Strait to safeguard its supply of imported oil. With this purpose designed the construction of a pipeline that will connect Pakistan and China for oil supplies [15]. China also relies on imports of coal and natural gas. Both oil, coal and natural gas are imported energy resources, do not guarantee security of supply, and there is also a risk of potential instability in the countries from which these resources are purchased [21]. In order to ensure security of energy supply, China has chosen to diversify its supply market [13], [21]. Oil and coal were already being purchased in several countries, while natural gas that was only acquired from Russia, started to be acquired also in Central Asia [21].

Small Island Developing States are considered vulnerable to the impacts of climate change, given their geographical locations, which make them subject to natural disasters and rising sea levels. Its predominant energy source is fossil fuel, which threatens the energy security of these countries. To ensure energy security they had to outline some policies for the implementation of sustainable sources of energy. For instance, Fuji projected to increase the share of renewable energy sources to 81% by 2020 and Mauritius to 35% by 2025 [22].

Some developed countries, while still using a low percentage of renewable energy sources compared to other developed countries, such as the US, have been discussing energy diversification and the promotion of renewable energy sources in face of concerns such as security of supply, limitations and fluctuations in fossil fuel prices, and threats of climate change [17].

2.3 Volatility of fossil fuel prices

Price volatility is another worrying issue associated with fossil fuels. In many developing countries, fuels are subsidized by the state to mitigate energy production costs, as returns on energy trading are not compensatory.

One of the important resources in the energy market is oil, due to the participation of its derivatives in the production of electricity, but it is subject to price volatility in the world market. By mid-2014 oil was traded on the world market at prices above $100 per barrel of brent and fell sharply below $50 in early 2015 after a long period of relatively stable high prices [23]. In 2016 in began to be traded above $50, in the first week of October 2018 was sold for $86.50 and in the second week of November of the same year had a decrease and sold for $64.66 [24], [25]. The world market price of oil is expected to continue to rise gradually, projections for 2020 point to Brent barrel trading close to $80, rising to $113 per barrel by 2030 and to $128 by 2040, as the required prices in the world market to balance supply and demand [26].

Other fossil fuels that have a strong influence on the energy sector are natural gas and coal, which are also subject to price volatility on the world market, albeit to a lesser extent. Natural gas prices have been reduced depending on regional factors and existing gas pricing mechanisms [23]. In the United States natural gas was being traded in mid-2014 at prices of $4.00 per million British thermal units (MBtu), and at the beginning of 2015 it was traded at less than $3.00. From August to October 2018 prices fluctuated from $2.75 to $3.205/MBtu [27]. In Germany, natural gas import prices were below $8.50/MBtu in the summer of 2014 [23] and by mid-2017 reached minimum values of $ 4.98 / MBtu [28]. Coal in Northwest Europe fell from $73 per tonne in mid-2014 to about $60/tonne in early 2015 [23], rising in 2017 to $84.51 [29].

The fall in fossil fuel prices since mid-2014 has had a major impact on the international market, but in different ways for importers and exporters. For oil and gas exporting countries felt obliged to significantly reduce planned investments, they had to revise their government budgets because their economic growth expectations were cut [23]. However, importing countries were relieved by lower oil prices and took advantage of the implementation of fossil fuel subsidy reforms [23]. This fall in fossil fuel prices has also not been well seen in the renewable energy technologies market, bringing a fear of weakening of the investments in these technologies [23].

Faced with the limitation of fossil resources related to fuel price volatility and its related environmental problems, new sustainable electricity options using renewable energy sources are required [30]. While world oil price forecasts tending to rise over the next years, there has been a reduction in costs of solar photovoltaic and wind power installations, by two thirds and 30% on average, respectively, in 2010-2015 period. This also allowed the Paris Agreement on climate change [10].

Examples of some countries where cost reduction has already been highlighted are the case of Morocco, where onshore wind generation reached its historical low in 2015 at $30 per megawatt hour (MWh); in solar photovoltaic technology the minimum costs of $30 per MWh were reached in May 2016 in Dubai and for the same amount in August of the same year in Chile [10]. These same technologies tend to lower their costs in the future, and faster. Is expected that highly resourced markets present stable policies, especially concerning regulatory and financing conditions, and that expected costs will be even lower in the future and at a faster rate than projected [10]. By achieving this goal, renewable technologies will become cost-competitive with fossil fuels, and this is expected, as the goal is to decarbonize the world electricity system.

