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Barriers Related to the Deployment of Renewable Energies in Cameroon

Jean Engo*

Center for Energy and Environmental Policy, School of Management and Economics Beijing Institute of Technology, Beijing 100081, China

***Corresponding Author:** ***Jean Engo**, Center for Energy and Environmental Policy, School of Management and Economics Beijing Institute of Technology, Beijing 100081, China*

Abstract *This paper applied the fishbone diagram as part of strengths, weaknesses, opportunities, and threats analysis related to the deployment of renewable energies in Cameroon. The results showed that the share of renewable energy in the country's energy mix decreased by 22.79%, from 98.90% in 2000 to 76.11% in 2015.This is attributable to the decline in hydroelectric generation and the increasing share of fossil fuels, as the country's potential for solar, wind and biomass remains untapped. Meanwhile, the under-exploitation of Cameroon's energy potential is mainly due to technological, financial, management, and the lack of skills barriers. However, the current rapid development of renewable energy technologies and financial support provided by the International Community under the Paris Agreement are opportunities that Cameroon can seize to engage significantly in R&DV, to promote its energy potential and reduce its dependence on foreign technologies. To this end, this paper provided some pathways through which policymakers should pay more attention.*

Keywords: *Cameroon; Renewable energy; Environment; CO2 emission, Fishbone diagram; SWOT analysis; Policy; Economy.*

1. INTRODUCTION

According to (IPCC, 2014)[1], global warming is expected to reach 4.8 ° C by 2100, and the current humanitarian goal is to keep these temperatures below 2 degrees [2]. To achieve this huge goal, a transition from fossil fuels to renewable energies is required. Currently, about 68% of greenhouse gas emissions are due to energy, and CO_2 accounts for 90% of these emissions [3]. Fossil fuels, which currently account for more than 70% of the world's primary energy supply, remain the most polluting energy source and account for 99% of total CO_2 emissions, of which 34% for oil, 20% for gas natural and 45% for coal [3]. From 1971 to 2015, the share of renewable energies in the world's energy supply increased from 14% to 18%, while that of fossil fuels decreased from 86% to 82% [3]. Thus, if in 44 years the share of renewable energy in the global energy mix has only increased by 4%, it means that the process of transition from fossil to renewable remains ineffective. Although a 4% growth has not been easy for countries that have become significantly involved in this transition process, many remain to be done when we consider that the share of fossil fuels tends to increase in developing countries today.

Over the last four decades, oil has been the main source of satisfaction for global energy needs. The trend has been reversed in recent years in favour of natural gas, whose demand is expected to reach 93 mboe/d in absolute terms by 2040. While annual demand for coal and oil is expected to increase by 0.4% and 0.6% respectively between 2015 and 2040, natural gas demand is expected to increase by 1.8% [4]. This is due to the strong demographic and economic growth of most developing countries, which is now driving growth in gas demand, particularly in the power generation, industry, residential, and commercial sectors. Although the share of fossil fuels in the global energy mix is currently declining, it should be noted that these energies will continue to meet most of the world's energy needs in the future. Therefore, to achieve the goals of the Paris Agreement in a dynamic and effective manner, developing countries should be significantly involved in the process of deploying renewable energies. However, (IEA, 2008; Karytsas & Choropanitis, 2017; McCrone, Moslener, D'Estais,

&Grünig, 2017)[5, 6, 7], have shown that the deployment of renewable energies remains ineffective because of the challenges posed by their implementation across countries. Given the differences in the socio-cultural, politico-economic, environmental, and renewable energy resources that exist between regions or countries, specific knowledge of these challenges in each of these countries or regions is needed. To this end, (Byrnes, Brown, Foster, & Wagner, 2013) [8] have presented these challenges in the case of Australia, (Luthra, Kumar, Garg, & Haleem, 2015)[9] have done in India, (Zhang et al., 2017) [10] in China, (Erdil & Erbıyık, 2015) [11] in Turkey, (Runko Luttenberger, 2015) [12] in Croatia, and (Kinab & Elkhoury, 2012)[13] in Lebanon. In the same vein as these studies, this paper aims to identify the strengths, weaknesses, opportunities, and threats related to the deployment of renewable energies in Cameroon.

