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An Overview of Electricity in Cameroon: Current Status, Influential Factors and Government Actions

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ABSTRACT

The mastery of demand for electricity in Cameroon is one of the concerns of the State, which is part of the development plan for the electricity sector by 2025. Thus, this paper identifies the factors that influence the electricity sector and mentions positive government actions. We use in this work data on the basis of previous work on one hand and a survey on the other hand in order to reinforce the analysis. The survey was conducted on a sample of 3,000 households in Douala in order to identify socio-economic factors that influence the electricity sector. For this, face-to-face approach was chosen. Households were randomly selected, then a questionnaire was submitted to them, assisting them in their response options. Results show that though certain factors have a positive influence on the electricity sector, Cameroon's current electricity system still remains unsustainable. A comprehensive view of how various factors influence the electricity sector in Cameroon would help in understanding the challenges for the future development of the sector. Government policies in this area would be more enlightened and undergo reorganization. Different models of electricity consumption could thus be formulated and adopted in order to predict the potential impacts of changes in planning.

Keywords: Electricity, Current status, Influential factors, Government actions, Cameroon
JEL Classifications: O13, O38, P28, Q42

1. INTRODUCTION

Improving the quality of energy services is one of the sustainable development priorities supported by the United Nations organization since 2015. Access to energy for all in general and to electricity in particular, is an important point for the sustainable development of the sub-Saharan African countries (International Energy Agency, 2020). Electricity is therefore one of the key poles of sustainable development and, as modern energy, it plays a key role in social development (International Energy Agency, 2020). As such, electricity is a key factor to Cameroon's emergence scheduled to be achieved by 2035 (MINEPAT, 2009). The sensitivity of the demand for electric power in time is justified because the generated electricity should be instantly consumed (Psiloglou, 2009). Its importance increases with technological progress, industrialization and need for modern comfort. Increasing and improving electricity require identification and control of factors that have a positive or negative impact on the electricity sector. A significant number of works describe the impact of economic factors, population and technology of electricity (Zhang et al., 2012; Jones et al., 2015; Fana et al., 2015; Jones and Lomas, 2015; Huang, 2015; Sharma and Kautish, 2019).

A comprehensive view of how various factors influence the electricity sector would certainly help in understanding the challenges for the future development of the sector. Government policies in this area could be more enlightened and undergo reorganization. Different models of electricity consumption could thus be formulated and adopted in order to predict the potential impacts of changes in planning.

The Ministry of the Economy, Planning and Regional Development published in 2015, the Growth and Employment Strategy Paper (GESP) which traces the main development axes of Cameroon. This document clearly shows that Cameroon fits completely into a development policy of all these sectors (GESP, 2009). This development is subject to high electricity demand. The generation of electricity should therefore be equal to its demand. Unfortunately, this is not the case for Cameroon. Despite its enormous hydropower potential[1] (Abanda, 2012), electricity in Cameroon is unevenly distributed. Only 20% of Cameroon's population has access to the national grid (Wirba et al., 2015). Moreover power cuts are frequent. The impact of the power cuts is impeded as cost bills to end-users. Power cuts in the Cameroon industries generate huge production losses for them (Tamo Tatietse et al., 2010; Diboma and Tamo Tatsietse, 2013). The electricity needs of end-users are continuously growing. For this, unscheduled and repeated power cuts, interrupt the operation and paralyzes the activities of these end users. The transmission and distribution networks of electricity in Cameroon are obsolete (SIE-Cameroon, 2011). These networks are the cause of approximately 26.32% of the losses in electricity in 2013 (MINEE, 2015). Thus, one quarter of the generated electric power is lost, while the populations' needs are more and more pressing. We also note that electricity prices are influenced by the British company ENEO (ENErgy Of Cameroon) in charge of generation and distribution of electricity in Cameroon (Tamo Tatietse et al., 2010; Diboma and Tamo Tatsietse, 2013).

Given the points mentioned above, it can be seen that only a deep knowledge of the factors affecting the electricity sector would be a starting solution to the electricity autonomy problem in Cameroon. Climate is among the key factors affecting energy consumption and electricity in particular (Hekkenberg et al., 2009; Hou et al., 2014; Moral-Carcedo, 2015).

A few studies have set out to identify the factors that influence the development of the electricity sector over the past three decades. Bunn and Larsen (1992) for example, present in 1992 a study giving an overview of how investment and various reforms could impact the development of the electricity sector in England. In addition, Kemmler (2007) made in 2007, an analysis of the factors which influence the electrification of households and the extension of the electricity grids in India. Several electrification models are formulated depending on the type of household, income and location (rural or urban). Such studies on the Cameroonian electricity sector are scarce, and the small margin of existing works is reports from a few active institutions in the electricity sector. Thus, the objective of this study is to show the influence of various factors identified on the development of the Cameroonian electricity sector and make suggestions that could allow the various current energy policies to effectively converge towards autonomy in Cameroon's electrical energy.

Is the Cameroonian electricity sector sustainable? The answer to this question necessarily involves collecting data based on previous works on the one hand, and a survey on the other in order to strengthen the analysis. An overview of the electricity sector is equally important, as well as a glimpse of the actions of the Cameroonian government in favour of autonomy in electrical energy.