3 Energy situation in Africa

It is considered that all the advanced economy required a secure access to modern energy to sustain its development and growing prosperity [1]. Reliable, high quality modern energy provides services such as lighting, heating, cooling, transportation, communication, better quality of life and higher yields [1]. In this perspective, Tessema et al. [31] stresses that access to electricity profoundly influences the lives of rural communities and is equally critical to all aspects of human well-being, including access to clean water, health care, education and agricultural productivity. For the vast majority of Africans, lack of access to modern services is a major obstacle to achieving well-being and in the broadest sense is a barrier to achieving the continent's development goals. Access to energy by poorer communities can make a significant difference in the fight against poverty [32], which has not yet happened in many African countries. Access to electricity is a challenge not yet met in sub-Saharan Africa, which is in a situation of energy poverty [1].

According to the IEA's report on access to electricity, in Africa around 52% of the population had access to electricity in 2016 [33]. That rate decreases to 43% on sub-Saharan Africa. The same report indicates promising signs in the energy sector, but nevertheless the projections for 2030 present a still critical scenario for universal access to electricity in sub-Saharan Africa. Despite the great progress being made in the energy sector, this will not be enough to match the growing demographic expansion in sub-Saharan Africa by 2030. Yet the same report notes that 674 million people worldwide, by 2030, will still have no access to electricity, of which 90% will be living in sub-Saharan Africa [33].. The rate of access to electricity is totally unequal in all regions of Africa. In the northern region virtually, every population has access to electricity [33]. In the Center region, Gabon is the country where the electricity access rate is higher (90% in 2016), followed by Equatorial Guinea with 68%. While, for this same region, the lowest rates stands for the Democratic Republic of Congo (15%), Chad (9%) and the Central African Republic with only 3% [33]. In the Western region, Kenya stands out with an electricity access rate of 65% in 2016, while the lowest rates were found in Burundi (10%) and South Sudan (1%) [33]. In the Eastern region, the highest electricity access rates in 2016 were reported by Cape Verde (97%) and Ghana (84%). For this region, countries such as Niger and Sierra Leone have the lowest rates of 11% and 9%, respectively [33]. In the Southern region, the highest electricity access rates are reported in Mauritius (100%), Seychelles (99%), South Africa (86%) and Swaziland (64%), while Malawi has the lowest rate in the region, which is 11% in 2016 [33].

The energy sector in most African countries is usually funded through national budgets, but finances are generally not sufficient to improve transmission and distribution networks to expand access to electricity [34].

3.1 Energy sources in Africa

North Africa is characterized by a high dependence on oil and gas (both for exports from countries such as Algeria, Libya and Egypt, and for imports from Morocco). In Southern Africa there is a marked energy dependence on traditional biomass (firewood, charcoal), except for South Africa which is heavily dependent on coal [35], [36].

In the case of Mozambique, almost all electricity produced is from hydro, representing 99.9% of the energy mix [37]. A change in this picture is foreseen with the insertion of sources such as coal and natural gas for electricity generation. By the year 2023, water should represent 93.7% of the energy mix [37].

In Botswana, the main source of energy is coal due to its abundance and ready availability [38]. In Namibia the main sources are coal-fired thermal power plants (Van Eck Power Plant), hydroelectric power station (at Ruacana Falls, Cunene – Angola) and diesel power plant (Paratus at Walvis Bay) [39].

Countries such as South Africa, Botswana, Mozambique, Zimbabwe and Swaziland that have large coal reserves use this energy resource for power generation, most notably South Africa, which has approximately 90% of these reserves on the African continent [36]. In communities where there is no access to electricity, the energy source for cooking and heating is traditional biomass (firewood).

It can be noted that the energy mix in sub-Saharan African countries is dominated by fossil fuels that emit GHG [40]. Electricity generation from clean sources, with the exception of water, is still negligible in sub-Saharan African countries.

3.2 Energy Potential in Africa

By global standards, Africa is not a continent characterized by wind, although there are some areas with excellent wind resources, as the Atlas Mountains and Northwest Atlantic Coast, the Gape area of South Africa, the coastal areas of Egypt and the Ethiopian mountains [41]. Nevertheless, some of these countries located in regions with abundant wind, referenced above, also have not made considerable use of wind power [41]. In 2012 Egypt had an installation capacity of 550 megawatt (MW), Morocco of 291 MW, Ethiopia of 81 MW, Tunisia of 104 MW, Cape Verde of 24 MW and other regions 24 MW. In 2013, of these five countries, only Ethiopia saw its potential increase by 90 MW, with a total installation capacity of 171 MW by the end of 2013, while the other countries maintained the previous year's installation capacities. Although Ethiopia has excelled in increasing its installation power, it has not taken advantage of its abundant wind resource for power generation, only to a limited extent for pumping water [42]. In 2015, South Africa surpassed the top five countries in wind power exploration, with a cumulative installed capacity of 1079 MW. In 2017, the installed power of these countries evolved to the following: South Africa 2094 MW, Morocco 934 MW, Egypt 750 MW, Ethiopia 324 MW and Tunisia 245 MW. Egypt and Ethiopia have remained at the same level of accumulated power since 2015, and South Africa's evolution stands out, an increase of approximately 94% for that period [43].