Cameroon's primary energy supply increased by 65.34% between 1971 and 2015, from 2.700.000 to 7.790.000 tonne oil equivalents [3].Meanwhile, oil, hydroelectric and bio fuel were the three main sources of Cameroon's energy supply until 2006. Natural gas has been introduced into the country's energy mix since 2007, and currently accounts for 3.8% of total energy supplies, while bio fuel, oil, and hydroelectricity account for 65.50%, 25% and 5.7% respectively[14].Cameroon's access to electricity increased from 30.06% in 1990 to 56.80% in 2014. During the same period, access to electricity in urban areas increased from 63 to 86.51% and from 13.3 to 22.16% in rural areas [15]. In its vision of emergence by 2035, Cameroon has planned to achieve an overall electrification rate of 75%, with 20% in rural areas[16].In addition, the country committed to reducing its greenhouse gas emissions by 32% by 2035[17].

Based on these considerations, it is clear that renewable energy is the most suitable solution for achieving these energy and environmental targets. Therefore, the identification of strengths and weaknesses related to the deployment of renewable energy in Cameroon is required. Knowledge of these barriers is very important for policymakers since they can serve as a basis for formulating effective energy and environmental policies for sustainable development in Cameroon.

The rest of this paper is structured as follows. Cameroon's energy policy is presented in section 2, while the current state of renewable energy development in this country is discussed in section 3. The results of surveys conducted in Cameroon's renewable energy sector are presented and explained in section 4. We conclude the study in section 5.

2. CAMEROON ENERGY POLICY

The development vision of Cameroon's energy sector aims to promote renewable energy and modernize its distribution network in order to respond effectively to domestic demand and export energy to neighboring countries. The main objective of this vision is to reach a total installed capacity of 3000 MW and 5600 MW in 2020 and 2030, respectively. However, Cameroon's energy sector development policies are organized around its long-term energy sector development plan[18], its strategic poverty reduction paper[19], its intended nationally determined contribution[17], its project to extend the electricity network[20], and its vision for emergence by 2035[16]. Meanwhile, the Cameroonian electricity sector is managed by a set of State agencies whose missions and regulations are recorded in Table 1.

Table1. *Cameroon legal electricity management framework*

Institutions	Assignments	General regulation
Ministry of Water and Energy (MINEE) www.minee.cm	Management of State energy policies	· Law No. 2011/022 of December 14, 2011 Governing Cameroon Electricity Sector · Law N ° 2002/004 of 19 April 2002 On Investments in Cameroon · Law N ° 2006/012 of 29 December 2006 Setting General Regime of Partnership Contracts
Electricity Development Corporation (EDC) www.edc-cameroon.org	Management of projects related to electricity sector development.	· Law No. 98/022 of 24 December 1998 regulating electricity sector · Law No. 2011/022 of December 14, 2011 Governing Cameroon Electricity

		Sector
Electricity Sector Regulator Agency (ARSEL) www.arsel-cm.org	Regulating, controlling and monitoring activities of operators in the electricity sector	· Law No. 98/022 of 24 December 1998 regulating electricity sector · Law No. 2011/022 of December 14, 2011 Governing Cameroon Electricity Sector · Decree of 28 June 2013 on the organization and operation of ARSEL
Rural Electricity Agency (REA) www.aer.cm	Management and promotion of rural electrification	· Law N 98/022 of 24 December 1998 establishing REA · Decree No. 99/193 of 8 September 1999; relating to REA functional organization
The Energy of Cameroon (ENEO) www.eneocameroon.cm	Management of electricity distribution policies	· Law No. 98/022 of 24 December 1998 regulating electricity sector · Decision n ° _0096_ / arsel / dg / dcec / sdct du_28 may 2012_ fixing the electricity-free sales tariffs applicable by the company eneo cameroon from the year 2012.