1 Cameroon has the second largest hydropower potential in Africa after the Democratic Republic of Congo.

2. METHODOLOGY

2.1. The Study Area

Cameroon's (Nematchoua et al., 2014a) population was 20 million inhabitants in 2015 whereas it was only about 5 million when the country gained its independence in 1960. Six towns exceeded the 200 thousand population threshold in 2001: Douala (the economic capital, with 1.5 million inhabitants), Yaoundé (the political capital and seat of the institutions, around 1.25 million inhabitants), Garoua (357 thousand inhabitants), Bamenda (316 thousand inhabitants), Maroua (272 thousand inhabitants), and Bafoussam (approximately 242 inhabitants). Nowadays, the ten most populated cities are: Douala (2.2 million), Yaoundé (1.7 million), Garoua (600 thousand), Bafoussam (400 thousand), Nkongsamba (300 thousand), Bamenda (280 thousand), Edéa (250 thousand), Kribi (220 thousand), Maroua (220 thousand) and Ngaoundéré (200 thousand). In fact there are twenty cities with least 50 thousand inhabitants. As for the number of households, it was estimated at 3,142,210 households in 2017 (SND30, 2020). Currently, more than half (53.2%) of these households are located in urban areas and the city of Douala alone represents 20% of these shares. The relatively large size of Douala is due to the fact that it hosts the economic capital of Cameroon.

The United Nations Development Program (UNDP) ranks Cameroon 153rd out of 188 countries in 2014, with a Human Development Index (HDI) of 0.512 (UNDP, 2021). This last ranking is based on socio-economic data such as education, health, access to electricity or income per capita. HDI gives an estimate of the general standard of living of a country. For Cameroon, it improved between 1980 and 2014, going from 0.405 to 0.512. According to the UNDP, poverty rate in Cameroon in 2004 was 35.6% of the total population. Poverty is much more present in the countryside (70%), while urban poverty affects nearly 2 million people, mainly in Yaoundé and Douala. Half of the households are not connected to the electricity network and more than three quarters cannot afford alternative sources.

2.2. Experimental Campaign

A questionnaire-based survey with a rather high response rate was used to collect detailed information about residents' traits and behaviors. First, a field trip was done to locate households in order to investigate a diversity of households. Some families (39%) preferred to make an appointment because of their schedule, while others (61%) chose to give us the interview in situ. For those with whom an appointment has been made, we sent them a reminder message 72 h before the day of the appointment and another reminder 24 h to confirm their availability. In both cases, all questions considered the household as a whole, including all occupants. There were at least two occupants per household, and we reassured ourselves that the answers apply to the entire household.

The number of questionnaires answered depended on the commune, with 684 copies distributed in the Douala 1 zone, 530 in the Douala 2 zone, 536 in the Douala 3 zone, 520 in the Douala 4 zone, and 730 in the Douala 5 zone. The questionnaires were written in English and French, which are the country's official languages. When distributing these questionnaires, the occupants' language choices were properly considered. All questionnaires were collected between November 1, 2018 and January 28, 2019.

2.3. Data Collection and Organization

Data and information were collected through face to face surveys and corresponding inspections of each household. Data was collected in the city of Douala for two reasons: it is the economic capital of Cameroon, and the most populated city in Cameroon and in Central Africa. Moreover, the city of Douala concentrates 20% of the country's urban population, which is more than any other city in Cameroon. Douala is today a mosaic of the different ethnic groups that make up Cameroon, the city facing its recent growth to the rural exodus that has pushed hundreds of thousands of Cameroonians to leave their countryside to settle in the cities. It is also in Douala that we meet all factors that influence the electricity sector.

The information collected were grouped as follows:

- Part 1. General information, including data on household location, area, number of rooms, number of occupants, year of construction, type of dwelling and number of floors.
- Part 2. Information on the annual income of each household.
- Part 3. Information on peak consumption times for each household. In particular, the hours of use of household appliances such as air conditioners, refrigerators, hot plates, televisions, computers, radios, irons, heaters, etc. Other information included information on electricity consumption habits; especially for lighting, refrigeration, other heating applications, the number of electrical appliances, the number and type of air conditioners installed in the house and, finally, information on the maintenance of household appliances and domestic electrical installations. Electricity consumption was obtained directly from monthly electricity bills.

This information and part of the data were obtained by careful analysis of the questionnaires, with an extract presented in the appendix. A database was created and the necessary quality control was carried out, while all extreme values were excluded. In the end, data from 3,000 households was used. Based on the annual income distribution, three income classes were sorted, and a specific analysis was performed for each income class in a comparative way. Income classes were defined using a mathematical approach called "clustering," which is a mathematical approach for classifying numeric data. It is based on the identification of subgroups on a set of data called "clusters," where all objects are described by similar characteristics.

3. OVERVIEW OF CAMEROON'S ELECTRICITY SECTOR

3.1. Electric Production, Supply and Energy Balance

Cameroon has a huge hydroelectric potential of 19.71 Gigawatts (GW) of which only 3.72% were valued in 2013 (MINEE, 2015). Its gross or theoretical hydroelectric potential is 294 Terawatts hour per year (TWh/year) while its feasible technical hydroelectric potential is 115 TWh/year (MINEE, 2015; Bunn and Larsen 1992). Some studies reveal a multitude of potential sites necessary for the development of the huge hydroelectric potential of Cameroon (Abanda, 2012; Kenfack, 2012; Tchouate, 2013). There are 74 micro hydro and 89 major hydro dams in Cameroon. As far as exploited sites are concerned, there are three large hydroelectric dams: the Edea hydropower plant, Song Loulou and Lagdo with respective installed powers of 276.2 Megawatts (MW), 384 MW and 72 MW in 2013 (SIE-Cameroon, 2011). Hydropower productions in Edea and Song Loulou are supported by three reservoirs: Bamendjin, Mape and Mbakaou reservoirs. All these reservoirs help regulate the flow rate of river Sanaga (Tchouate, 2003).