The most substantial hydro potential for power generation may be found in Guinea, Nigeria, Democratic Republic of the Congo, Angola, Mozambique and Zambia [36], [44]. Only 11% of Africa's water potential is being used for electricity generation. In 2018, the African continent had only 36 GW of installed hydroelectric power, having produced 138 terawatt hours (TWh) of electricity from this generation source in the same year [45].

As far as natural gas is concerned, the top 20 countries with the largest proved reserves in 2016 include four countries in Africa, namely Nigeria, which has 5.2 trillion cubic meters, ranking tenth worldwide and the first in Africa. Following is Algeria with 4.2 trillion cubic meters, Egypt with 1.8 trillion cubic meters, and Libya with 1.4 trillion cubic meters [46]. Egypt is the country that most uses natural gas for electricity generation. In 2016, 137.5 terawatt hours (TWh) of electricity from natural gas was generated and in 2017 increased to 149.9 TWh. Likewise, South Africa, although not in the countries with the largest reserves in the world, ranked second in Africa in the use of natural gas for electricity generation. In 2016 production was 1.7 TWh and in 2017 was 1.9 TWh of electricity [12].

As for the solar resource, solar maps indicate Africa has abundant solar radiation, especially its northern and southern regions [44]. By 2017, the installed capacity to harness energy from the solar resource was 4155 MW [47]. South Africa leads the number of the few countries that have invested in solar energy, has an installed capacity of 2486 MW, as recorded in 2017. Next is Algeria with 425 MW, Morocco with 205.5 MW and Egypt with 189 MW of cumulative installed capacity for that year [47].

Africa has significant energy resource potential from both fossil fuels and renewable resources. The potential for renewable resources other than water remains largely untapped [48]. Progress on renewable energy, such as photovoltaic solar, is very slow [49], and the continent remains subject to energy poverty. Only South Africa, Morocco and Egypt have made greater use of their abundant solar and wind resources for energy purposes. Given the potential of Africa's solar resource, it is assumed that if it was well employed it would exceed the capacity of the energy supply to meet the needs of all Africa [33].

3.3 Energy Sector Outlook in Africa

Access to electricity remains a major dilemma for African countries. The main challenge remains in sub-Saharan Africa, particularly in rural areas, which are characterized by low access to modern energy services [35]. Khennas [35] advocates the implementation of strategies consisting of decentralized energy options for most rural areas and also the strengthening of energy systems particularly through interconnections of regions. The author points to countries such as Democratic Republic of Congo, Ethiopia and Guinea as countries with great potential to export of hydroelectric power, and this should contribute to a significant reduction in capital investment costs and operating costs. However, lack of strategies has contributed to the non-implementation of this regional interconnection. This translates into difficulties in many sub-Saharan African countries in designing and implementing energy planning. The lack of a vision to promote renewable energy and energy efficiency is found in Central Africa, although being a region rich in almost all energy resources, the majority of its population remains without access to electricity [50].

There are endogenous and natural energy resources in Africa, but they are not harnessed to address the existing energy poverty problem. The most widely used sources of electricity generation in most African countries are fossil fuels and are unsustainable both from an environmental and security of energy supply perspective. In addition, the production of these sources is reduced. Defining strategies through energy planning to reduce energy poverty is essential.

Authors such as Prasad et al. [51] consider energy planning as one of the pillars for the development of policies for the sustainable development of a given country. According to the authors, it can be pointed several criteria that guide the energy planning [51] such as:

(a) Environmental, consisting of greenhouse gas, air pollution and depletion of natural resources reduction;
(b) Economic, which consists in reducing dependence on fossil fuels and increasing local investment in renewable energy and business generating projects;
(c) Social, aimed at improving human health, creating jobs, enhancing comfort and citizen participation in decision-making processes;
(d) Technical and geopolitical. Although the ultimate policy makers for a national energy system are government ministers and officials, they should be guided by the work of energy planning technicians to make sound decisions.