Source: *adapted from [23, 24]*

3. Resources and Current Situation of Renewable Energy in Cameroon

Cameroon's renewable energy policies are organized around the first section of Chapter Two, Title 4 of Law No. 2011/022 of 14 December 2011 governing the electricity sector in the country. This section includes five articles namely Article 63, which specifies the types of renewable energy; Article 64, which defines the nature of renewable energy consumption; Article 65 includes four paragraphs, it defines the management arrangements (production, promotion, R&DV, taxes, and customs); Article 66 includes two paragraphs, it defines the terms of purchase and the involvement of operators in the sector; and Article 67, which stipulates that an agency for the promotion and development of renewable energies may be created in case of need[21]. Meanwhile, Figure 1 shows trends in the share of renewable energies and fossil fuels in Cameroon's total electricity consumption over the period 1999-2015.

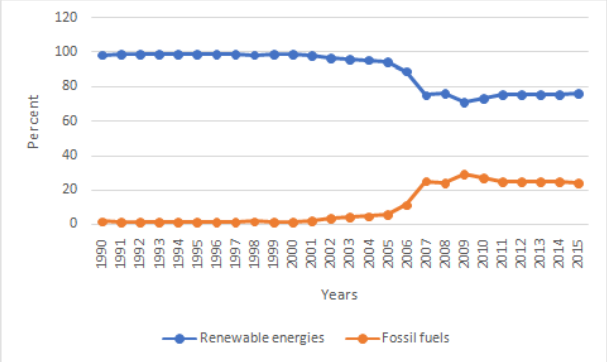

Figure1. *Renewable energy trends in Cameroon's electricity mix between 1990 and 2015*

We can see from Figure 1 that there is a significant challenge in Cameroon's electricity supply system. In this challenge, it appears that the renewable energy sector is not healthy in Cameroon since 2000. From 1990 to 2001, renewable energies accounted for about 98% of the country's electricity supply, while fossil fuels accounted for 2%.The share of renewable energy suddenly dropped to 74% and 76% in 2007 and 2015, respectively, while that of fossil fuels increased to 25% and 23% during the same period. However, to better understand this growing decline, it is important to look at the different sources of renewable energy in Cameroon.

3.1. Hydropower

As shown in Figure 2 [22], Cameroon is one of the African countries with huge hydropower resources. The country's hydropower potential is estimated at about 23 Gw and is the third largest in the

continent after the Democratic Republic of Congo and Ethiopia. The development of this important potential could enable Cameroon to produce more than 115 billion kWh of electricity each year. Unfortunately, only 734 MW of this potential has been developed to date[23, 22].

Source: from [22]

Figure2. *General view of Cameroon's hydropower potential*

Electricity generation from hydro sources is currently provided by three major dams, which account for about 58% of the country's total installed capacity. Among others, we found the Edéa hydroelectric dam (398 MW) acquired in 1952, Song Loulou (264 MW) and Lagdo (72 MW) hydroelectric dams acquired respectively in 1981 and 1982. Next, to these dams, the country has three water retention dams with a total capacity of 7600 million cubic meters, namely Mapé, Mbakaou, and Bamendjin [23]. Currently, several hydroelectric dams are under construction since 2010, and some of them will be fully operational by 2020 at the latest. These projects are part of Cameroon's vision to increase its actual total installed capacity from 1400 MW to 3000 MW by 2020, and to see more than 5000 MW by 2035. Meanwhile, Figure 3 shows the trend of hydropower in Cameroon's electricity mix over the period 1990-2015[14].