Table 1 shows that hydroelectric energy source is dominant in the generation of public electricity in Cameroon. It represents 57.61% of the installed power corresponding to 80.91% of electrical energy. Total production without accounting that from isolated power stations is 5406.72 GWh in 2015. Interconnected or isolated thermal power plants are unevenly distributed throughout the country on three networks: the South interconnected grid network (which is the largest and covers six regions), the North interconnected grid network (which covers three regions), and the East interconnected grid network (which only covers the East region). It is worth noting that there is not yet an installed hydroelectric plant in the East interconnected network in Cameroon despite potential hydropower sites. Many of the thermal power plants (interconnected and isolated) (Table 1) operate on heavy fuel oil (HFO) (67.78 million liters of HFO were consumed for power generation in 2015), or on light fuel oil (LFO) (49.32 million liters of LFO were consumed for power generation in 2015). The Kribi gas plant is the only plant that runs on natural gas with an installed capacity of 216 MW and 117 760 000 Nm3 consumption in 2015.

Self-electricity production helps support public power consumption in Cameroon. The share of auto producers in the thermal sector reflects the will of industries and populations to satisfy themselves by using electricity generator engines to guard against insufficient supply of public electricity or substitute in areas not covered by grid networks. In 2010, self-thermal generation represented 36% (586 MW) of total installed capacity in Cameroon (SIE-Cameroon, 2011). This is well below hydropower (45%) and public thermal (18%).

Figure 1a clearly shows that generated electricity is greater than what is sold. The difference between the two variables represents total electricity loss. These losses are of various origins: undistributed energies which reflect the quality of the technical service; technical losses which include losses due to the

Table 1: Summary of Cameroon power plants capacity, transmission and distribution lines in 2015 (MINEE, 2015).

a) Power plants capacity

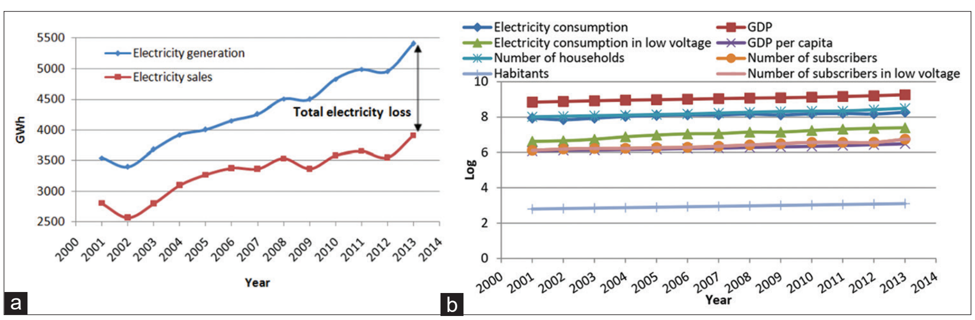
Power plants	Interconnected grid	Electricity generation (GWh)	Installed power (MW)		Available power (MW)		Fuel	Year of commissioning
			Hydro	Thermal	Hydro	Thermal		
Lagdo	North grid	304.84	72		66.78		Water	1983
Song Loulou	South grid	2396.14	384		363.89		Water	1981
Edea	South grid	1671.70	276.2		236.51		Water	1953
Oyomabang 1	South grid			18		n.a	HFO	2000
Oyomabang 2	South grid			8		n.a	LFO	2002
Limbe	South grid			85		n.a	HFO	2005
Bafoussam	South grid			13		n.a	LFO	1986
Logbaba 2	South grid			12		n.a	HFO	2009
Mbalmayo	South grid			10		n.a	LFO	2012
Bamenda	South grid			20		n.a	LFO	2012
Ebolowa	South grid			10		n.a	LFO	2012
Dibamba	South grid			88		n.a	HFO	2009
Kribi	South grid			216		n.a	Natural gas	2013
Djamboutou 1	North grid			17		n.a	LFO	1971
Kousseri	North grid			4.66		n.a	LFO	1976
Bertoua	Est grid			8.6		n.a	LFO	1972
Bassa-Logbaba	South grid			50		n.a	Natural gas	2015
Isolated thermal power plants (122)	Isolated	84.50		77.93		n.a	Diesel	
Total ENEO power plants		5406.72	732.2	637.19	667.18	n.a		

b) Transmission and distribution lines

Lines	Potential difference	Interconnected grid	Length (km)
High voltage	225 kV	South grid	795.95
	110 kV	North grid	337.63
	90 kV	South and North grid	1210.55
Medium voltage	30/15/10/5.5 kV	South, North and East grid	12845*
Low voltage	220/240 V	South, North and East grid	13845*

n.a: Not available. *These values are for the year 2010

Figure 1: (a) Electricity generation and sales in Cameroon from 2001 to 2013 (MINEE, 2015); (b) Evolution of indicators for the period 2001-2013



Joule effect during the transport and distribution of energy; and non-technical losses due to fraud. Electricity fraud in Cameroon occurs on distributions lines before the meter by direct stitching, in order to reduce bills (Fondja Wandji, 2011). Note that the actual electricity consumption in Cameroon is the sum of sold electricity, non-technical losses and self-electricity generation. Since auto production and non-technical losses have not been inventoried, only sold electricity will be treated as electricity consumption in the remainder of this study.