It should be noted that energy planning requires a balance between energy supply and energy demand; and it is noted that when choosing energy models, the first consideration for the energy planning technician is whether the determined values will have any economic significance and whether the chosen model is appropriate for the region under study [51]. In this regard, some African countries have defined their strategies to increase their energy supply, although in different ways.

In North Africa, the policies outlined aim to minimize the use of fossil fuels to produce electricity. For example, Morocco and Tunisia focused on the reduction of the dependence on fossil fuel imports, and in the case of Libya, Algeria and Egypt, the relevance was given to the maximization of export revenues from national oil reserves and gases, and to the valuation of renewable energies, in this case wind, solar, geothermal, hydro and nuclear [52].

In the case of Morocco, which has abundant renewable energy resources such as wind and sun, it is, however, extremely dependent on imports of fossil energy resources, with its energy needs being met by around 96% [53], [54]. In order to minimize this dependence on fossil fuels, the Government of Morocco first defined some strategies, such as the National Energy Plan and the National Priority Action Plan, in order to safeguard energy security, environmental protection, economic growth and social responsibility during the transition from conventional sources to renewable energy sources. The latter strategy is based on four axes, namely: (a) security of supply with diversification of fuel types and origins; (b) access to energy for all segments of society at competitive prices; (c) promotion of renewable energy and energy efficiency; (d) regional energy integration of energy markets between Europe and the Mediterranean [53], [54].

Morocco is a good example in meeting these goals, for the various investments that have been made in the development of renewable energy sources. It projected the insertion of 42% of renewables by 2020 [55], and 50% in 2050 [44]. Regarding the various projects under construction in that country, the four thermo-solar projects stand out, the largest being a 500 MW solar park, which is being developed by a consortium led by the Saudi company ACWA; the construction of the first 160 MW satellite dish, which will have three hours of thermal storage and the construction of a solar energy complex with two projects of 100 MW and 200 MW, respectively [55]. The great progress made by Morocco in exploiting its Africa-wide renewable energy potential is due to the substantial investments made in the development of wind energy, photovoltaic solar energy (PV) and solar thermal energy projects [41].

Algeria holds large reserves of energy resources, most notably hydrocarbons and solar energy [56]. But given the environmental concerns and the need to provide electricity to serve its population, as well as to export to Europe under the MENA project, there are ongoing projects to develop renewable energy sources, although still at a primary stage [56]. To this end, it has defined tasks deemed essential in the realization of these projects, as educating the population about the importance of renewable energy sources and implementing special energy legislation to promote clean energy sources in public and private sectors [56]. One of the most important ongoing projects is solar Hassi R´mel, which could play a crucial role in the implementation of renewable energy technology in the MENA region. It has been developing some programs and have set some national targets for renewable energy sources, namely the continuous development of solar and wind sources, and aiming to achieve a renewable energy quota of 10% of the primary energy supply that was foreseen until 2020, 20% by 2030 and 35% by 2040 [57].

South Africa is committed to increasing economic growth, and a key component in achieving this goal is the supply and expansion of electricity, making energy accessible to all its citizens and able to serve industries. However, it is intended that the same energy will protect citizens' health and the environment and uphold international commitments on GHG emissions [58]. South Africa is provided with adequate resources for renewable energy generation to minimize the energy deficit and the heavy carbon footprint, but nonetheless requires a clear strategy for renewable energy and human resources, so that industry can move forward in a sustainable way [59]. This has led South Africa to make great strides in setting up research centers focused on energy studies and in fostering South African industry in technological development and innovation [36]. These steps can provide a foundation for sustainability and security as technologies are made locally. In 2011 South Africa has implemented a strategy that consisted of a power purchase agreement from renewable energy sources of private producers. This same strategy set 2020 as a target for private producers to increase their share of the energy supply with an accumulated installed capacity of 8000 MW [55]. This measure fits in with the policy of attracting the private sector to invest in that country's energy supply.

In Namibia it is foreseen the insertion of natural gas energy sources, which by the year 2022 should represent 75.7% of the energy mix of the Namibian territory, and also the joint project with Angola that is being developed building a Baynes hydroelectric facility on the Cunene River [39].

Botswana considered one of the richest countries in Africa in terms of per capita income and by its strong economic growth, which implies a steady increase in electricity demand, expects a share of 30% of renewable energy sources in electricity generation by 2030 [38].