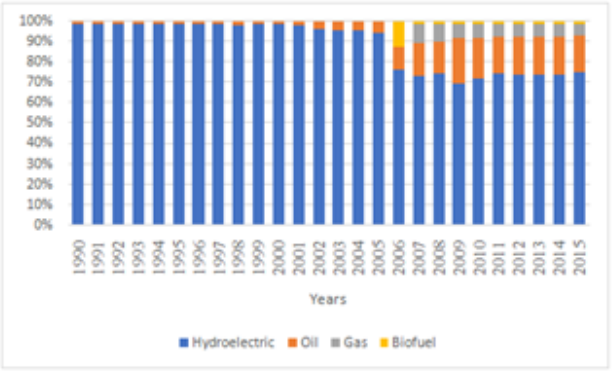

Figure3. *Hydropower trends in Cameroon's electricity mix between 1990 and 2015*

Source: *[14]*

As shown in figure 3, hydropower's share of Cameroon's total electricity supply declined from 98% in 1990 to 96 and 73% in 2002 and 2007, respectively. It fell to 72% in 2010 and rebounded to 75% in 2015, a position it had maintained until today. This gradual decline is largely due to the aging of the production equipment since the youngest hydroelectric dam in Cameroon is 36 years old today. In addition, Cameroon's decision to boost energy efficiency through fossil fuels has helped to reduce the effect of hydropower on the country's total electricity supply since 2006, as shown in Figure 1 and 3.

3.2. Biomass Energy

Cameroon has the third largest biomass potential in sub-Saharan Africa. It is estimated at about 18.8 million hectares of forest [24], mainly concentrated in the central, southern and eastern regions of the country, as shown in Figure 4 [25].

Figure4. *The forest potential of the Congo Basin*

Source: *From [25]*

Figure 3shows that bio fuel energies have finally received the attention of Cameroon since 2006 when they accounted for 2% of the country's total electricity supply. This share dropped to 1% since 2007 until today, since the marketing of bio fuels is not an integral part of Cameroon's energy market and that no effective policy is available to promote this energy. Yet, any significant involvement of Cameroon in the production of bio fuels will strongly contribute to increasing the share of renewable energies from this source, given the country's strong production of maize, sugarcane, palm oil, cassava, sunflower, peanuts and inedible plants such as jatropha. Meanwhile, Cameroon is expected to produce 77 million litres of bio ethanol and 74 million litres of biodiesel by 2020 [26, 17].

However, deforestation is the main factor currently destroying the Cameroonian forest. Between 1990 and 2015, Cameroon lost 220 000 hectares of forest every year, and even 1% of this forest has never been restored [27, 24]. Three main factors are at the root of this deforestation, namely the rise of global warming, the intensification of agricultural activities and the increase in energy needs. Cameroon is one of the recognized countries highly vulnerable to climate change and more sensitive to any change in temperature due to its geographical location. From 1960 to today, temperatures have risen by about +0.7 degrees Celsius and the country's agro-ecological zones are thus the most affected [28, 29]. Currently accounting for about 23% of national GDP, agriculture remains the central pillar of Cameroon's economy. Moreover, apart from importing products such as rice, fish, etc., most of Cameroon's food comes from its land. Similarly, about 90% of Cameroonians currently use firewood, charcoal, and other wastes to meet the energy needs of their household activities such as cooking, heating, lighting, and many others. Therefore, the effects of agriculture and energy consumption on this forest will continue to increase, given the strong demographic growth in Cameroon today.

3.3. Solar and Wind Energies

After biomass and hydropower, Cameroon also has good potential for solar and wind energy. The country's average solar radiation is estimated at about 4.9 to 5.8 kWh/day/m2 and is more abundant in the north as shown in Figure 5 [30, 24]. Cameroon average wind speed is estimated at about 2 to 4 meters per second, at a height of about 100 meters. As shown in Figure 6, this potential is abundant in the coastal areas and in the north of the country (5-7 m /s)[30].