3.2. Electricity Transmission and Distribution

ENEO uses three lines for electricity transmission: the high voltage, medium voltage and low voltage lines (Table 1). Note that the high voltage lines are inexistent in the East interconnected grid network. Electricity carried by high voltage lines in the South interconnected grid network are of two types: 225 kV and 90 kV (of 1009.4 km long). Similarly, two types of voltages are available in the North interconnected network: 110 kV and 90 kV (of 201.15 km long). Electricity carried by high voltage lines is distributed only in three industries (ALUCAM[2] and SOCATRAL[3] found in the South interconnected network, and CIMENCAM[4] in both the North and South interconnected networks) in Cameroon in 2015. All other industries operate on medium voltage electricity.

2 Cameroon Aluminum Company (an extracting industry)
3 Cameroon Aluminum Processing Company
4 Cameroon Cement works Company

The low-voltage power distribution is reserved for end-users (residential and public sectors) only.

The transmission and distribution system of electrical energy has experienced significant losses. These losses represent 245 GWh for transmission and 1178.1 GWh for distribution relative to the total electrical energy produced; that is 4.53% and 21.79% for transmission and distribution respectively. As for the number of subscribers per level voltage electricity, there are only three high voltage power subscribers; namely: ALUCAM, SOCATRAL and CIMENCAM. A total of 888844 subscribers are formally identified in 2013. There are 1539 and 887302 medium voltage and low voltage subscribers respectively. Electricity sold to subscribers per level voltage in 2013 is 1623.46 GWh, 1005.14 GWh, and 1281.62 GWh for low, medium and high voltage, respectively. Thus, undistributed electric power amounts to approximately 74 GWh for the same period.

4. IDENTIFICATION OF ELECTRICITY-RELATED FACTORS IN CAMEROON

4.1. Socio-economic Factors Influencing Electricity Consumption in Cameroon

Socio-economic factors influence the electricity sector at the level of consumption, particularly in the residential sector. Past studies have identified socio-economic factors as one of the key factors influencing electricity consumption. Their impact can be positive or negative (Jones et al., 2015; Jones and Lomas, 2015; Tiwari, 2000; Halvorsen and Larsen, 2001; Santamouris, 2007; Druckman and Jackson, 2008; Louw et al., 2008; Wiesmann et al., 2011; Sanquist et al., 2012; Brounen et al., 2012; McLoughlin et al., 2012; Wyatt, 2013; Zhou and Teng, 2013).

Evolution of indicators identified in this study are illustrated in Figure 1b. We observe a strong correlation (0.92) between electricity consumption and economic growth in Cameroon in line with results of Tamba et al. (2017) and Fondja Wandji (2013). Similarly, there are also strong correlations between low voltage electricity consumption and other socio-economic indicators. Figure 1b shows the evolution of indicators for de period 2001-2013. It can be observed that these indicators have similar long-term trends. The logarithmic form of indicators was used to standardize the units with the aim of facilitating analysis. From the curves of Figure 1b and correlation coefficients, we can say that there is significant influence between electricity consumption and socio-economic factors in Cameroon. Therefore, electricity consumption will rise if socio-economic factors increase.

Other factors impact electricity consumption and influence the development of the Cameroonian electricity sector. The surveys carried out by the authors make it possible to group these factors according to the different categories presented in Table 2.

Investigations of socio-economic characteristics carried out in December 2018 by the authors only concerns 3,000 households (corresponding to 1,000 subscribers). This survey was conducted in the city of Douala (the economic and industrial capital of Cameroon). Results from these investigations are summarized in Table 3. The electricity consumption in households were grouped into three categories namely: 2.2-2.4 kW, 3.3-3.6 kW and 6.6-7.2 kW; which corresponds to the low voltage 220/240V for currents of 10, 15 and 30A, respectively. Table 3 shows that apart from the tenue that does not significantly influence electricity consumption in Cameroon, all other features have a positive effect on consumption. Moreover, we find that households that consume energy of 6.6-7.2 kWh have a significant positive effect than others on the consumption of electricity.

4.2. Geographical Factors

Geographical factors have a strong influence on the electricity sector in Cameroon. Since the electric power system in Cameroon is dominated by hydropower, hydrology is identified as one of the most important factors. It can affect electricity production either positively or negatively. SIE-Cameroon (2011), MINEE (2015) and Guefano (2015) have conducted a detailed study on the evolution of the quantity of water in existing storage dams used for electricity generation from 2010 to 2013. We find that the fill rate of Mbakaou dam in 2013 was 99.92% in a normal period and 6.12% in dry periods. Similarly, the Bamendjin dam was 85.36% in normal times and 25.28% in dry periods; Mape that corresponded to 60.70% and 18.18% in normal times and low water, respectively. This corresponds to a total occupancy rate of 79.77% and 15.86% in normal times and low water in 2013, respectively. Note that the low water period in Cameroon is around 4300/4400 h, it varies from November/December to April/May. The low water period is characterized by the dry season period in the river Sanaga basin. The low water period has a totally negative effect on the production of hydro-electricity. What appeals to the use of thermal power plants to support production. To solve the problem of lack of water for hydroelectric plants and increase the amount of water during the low water period, Cameroon is looking forward to initiating new dams.