In Mozambique, net energy consumption is projected to increase from 9.9% per year over a 10-year period, from 14.2 TWh in 2014 to 33.2 TWh in 2023 [37]. In order to meet the energy sector's development, Mozambique needs to rely on some key funders such as the World Bank, the European Union and the African Development Bank [37]. The major difficulties for the energy sector are the huge territorial extension and the remoteness of communities aggravated by poverty. More than 54% of the population is poor, which limits the energy sector to increasing electricity prices [37]. Other concerns are pointed out by the fragile political instability, the sometimes-hostile commercial environment and the high corruption, as well as the very high dependence on hydroelectric power in which the rainless period can endanger the production of electricity. Despite being an energy exporting country to Swaziland, Botswana and Zimbabwe, it still imports energy from South Africa at high prices [37]. However, the government have been following policies enhancing private investors to participate in the generation, transmission and distribution of electricity, and committed to the development of renewable energy as solar, wind and waves [37].

The major projects in the African continent have been implemented based on foreign investments, notably the European Investment Bank (EIB), which has funded several renewable energy projects in several African countries. Examples of this are the case of the Khi Solar project in South Africa with a €50 million funding for the application of solar heat storage technology for power generation [60]; The EIB manages a contribution of EUR 25 million invested as equity in the project to build a 300 MW wind farm near Lake Turkana in Kenya [60] and also funds the high voltage CLSG Interconnection project for the export of low cost renewable energy over 1300 kilometres (km) to connect Ivory Coast, Liberia, Sierra Leone and Guinea [60].

Another aspect to be stressed in the development of renewable energy sources in Africa is the contribution that non-governmental organizations have made implementing many projects with solar photovoltaic systems to supply electricity to schools or health centers for the conservation of medicines in communities without electricity, as opposed to the governments lack of concern about the electrification of these localities [41].

There are also cases where projects are prepared but not executed, as is the case of Nigeria. The Nigerian government, in view of the global climate change phenomenon and the scarcity of conventional resources, intended to develop more sustainable energy systems to meet growth and economic development [61]. In 2003, the Federal Government of Nigeria had approved the national energy policy to develop the exploitation of all energy resources, considering as key elements:

promote and harness that country's renewable energy sources and resources; promote decentralized energy supply, especially in rural areas, based on renewable resources; promote efficient methods in the use of biomass energy; discourage the use of wood as fuel [40]. Nevertheless, the policy was unsuccessful due to the lack of guidelines for its implementation, and there is still little use of renewable energy sources to diversify its energy mix. The lack of infrastructure was also a factor in this failure [40]. Effective policies and regulatory frameworks for the development of renewable energy sources in Nigeria are seen as solutions to diversify their energy mix and ensure security of supply. Some measures are suggested such as electricity extension in urban areas, the combination of electricity from the centralized grid and that from the decentralized grid of renewable energy sources such as mini-hydro, solar PV and small wind systems for rural areas close to the power lines, while in remote rural areas a better option should be to implement isolated networks [62].

Access to electricity can ensure development and improve the quality of life in African countries as happened in developed countries. However, the electrification of most developing countries should be significantly different from the electrification of developed countries, as they have different social and energy paradigms. Sub-Saharan Africa stands out as having the least access to electricity with only 26%, while developed countries have a rate of 99.5% [63]. Pillot et al. [63] argue that renewable energy is a sustainable and viable economic alternative in developing countries.

Other authors such as Sokona et al. [32] admit the need to evaluate existing practices and processes in order to develop models, policies and institutional arrangements that consider the context of the problem and the conditions of the entire African continent. The same authors warn developing countries to make more cautious energy choices by looking at climate change issues aimed at social and economic development. Fossil fuels have unequivocally driven human progress to extraordinary levels, but nonetheless this has considerable environmental and social costs, and countries that need to develop must go through the way of renewable energy. As for fossil fuels, in the particular case of oil and natural gas, another problem arises which is the fluctuation of fossil fuel prices in the world market. Some specific requirements need to be assessed before a resource is found to be useful for power generation with regard to costs, environmental pollution, technological robustness, fuel supply stability and energy supply efficiency [64].

In countries with dispersed populations and in remote areas, the extension of the electricity grid to supply population would become costly and unviable. In the case of Algeria, given the small villages located in remote and mountainous areas and the military bases in non-permanent sites, it was found that grid extension would not be the best solution, as opposed to decentralization of power generation from renewable energy, which may include hybrid energy systems such as solar-wind PV-diesel, wind-diesel, solar PV-diesel and others, with or without battery backup option [65]. Once properly optimized, hybrid systems become cost effective and reliable compared to single power systems [65]. Countries like Ethiopia, given the enormous difficulties in expanding the power grid to all rural schools, have opted for the implementation of solar photovoltaic-diesel hybrid systems to maintain the power supply, as the PV solar system is discontinuous, with the added advantage of minimization of associated costs as the independently operating diesel system has high costs for either maintenance or fuel [66].