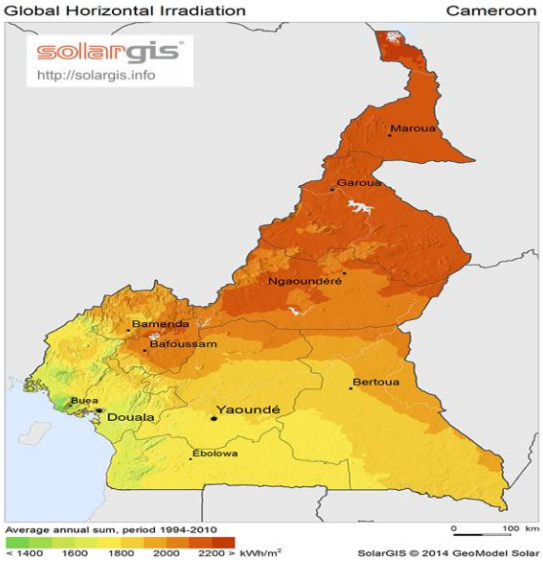

Figure5. *Cameroon's solar energy potential*

Source: *From [30]*

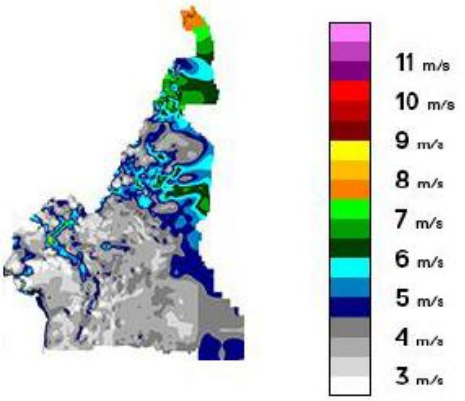

Figure6. *Cameroon's wind energy potential*

Source: *From [30]*

Currently, solar and wind energies remain exploited for the satisfaction of primary lighting needs such as solar lamps, recharging the phone's battery, etc. As in the case of biomass, Cameroon's current desire to develop solar and wind energy is strongly linked to the country's vision to reduce its greenhouse gas emissions by 32% by 2035. As part of this vision, Cameroon plans to increase the share of these two energy sources from 0 to 25% in its electricity mix. To this end, solar photovoltaic and wind energy are expected to produce 1345 GWh and 464 GWh of electricity, respectively, in Cameroon by 2035.

However, this paper applied the fishbone diagram and SWOT methods to identify not only the reasons for the under-exploitation of Cameroon’s energies sources, as noted above, but also to identify the available opportunities for Cameroon to promote its renewable energies sector. The SWOT (Strengths, Weaknesses, Opportunities, and Threats) method is a strategic analysis tool that combines the study of strengths and weaknesses of an organization, a territory, a sector, etc. with that of opportunities and threats of its environment, in order to provide a development strategy. The purpose of this analysis is to consider both internal and external factors in the strategy, maximizing the potential for strengths and opportunities and minimizing the effects of weaknesses and threats[31, 32].A fishbone diagram method is an analytical tool that helps improve the business management process and is part of quality tools released in 1977 by the Japan Union of Scientists and Engineers (JUSE).The principle of this method is to link the causes of a problem to its apparent effect while breaking it down into several sub-problems that are easier to deal with[33, 34].Meanwhile, the results of our investigations based on these two methods are presented in the following section.

4. THE SWOT ANALYSIS OF CAMEROON'S RENEWABLE ENERGY SECTOR

As in most countries in the world and more particularly developing countries, the implementation of renewable energies is subject to several obstacles in Cameroon. Some of these obstacles coincide with those identified in previous studies and others are specifically related to the Cameroonian context, as shown in Table 4 and Figure 7.

Table2. *The SWOT matrix of Cameroon's renewable energies sector*

	HELPFUL	ARMFUL
INTERNAL ORIGIN	· The country has a huge desire to boost its renewable energy sector, · Renewable energy potential is available in large quantities, · A large workforce is available across the country, · Natural resources needed for the implementation of renewable energy technologies are available, · The country's working environment is favorable, · People are not against the implementation of renewable energy projects in their localities, · The country is relatively stable politically.	The weaknesses or barriers related to the deployment of renewable energies in Cameroon were analyzed by the fishbone diagram whose results are presented in Figure 7.
EXTERNAL ORIGIN	· The strong growth experienced by renewable energy technologies today, · The gradual decline in the costs of renewable energy technologies, · The financial support of the international community provided for by the Paris Agreement, as regards the countries emitting less greenhouse gases such as Cameroon, · Energy market of the Central African sub region, · Development aid of various origins, etc.	· Dependence on foreign technologies, · Dependence on foreign investment, · Dependence on global economic conditions, · Dependence on the effects of climate change, · Dependence on the financial security of its international trading partners