The uneven distribution of the three interconnected networks in Cameroon has a negative impact on the electricity sector (SIE-Cameroon, 2011). The South interconnected network is very unstable for electricity and faces problems (with the example of repeated power cuts) both in normal periods and low water periods (Guefano, 2015). Moreover, supply is well below demand, hence the repeated support of thermal power plants (interconnected and isolated auto production). The North interconnected network has an offer that is greater than the demand for electricity (SIE-Cameroon, 2011). This is due to the low number of subscribers (no high voltage subscribers), and transmission and distribution lines are not widespread enough. Currently, when the power plant that feeds the interconnected network of East Cameroon fails, this area of the country remains without electricity throughout the duration of the repair. In addition, the interconnected networks favor a few large cities (with the example of Yaounde, Douala and Bafoussam) to the detriment of other cities and especially rural areas (SIE-Cameroon, 2011).

4.3. End Users Factors

According to the literature (Jones et al., 2015; Jones and Lomas, 2015; Brounen et al., 2012; Wyatt, 2013; Zhou and Teng, 2013;

Table 2: Identification of factors and their scope as identified in the literature

Classification of factors	Identified factors	Application area
Socio-economic (Fondja Wandji, 2013)	GDP	Generation, transport, distribution and electricity consumption
	GDP per capita	electricity consumption
	Number of dwellings	electricity consumption
	Number of subscribers	electricity consumption
	Population	electricity consumption
Geographic (SIE-Cameroon, 2011)	Hydrology	electricity generation
	Geography of interconnected networks	Generation, transport, distribution and electricity consumption
	Electrification (rural/urban)	Transport, distribution and electricity consumption
End user (Nematchoua et al., 2014a, 2014b)	Habitat	electricity consumption
	Industry	electricity consumption
	Public administration	electricity consumption
	Agriculture	electricity consumption
Climatic (PDSE, 2013)	Temperature	electricity consumption
	Precipitation	electricity generation
Technical (Diboma and Tamo Tatietse, 2013)	Technical losses	Distribution and consumption of electricity
	Fraud	Distribution and consumption of electricity
	Undistributed energy	Generation, transport, distribution and electricity consumption
	Pricing	electricity consumption
	Autoproduction	electricity consumption
Political (Kenfack and Hamandjoda, 2012)	Reglementation	electricity consumption

Table 3: Results obtained from questionnaire-based survey

Socio-economica characteristics	Number of home by subscribed power			Total homes	Effect of characteristics on electricity consumption
	2,2/2,4 (kW)	3,3/3,6 (kW)	6,6/7,2 (kW)		
Number of occupants					Positive significant effect
1-3	88	410	749	1247	
4-5	358	389	213	960	
>5	554	201	38	793	
Family composition					Positive significant effect
Children	492	317	135	944	
Without children	0	45	109	154	
Presence of teenagers	284	301	102	687	
Presence of adults (22-69-years-old) (HRP)	139	257	489	885	
Presence of elder people (70-years-old)	85	80	165	330	
Annual household income					Positive significant effect
35000-50000 FCFA	613	144	0	757	
50000-100000 FCFA	359	598	0	957	
>100000 FCFA	28	258	1000	1286	
Tenure					Non-significant effect
Owned house	154	425	894	1473	
Rented	846	575	106	1527	

HRP: Household responsible person

Tso and Yau, 2003; Iovino and Tsitsianis, 2020a, 2020b; Jones, 2014), several features come in for the home factor. Only a few have been identified for Cameroon. The type of housing has a positive effect on the next electricity consumption it is modern and negative following it traditional. There are four housing types in Cameroun: brick made modern dwelling, board made traditional dwelling, bamboo made traditional, and brick made dwelling (Nematchoua et al., 2014a, 2014b). Traditional houses consume little or no electricity compared to modern ones. There is no significant effect between certain characteristics (age of dwellings, number of rooms, number of rooms, size of the dwelling) and electricity consumption in the traditional dwellings in Cameroon. Nonetheless, these characteristics have a positive effect on the consumption of electricity in modern houses. The high electricity consumption in modern homes is justified by the presence of certain appliances (e.g. heating appliances, mechanical ventilation, water heating system) that do not exist in traditional homes. Just as modern dwellings, public administration has a positive effect on the consumption of electricity in Cameroon. This positive effect is justified by the use of electrical appliances (number, frequency of use and power devices) (Jones et al., 2015).

The works of Diboma and Tamo Tatietse (2013) and Tamo Tatietse et al. (2010) show that electricity demand in the industries in Cameroon exceeds supply. We find that if electricity demand was satisfied, the industrial sector would have a significant and positive effect on electricity consumption. At present, we cannot identify the nature of the impact (positive or negative) between industries and electricity consumption in Cameroon. On the other hand, in the opposite direction, Diboma and Tamo Tatietse (2013) and Tamo Tatietse et al. (2010) show the country's industrial production is frequently disrupted by power supply problems. Data collection and surveys conducted by these researchers have shown that expenses related to electricity in Cameroon's industrial companies have significantly increased due to the untimely power cuts. The increase in expenses related to the consumption of electricity is caused by the search of a solution. One of the solutions found is the generation of electricity by auto production using generators. This negatively affects industries in Cameroon.