Sub-Saharan Africa, in order to overcome its current energy crisis and to meet the rapidly rising energy demand, will need, by 2040, 385 gigawatts (GW) of electricity generation capacity, including centralized generation, isolated networks and backups [1]. Achieving this goal will depend on the development of three energy policy areas, namely: (i) increasing investment in energy supply, in particular electricity, to meet the region's growing energy needs; (ii) improving natural resource management and associated revenues and; (iii) deeper and more cohesive regional cooperation. It is stressed that the pace of change will be set by the quality and integrity of the public institutions involved, as well as the transparency and accountability of their operations [1].

Africa is potentially rich in solar energy resources, with bright sunlight exposure averaging over 320 days per year and average irradiation levels of almost 2000 kilowatt hours per square metre (kWh/m^2) in most countries [1]. By 2013 only 280 MW of photovoltaic solar power had been installed in sub-Saharan Africa, and in 2017 with South Africa's largest contribution, the cumulative installed power increased to 3280 MW [47]. This power is expected to increase with projects under construction, notably that of Nzema, Ghana, of 155 MW of power and that of South Africa with 150 MW of power [1]. Solar technologies still play a limited role in sub-Saharan Africa, although they are gaining attention in many countries in this region. Solar technologies are being considered to be very competitive in single grid or small grid applications, and where the main alternative is petroleum-based power generation [1]. This has an advantage for its implementation in various regions of Africa compared to other sources of renewable energy.

Renewable energy sources are the pillar for sustainable development, they strike the balance between energy needs, environmental protection and the economy [57]. Tosam & Mbih [67] state that the prospects for long-term economic growth in Africa are based on the development of alternative sources and renewable energy such as solar and wind, along with sustainable agricultural development, infrastructure development and drinking water, and the development of natural gas. These sources of renewable energy, in addition to promoting economic growth, tend to be cheaper and more affordable for communities and families, to contribute to improving energy efficiency, to minimize deforestation, thereby ensuring environmental protection and reducing carbon dioxide, thus providing a healthy environment for all [67]. On the other hand, the use of renewable energy sources prolongs the duration of fossil sources, increases employment, has dampening effects on energy prices, reduces local and regional pollution and increases security of energy supply [57].

4. Literature review

The low rate of access to electricity in Angola has been justified by the low energy supply and by the high demographic growth [68], jointly with the lack of significant investments and energy planning. Decisions involving large investments have always been made at central government level, that is, by the central agency of MINEA (Ministry of Energy and Water of Angola), although this entity has its representation in all provinces. This form of management can discourage energy provincial representations of developing important projects within their jurisdiction.

From the scarce recent literature available for Angola's energy sector, two main plans and an energy manual developed by MINEA have been accessed, namely: the Energy and Water Sector Action Plan 2013–2017 [69], the Energy and Water Sector Action Plan 2017–2022 [70] and, the book entitled Angola Energy 2025 - Long-term vision for the electricity sector [68].

- The 2013–2017 Energy and Water Sector Action Plan was prepared as part of Angola's energy security strategy and also aimed at universal access to electricity, its efficient use and sustainability of economic activity, among other objectives [69]. The energy security plan encompassed four strategic guiding principles [69]: (a) stabilizing energy as a lever for economic development. This would be possible by ensuring quality and cost-effective supply as a source of competitiveness for the business community; (b) promotion of universal energy supply, for which the main focus was on infrastructure development and affordable energy supply for all the population supplied; (c) encouraging the efficient functioning of the energy sector, aimed at promoting the quality of services and ensuring financial balance; (d) promoting the balance of society and economy. The intention was to mitigate social and geographical asymmetries and the development of a diversified energy mix. Also, in this action plan, it was foreseen, until 2016, the installation of 5000 MW accumulated power, also the interconnection of the Norte and Centro electrical systems, and the operation of the Leste system.
- The Energy and Water Sector Action Plan 2017–2022 aims to promote sustainable and diversified development, with economic and social inclusion, and reduction of inequalities [70]. This plan is based on three key programs [70], namely: (a) expansion of access to electricity; (b) optimization and sustainable management of the electricity sector and; (c) private participation in the electricity sector. With regard to access to electricity, its goal is to reach 50% of electricity for the whole country by 2022. The priorities are: the electrification of some provincial capitals (covering Mozamedes, given the recent increase in electricity its production capacity); rural and municipal electrification (for Namibe province only two electrification projects were contemplated: Bibala village and the construction of a 60 kilovolt (kV) power line between Mozamedes and Tômbwa). With regard to optimization and sustainable management, the aim is to ensure the maintenance and availability of existing generation, and to optimize the location and availability of thermal generation, in order to guarantee 30% coverage of consumption at peak times. The main priorities for this program are: the engineering and network feasibility study for