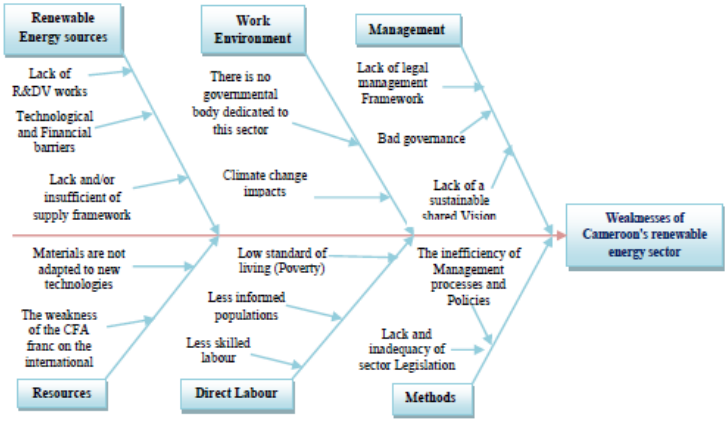

Figure7. *Weakness related to Cameroon's renewable energy sector*

Mainly due to technological and financial barriers, Cameroon's renewable energy sources remain very under-exploited. Indeed, the technologies related to the implementation of renewable energies namely, solar photovoltaic, solar heating, wind turbine, and many others, are still very poorly known in Cameroon. Moreover, the country does not have the necessary funding to become significantly involved in the promotion of renewable energy technologies, which means that no project could be easily executed by the State unless it is strongly supported by foreign investment. Meanwhile,

Cameroon's willingness to develop its renewable energy potential continues to focus mainly on hydropower. This is not a bad idea if the Government's means allow it to develop only this source of energy. However, the disadvantage related to this energy source lies in the uncertainty of hydroelectric resources availability in the long term. Hence, developed countries tend to develop more solar and wind energy today. The weakness of Cameroon's education system is also one of the biggest problems preventing the deployment of renewable energy in this country. No effort is currently being made to carry out R&D projects, and the country's universities lack a specific training program for renewable energies.

Cameroon's hydropower generation is less efficient today due to the poor state of equipment used in this sector. The majority of these devices are currently very old; they are not adapted to new technologies and lack of effective maintenance. Given the weaknesses mentioned above, equipment related to the efficient development of hydropower, and especially those related to solar energy, wind turbine, etc. are still poorly known in Cameroon. Aside from this material aspect, there is a huge weakness in financial resources. Apart from the fact that it is obliged to deposit about 50% of its revenue in the operating accounts of the French Treasury [35], under the pretext of guarantee of international exchanges, Cameroon does not have effective financial resources to promote its renewable energies sector. Meanwhile, as currency is a very important factor in terms of trade, the CFA franc is therefore very inefficient on the international markets because it does not allow Cameroon to better express itself on the markets of renewable energy technologies [36]. This calls into question the existing monetary policies between the French Republic and African countries of this CFA Francs zone.

There are several weaknesses in Cameroon's renewable energy management process. Among others, we noted the lack of a management framework appropriate to these energies, lack of this sector sustainable development's vision, administrative slowness, and bad governance. Among other scourges harmful to good governance, there is corruption, bad business climate, massive embezzlement of public funds, mafia networks, lack of alternatives to positions of responsibility, and many others. According to(Transparency International, 2016) [37], Cameroon's perceptible corruption index in 2016 was in the 10-19 range, ranking the country 145th out of 176 corrupt countries in the world. In its 2016 report, Doing Business had identified Cameroon as 172th out of 189 countries easy to do business [38], which does not promote good health of private investment. In terms of management methods, we noted the absence or the inadequacy of a specific legislative framework for this sector, the lack of management policies, and inefficient management processes.