4.4. Climatic Factors

Since the South interconnected network is the largest of Cameroon, we will consider it as proxy of the electricity grid in this part. This consideration can be justified by the fact that the peak load of the network is the highest (the South interconnected network peak load is as high as 684.36 MW, while the North and East interconnected networks peak load are 59.10 MW and 12.51 MW in 2013 respectively (MINEE, 2015). Cameroon's climatic data as revealed by PDSE (2013) helps to verify that the country is characterized by an average of the following three seasons:

- The dry season (slightly rainy) in November, December, January and February, is characterized by a precipitation level <200 mm/month, an average number of raining days of 5 days/month and average temperatures ranging between 24.5°C and 26°C/month;
- The short rainy season: mainly covering the months of April, May, June and October, with precipitations ranging between 200 and 400 mm/month, number of raining days estimated at average 15 days/month and temperatures average of the order of 25°C/month;
- The long rainy season: covering the three months of July, August, September and may include the 1st week of October, with dense rainfall exceeding 400 mm/month, number of raining days exceeding 20 days/month and average temperatures are the lowest of the year, between 23.5°C and 24°C on average per month.

The electric power demand reached the highest levels during the dry season (PDSE, 2013). It is characterized by relatively high temperatures. Hence a tendency to a relative increase of the electricity consumed. This is generally recorded in modern homes and public administrations. It is caused by the use of air conditioning and fans. However, the electric power demand reached low levels during the long rainy season. We can justify this reduction in demand by the impact of rain on some economic and socio-collective activities. Some studies (Hou et al., 2014; Moral-Carcedo, 2015; Avordeh et al., 2021) show that the temperature (depending on the cooling degree-days or heating degree-days, the summer or winter) significantly affect electricity consumption. Consequently, in Cameroon, very low temperature variation between the months and seasons of the year (between about 23°C and 26°C) can only slightly impact on the load profile (PDSE, 2013). Therefore, the temperature does not significantly affect the consumption of electricity in Cameroon. Despite the fact that there is an electricity pricing by season in Cameroon, it is found that the electricity used in the dry season (slightly rainy) is almost 2.5% higher than that consumed in the short raining season, and 6% higher than that consumed in the long raining season (PDSE, 2013). In addition, in the long raining season the flow of the Sanaga River and other rivers is higher than the speed of the turbines of hydropower plants in the country. Therefore, the change in seasons and rainfall significantly affect the electricity sector.

4.5. Technical Factors

Overall, technical factors have a negative impact on the electricity sector in Cameroon. This is due to the ageing of transmission and distribution of electricity lines, and saturation of the interconnected South network. Thus, the technical losses are estimated at 26.32% of the total electricity production (SIE-Cameroon, 2011; MINEE, 2015). The undistributed electric power (outages, programmed works and incidents) in turn is 73.24 GWh in 2013 (MINEE, 2015). Regarding electricity fraud (i.e. the consumer is connected directly to the grid without acquiring a subscription agreement), it ranges from 4% to 9% of electricity generation following that the check is strict or not (SIE-Cameroon, 2011). The technical factors mentioned above, on one hand play the role of a regulator from the pricing of electricity and influence the purchase of a generator for self-generation of electricity on the other hand.

The installed capacity of self-production in Cameroon is estimated at 586 MW in 2010 (SIE-Cameroon, 2011). This causes a negative effect from an economic point of view among end users and private industries (Tamo Tatietse et al., 2010; Diboma and Tamo Tatietse, 2013). In addition to the costs of production, transportation and distribution, the tariffs for electricity subscribers in Cameroon also take into account the aforementioned technical factors (Guefano, 2015). Thus, Table 4 shows the pre-tax price of a kWh of electricity in the low, medium and high voltage of the country. The price of electrical energy is not officially known for high voltage subscribers. This is a contract between the subscribers and the electricity distribution company in Cameroon. Then the price of electricity for medium voltage subscribers is influenced by the time of use and life of the contract power. Finally, the electricity prices in low voltage are influenced by the amount of energy consumed by customers and by customer type.

Table 4: Price of 1 kWh of electricity in Cameroon till present

Low voltage		
	Consumed energy in kWh	**Price in FCFA**
Domestic or residential	Social class (<110 kWh)	50
	From 111 to 400 kWh	79
	From 401 to 800 kWh	94
	More than 801 kWh	99
Other users or nonresidential	Social class (<110 kWh)	84
	From 111 to 400 kWh	92
	More than 401 kWh	99
Public lighting		66
Medium voltage		
Time of consumption of subscribed power	**Time interval**	**Price in FCFA**
From 0 to 200 h	between 23 h and 18 h	70
From 0 to 200 h	between 18 h and 23 h	85
From 201 to 400 h	between 23 heures and 18 h	65
From 201 to 400 h	between 18 h and 23 h	85
Above 401 h	between 23 h and 18 h	60
Above 401 h	between 18 h and 23 h	85
High voltage		
	By contract	

4.6. Political Factors

The multitude of Cameroon laws and decrees in the electricity sector shows that political factors have a positive effect (Kenfack and Hamandjoda, 2012). This is contradictory to reality, as for end users these factors have a negative effect. This is justified by the fact that every sector losses are charged to end users. Poor understanding and application of energy efficiency leads to inappropriate regulations for end users. This resulted in an increase in the price of electricity despite the huge hydroelectric potential that has Cameroon. In order to reduce the power deficit of Cameroon, to coordinate actions between the different actors and to improve the legal and regulatory framework in the field of electricity, Cameroon will develop new energy sector strategy.