the creation of ocean thermal power plants (in Namibe and Lobito) and the technical and economic feasibility study of the relocation of turbines to Luena and Luau. On private participation, it is projected that by 2022 the accumulated installed capacity should reach 7.5 GW. For this purpose, the private sector was called to participate in the development of projects related to medium and large hydroelectric sources, as well as in new natural gas thermal power plants.

- Angola Energia 2025, is a book that approaches the energy sector in a long-term view [68]. It is based on six key strategic axes of Angola's energy security policy [68]: (a) generation park growth; (b) enhancing the role of renewable energy; (c) expansion of electrification; (d) tariff review and economic and financial sustainability; (e) restructuring and strengthening of operators; and (f) promotion of capital inflows and private know-how. In this book, it is recognized that the full electrification of the territory is incompatible with the technical and financial issues, and as a solution it was projected to reach Angola's target of only 60% by 2025. To this end, three alternatives were studied: (a) the low-yield model (based on network expansion with investment minimization. This model targets the electrification of all provincial capitals and only 74 municipal headquarters out of the 164 existing ones); (b) expansionist model (based on network expansion to all municipal headquarters through a 60 kV high voltage line); (c) equilibrium or economistic model (considered close to the expansionist model, but this one opts for isolated systems, when these are necessary, in this case competitive mini-hydro alternatives. The isolated systems, whose zones of operation are the most distant or still in the areas of distant areas and outside the grid, with reference to rural areas). As for supply, to reach the 60% electrification rate, there are the generation projects already referenced in chapter 2 of this work, and some small projects. Relief hydroelectric projects are mostly located in the Northern electricity system.

All these plans lead to an increase in the rate of electrification, most notably the provincial capitals and municipal headquarters, especially those with a high population. Although they advocate the minimization of asymmetries throughout Angola, they do not provide coherent solutions for all Angolan localities, especially those located further from the electricity grid. On the other hand, the definition of priorities in the attribution and development of these projects demonstrates the ambiguity regarding the reduction of existing asymmetries in Angola, as the priority establishes a privileged status for some localities over others. For example, in the province of Namibe, the priorities only fall to the cities of Mozamedes and Tômbwa and the village of Bibala, while the other locations are not covered by these action plans and the Angola Energias 2025 manual. Electricity supply is the basis of diesel fuel burning, and most of the population does not use electricity. Local electricity planning would be important, would allow the identification of endogenous and most available sources to provide adequate solution to the existing energy needs in each province of Angola. Moreover, this should minimize regional asymmetries regarding MINEA's policy on Angola's electrification.

In many cases, where announced energy policies do not have an integrated approach to energy planning using modelling tools, some problems in their implementation or consistency are likely to occur, as in the case of Pakistan [71]. Several studies have been done on energy planning for Pakistan, without, however, having an integrated planning approach, and the lack of adequate use of indigenous energy resources and the lack of infrastructure have been noted [71]. For instance, many energy policies put forward for Namibe's energy sector have not always been considered when certain situations have occurred. In the recent case of the installation of the 25 MW turbine (in Xitoto III, Mozamedes) that due to lack of infrastructure (expansion electricity supply) to the needy local populations, now supplies electricity to Lubango, which is about 180 km from Mozamedes. If planned, the installation of this turbine would probably meet certain criteria, in addition to the definition of the target population, and also the creation of infrastructure for the supply of energy to this population would be paramount.

Many countries have made energy planning to better guide their energy policy decisions. Planning is a complex process and aims the balance of supply and demand. Supply should be in line with demand at any time, if supply is lower, power outages will occur in the system [72]. One of the important factors in energy planning is the time horizon within which the planned tasks must be performed. Planning can be done for the short, medium and long term, and short-term investment programming should be preceded [72]. In this regard, it is argued that for rural electrification, planning should not take place further from 10 to 20 years, to facilitate the limitation of uncertainties regarding parameters and assumptions, and over five years, there must occur a review of ongoing planning [72]. The choice of timeframe can have an impact on investment decisions: short-term planning could be justified in case of a less costly investment in order to achieve a return on investment within a few years; and for distant planning, it would be for the implementation of palliative measures, considered as pre-electrification, in communities for which planning is done at a later stage [72].