Cameroon is a country of great socio-cultural diversity where currently live more than 24 million people, of which more than 50% are between 20 and 30 years old. This population, native to more than 200 ethnic groups and regularly distributed across the ten regions of the country, can easily communicate in English and French. Meanwhile, about 45% of the Cameroonian population currently lives below the poverty line [38], and almost 50% of this population still lives in rural areas where about 99% of this 50 % are engaged in farm work. In 2015 Cameroon's HDI value was estimated at 0.518, which placed the country in the low human development category, ranking 153 out of 188 countries and territories [39].This situation thus reveals the existence of a low standard of living, the lack of effective communication techniques, and above all the lack of skills. At the educational level, about 78% of Cameroonians have completed primary school, and only 13.4% in secondary and 7.7% in higher education of Cameroonians are currently enrolled in technical studies [16]. This reflects the country's inability to carry out the R&DV activities required for the implementation of renewable energy technologies.

As shown in Table 1, we noted that there is no specific State agency in charge of the renewable energy sector in Cameroon. Yet, the sustainable promotion of this sector requires the establishment of a physical and moral State's agency, which will deal specifically with issues related to this sector, as is the case in more developed countries than Cameroon. Meanwhile, Cameroon is not spared the adverse effects of climate change that continues to grow in power today. Global warming, floods, landslides, and many others have already marked Cameroon's history on several occasions. Hydropower, which accounted for about 98% of the country's total electricity supply, has continued to become less efficient since 2001, due to the drought of rivers that Cameroon frequently experiences in the first half of each year. This drought, which is mainly due to the increase in temperatures, also contributes to the destruction of the Congo Basin forest, which covers Cameroon in particular. On the

security front, Cameroon is one of the African countries that continue to enjoy relatively favourable political stability for development, despite security challenges related to terrorism in the country's border with Nigeria [40].

5. Conclusion and Policy Implications

5.1. Conclusion

The main objective of this paper was to identify barriers related to the deployment of renewable energies in Cameroon. To achieve this goal, we applied the fishbone diagram as part of a SWOT analysis to evaluate Cameroon's renewable energy sector. This has not only made it possible to define barriers but also to identify the strengths, threats, and opportunities related to the sustainable development of renewable energies in Cameroon. The results showed that Cameroon has a large potential for underutilized renewable energy, including hydropower, solar power, wind turbines, and biomass. Among others challenges, technological and financial barriers are major problems that prevent the promotion of renewable energies in Cameroon. However, to enable Cameroon not only to achieve its energy and environmental goals but above all to develop a low-carbon economy, policymakers should pay more attention to the following points.

5.2. Policy Implications

In terms of renewable energy resources, Cameroon should intensify its hydropower efficiency, while launching significantly in the development of solar, wind, thermal, and many other sources. This would require the development of a technology implementation process strongly rooted in R&DV. Moreover, it would be preferable for Cameroon to further promote the development of solar and wind energy sources, given the uncertainty of the long-term availability of hydropower. To ensure the proper transfer of technology and avoid long-term dependency, Cameroon should reform its education system to enable it to provide the necessary skills for the sustainable development of its renewable energy sector. On the material side, Cameroon should develop a maintenance policy that will promote the rapid implementation of advanced equipment while remaining closely linked to the country's R&DV policy. In addition to these human and material resources, the acquisition of necessary financing for the progressive deployment of renewable energies should constitute a permanent conquest for Cameroon. Thus, given the cost and complexity of access to renewable energy technologies, good planning, and investment choice are required. Meanwhile, Cameroon and all African countries in the CFA Franc zone should review the monetary policies that link them to the French Republic, in order to overcome the weaknesses of this currency in international markets. This initiative will allow these countries and Cameroon in particular, to better express themselves on the international markets for renewable energy technologies. In terms of management, Cameroon should set up a State agency with well-defined missions and responsibilities, which will deal specifically with issues related to its renewable energies. This requires the formulation of dynamic and effective policies and management methods, including a sustainable development’s vision of this sector in Cameroon. Meanwhile, Cameroon should intensify and continuously promote good governance practices. This would require eradicating corruption, misappropriation of public funds, mafia networks, etc. The country should also improve its business climate, in order to facilitate the easy penetration of private investment and the innovation of local businesses. However, note that, despite the significant challenges, renewables will remain Cameroon's main source of energy supply, and will further contribute to the development of a low-carbon economy in the future.

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