5. RENEWABLE ENERGY AS A POSITIVE FACTOR OF CAMEROON ELECTRICITY SECTOR

The development of Cameroon electricity sector can be boosted by renewable energies but the extent to which renewable energy sources can potentially contribute to develop the electricity sector is still not well known (Tansi, 2011). Cameroon is incredibly rich in renewable energies, namely: abundant sunlight in almost all the parts of the country, wind on hillsides and on top of mountains (Tchinda et al., 2000; Tchinda and Kaptouom, 2003), biomass in the southern forests and rearing zones (GVC, 2007), small waterways in mountainous regions of the country, etc. However, these sources are sparsely located and their exploitation sometimes requires numerous studies, technical predispositions and huge investments. It should be noted that exploitation of renewable energies in Cameroon greatly depends of the government's willingness rather than on individuals (GVC, 2007). Nevertheless, considerable efforts are being made by a number of local institutions to adapt the existing technology to the Cameroonian context.

Many studies reveal that solar energy intensity in Cameroon is about 4.9 kWh/day/m^2 on average (SIE-Cameroon, 2011; Wirba et al., 2015), and solar photovoltaic energy has been experiencing a rapid development for some years now. One example is the "Cameroon 2020 photovoltaic plants project" is aimed at producing 500 MW from solar energy (Kenfack et al., 2011). This will help the lightening of more than 250 localities with priority to rural localities.

The places of Kaélé, Bamboutos Mountains and Kousseri are potential reservoirs of wind energy, with wind speeds ranging from 2.53m/s to 4.2m/s. The best way to value this type of energy in Cameroon is through its usage to pump water in rural zones which could reduce dependence to grid connections that is too costly for villagers (Nfah et al., 2010).

There are 29 small hydropower plants in the west region that could help reinforce the three major existing plants (Edea, Songloulou and Lagdo) during droughts (Tekounegning, 2010; European Investment Bank, 2012). The southern part of the country is covered by forest that provides wood, sawdust and wood chips from forestry companies and coal (SIE-Cameroon, 2011). Biomass combustion technology is peculiar in the east region (Pouna, 1999). Agricultural waste can be gasified and used to generate electricity, especially in rural areas where grid connection is impossible to power fridges in medical centres.

Cameroon has few exploitable geothermal potential areas: Ngaoundere; the Mount Cameroon area; and the area around Manengouba. Given that tectonic activities are quite common in Cameroon due to the presence of Mount Cameroon, it is reasonable to investigate how geothermal energy can be exploited to develop the electricity sector. Cameroon has a coast of almost 300 km with the Atlantic Ocean. This represents a possible development of tidal energy. The Cameroon Ministry of Energy has signed a memorandum with the Nigerian MRS Ltd for the development of tidal energy in Cameroon (Abanda, 2012). This project could constitute a great advancement in Cameroon if it comes true.

6. MID-TERM CAMEROON GOVERNMENT ACTION IN FAVOUR OF ENERGY ELECTRIC AUTONOMY

The Cameroon government has as political objectives to improve the fight against poverty by increasing the gross national product per capita, by changing it from approximately 438951 FCFA in 2010 to four times this value in 2025 (World Bank, 2015). This ambitious program requires the implementation of a development plan in the medium and long term in the sector of energy and electricity in particular. To achieve these objectives, the Cameroonian government decided to rely on available resources (important and less costly), mainly hydroelectricity and natural gas (gas power plant at Kribi). Most hydropower potential in the medium term facilities (project commissioned in 2025) has been identified on the different basins. According Kenfack and Hamandjoda (2012) and SIE-Cameroon (2011), for the Sanaga basin, we have: more equipment at Song Loulou (102 MW) and Edea (68 MW); Nachtigal upstream (275 MW); Lom Pangar dam (6 km^3 for storage dam and 30 MW for hydropower). For the south basin, we have: Memvé Elé on the Ntem river (201 MW); Mekin hydropower on the Dja River (12 MW). For the north basin, we have: more equipment at Lagdo (8 MW); Bini Warak on the Nord Vina river (75 MW); and so on.

To meet with passed objectives of the development plan by maintenance, rehabilitation, expansion and/or construction of electric power infrastructure. Thus, a presentation of the implementation scenario of power generation projects is illustrated in Table 5. In addition, some case studies are described in further work.