Karunanithi et al. [73] consider energy planning as a long-term policy development process for a local, national, regional and even world energy system in order to save the future. They define as the main objective of the energy-planning model the environmental and economic impact analysis in various energy strategies. However, planning requires analyzing the effect of demand and supply side management in ways that should result in economic and environmental benefits, as well as improving system reliability [73].

Ouedraogo [74] warns of the urgent need to increase and improve the capacity of the energy sector in Africa. In this context, it stresses that all options for supplying energy to meet demand are possible in energy system planning that ensures policy-related decisions and related investments [74]. It also considers forecasting demand for electricity as a prerequisite for energy system planning [74].

Many energy-planning models have been developed to help energy policymakers act on energy supply and demand. These models are tools that help identify the best combination of short, medium- and long-term delivery options [72]. The use of these tools depends on what the planner wants to achieve. There are numerous modelling tools for long-term energy forecasting, which can be divided into seven main categories, as referred to by Ouedraogo [48]: (i) simulation (RAMSES, BALMOREL, LEAP, WASP); (ii) scenarios (MARKAL / TIMES, MESSAGE, LEAP); (iii) equilibrium (MARKAL, PRIMES), (iv) top-down (ENPEP-BALANCE, LEAP); (v) bottom-up (HOMER, RAMSES, MARKAL / TIMES, MESSAGE); (vi) operation optimization (BALMOREL, MESSAGE, RAMSES) and (vii) investment optimization (MESSAGE, MARAKAL / TIMES, RETScreen). These are models that provide insight into how energy systems can evolve in the future, but that there is no specific tool for a specific task [48].

The constant increase in electricity demand requires new investments in generation capacity on a regular basis. For this, the efficient planning of the new generation units is an optimization problem that must answer to four basic questions, which must ensure the necessary match between installed generation capacity and demand growth. These questions are: (a) what types of generation technologies will be added to the power grid, (b) what is the size of each generation source, (c) where will the generation sources be located, and (d) when will they be new generation units implemented [75]. Ouedraogo [48] in his approach to the future of energy in Africa emphasizes that long-term planning of supply and demand for electricity in Africa is a matter of the utmost importance due to the steady increase in energy needs. Given the prevailing energy needs, long-term electric power planning becomes relevant and allow better implementation of projects. For supply to meet the demand at any given time makes it a very costly task in terms of investments, and in view of this obstacle, phased and graduated project implementation would be a wise option.

5. Conclusions

The energy issue has been debated worldwide, and the issues addressed have focused on security of supply, environmental protection and socio-economic development. Many countries seek to address this challenge by using renewable energy sources, which, in addition to diversifying their energy mixes to ensure security of energy supply, are also good sources for climate change mitigation, and little by little have been become competitive in some regions of the world.

Africa has an enormous energy potential. It holds various energy resources of both fossil and clean energy. Its fossil resources include petroleum, coal, natural gas, and its clean energy resources include water, solar and wind, although the latter only in a few countries. However, there is still a poor use of them for the production of electricity.

Developing countries, particularly those in sub-Saharan Africa, have been identified as having a very low rate of access to modern electricity services [76]. Its energy policies are weak or practically non-existent for the development of the energy sector. Nevertheless, some prospects are open in Africa, albeit timidly, for the development of renewable energy sources. Examples are some countries such as Morocco, Algeria, Ghana, Kenya and South Africa, which have ambitious solar photovoltaic systems projects to increase electricity generation capacity and ensure security of supply.

Africa needs to address its energy issue through renewable energy sources, diversifying the energy matrix to ensure security of energy supply, environmental protection, access to modern energy services and boost socioeconomic development. Given Africa's solar resource potential, it is recognized that it would exceed the power supply capacity to meet the needs of all of Africa [33]. For this, it is important that each country or region always make energy planning to outline appropriate measures for the energy sector. However, it is important to implement policies aimed at the integration of renewable energy sources, such as the creation of legislation, the promotion of energy planning, the dissemination of information, the creation of training and research centers, the adoption of tax credit mechanisms at reasonable interest, the reduction or exemption of customs duties for energy technologies and the application of the feed-in tariff system in order to attract the private sector to invest in the development of renewable energy sources.

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