7. DISCUSSION AND RESEARCH IMPLICATIONS

20 factors have been identified as having an effect on the electricity sector in Cameroon. The effects of some of these factors vary considerably, and it appears that some have been studied more frequently than others (Jones et al., 2015). However, most studies, like the present one, confirm a significant positive effect of socio-economic and end-user factors on the electricity sector (Fondja

Table 5: Forecasting timetable of electrical power plants projects in Cameroon, 2010-2025

Grid	Power plants	Types	Fuel	Installed power (MW)	Origin of the increase	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
South grid	AES-Sonel park	Thermal	LFO/HFO	262	Already exist/Reabilitation	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
	Dibamba	Thermal	HFO	43	Already exist	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
				43	Construction	Preliminary work (study)	Construction and rehabilitation work	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
	Kribi	Thermal	Natural gas	216	Construction	Preliminary work (study)	Construction and rehabilitation work	Construction and rehabilitation work	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
	Emergency Thermal program	Thermal	LFO/HFO	100	Construction	Preliminary work (study)	Construction and rehabilitation work	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Out of service	Out of service	Out of service	Out of service	Out of service	Out of service	Out of service	Out of service
	Edea	Hydro	Water	264.2	Already exist	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
				12	Reabilitation	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
				68	Lom Pangar									Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
	Song Loulou	Hydro	Water	384	Already exist	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
				18	Reabilitation	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
				102	Lom Pangar									Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
	Nachtigal	Hydro	Water	275	Construction	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
	Menve'ele	Hydro	Water	201	Construction	Preliminary work (study)	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
	Mekin	Hydro	Water	12	Construction	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
North grid	AES-Sonel park	Thermal	LFO	24.2	Already exist/Reabilitation	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
	Lagdo	Hydro	Water	72	Already exist	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
				8	Reabilitation	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
	Bini Warak	Hydro	Water	75	Construction	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Preliminary work (study)	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Put into service	Put into service	Put into service	Put into service
East grid	AES-Sonel park	Thermal	LFO	13.4	Already exist/Reabilitation	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service
	Lom Pangar	Hydro	Water	30	Construction	Preliminary work (study)	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Construction and rehabilitation work	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service	Put into service

Put into service | Construction and rehabilitation work | Preliminary work (study) | Out of service

Wandji, 2013; Nematchoua et al., 2014a, 2014b). Unfortunately, it is very difficult to compare the quantitative values of the factors identified in this study with those that preceded it. The reasons for this are as follows:

i. There is no standardized classification of factors to facilitate comparison between studies (Jones et al., 2015).
ii. Contextual information on the sample of households surveyed from which models were developed is often poorly reported (Jones et al., 2015), which distorts the interpretation of results. Worse still, only a few studies specify whether the sample analyzed is representative of the country in which the study was conducted. This prevents the results from providing useful support for the design and implementation of effective energy policy.
iii. Survey methods vary considerably from one study to another. The combination of methods used in different studies could introduce uncertainties in the results obtained.

For intance, studies such as Kemmler (2007) and McLoughlin et al. (2012) that used household electricity consumption monitoring instead of supplier electricity meter readings (Wyatt, 2013), or electricity bills (Sanquist et al., 2012), should be much more reliable than those using the latter methods. Finally, studies that employ building professionals to carry out detailed energy audits of dwellings (Fana et al., 2015) are likely to have more accurate information on dwelling characteristics than studies that have relied on occupant self-reporting through interviews (Tso and Yau, 2007), telephone surveys and questionnaires (Nematchoua et al., 2014a, 2014b).

As households move towards smart meters, more accurate and reliable data will become available at the individual dwelling level. Future studies should therefore seek to exploit this data and link it with data from detailed household surveys. Thus, as this study is the first to make a comprehensive analysis of the inventory of all indicators, current status and government actions, which affect the electricity sector in Cameroon, future research should address the above-mentioned limitations in order to suggest directions in which researchers could advance the current literature.

Overall, looking at Cameroon's energy policy and potential, it is evident that the electricity sector is not yet sustainable as confirmed by Nkue and Njomo (2009). In the implementation of energy policies, there are issues that can hinder or accelerate the sustainability process. The development of commercial and industrial activities in Cameroon can be hampered by several factors, such as: the institutional environment, a lack of standards and quality control mechanisms, and the lack of initial financial investments.

This study therefore shows that renewable energy, especially hydropower, has the potential to meet energy demand, especially in rural areas, where access to electricity is very low. Appropriate policies could stimulate private and foreign investment in the sector for future development. The government should therefore play a leading role in raising public awareness of the benefits of renewable energy.

8. CONCLUSION

Energy is essential for economic and social development (Yüksek and Kaygusuz, 2006, Yüksel, 2007; 2010). Cameroon like other poor and underdeveloped countries must meet its energy needs to achieve a global and sustainable socio-economic development, with the aim of becoming an emerging economy by 2035. The energy system of Cameroon is dominated by traditional fuels. Modern energy such as electricity, contributed up to 4.3% of the total energy production in Cameroon in 2010 (SIE-Cameroon, 2011; European Investment Bank, 2012). This very small share of electrical energy produced is distributed as follows: 73% hydro, 10% for thermal power plants and 17% from auto production (SIE-Cameroon, 2011). Per capita electricity consumption (266 kWh/capita) is very low in comparison with the African average (561 kWh/capita) and very far away from the average of the OECD countries (8012 kWh/capita) (Fondja Wandji, 2013).

Access to electricity in Cameroon is still very inadequate and unaffordable for many communities, especially in rural areas. Thus, the increase of Access to electricity is a necessary tool, but not sufficient to ensure economic and social development. To achieve this, we should therefore develop a good, effective and efficient development plan for the electricity sector to solve the current problem of power deficit in electrical energy in the country.

Hydropower is a renewable source of energy and it has many advantages (Yüksel, 2009; 2010, Luu et al., 2017), the development of the important hydro potential of the Sanaga River and the Lom Pangar storage dam is the best option for the country. Ultimately, the success of development plans in the power sector will certainly make Cameroon a net exporter of electricity to its neighbors in the sub-region and an emerging country by 2035.

9. DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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