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Electricity generation technology options under the greenhouse gases mitigation scenario: Case study of Cameroon

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ABSTRACT

Cameroon's economic growth demands an increase in energy-services. These, in turn, increase demand for energy carriers, such as electricity. However, electricity generation based on fossil fuels emits greenhouse gases (GHGs). In this paper, three scenarios of electricity demand in Cameroon are presented, assuming different economic growth levels. The corresponding expansion of the electricity generation system (and its emissions) was then analyzed. The MAED model is used for energy demand assessment. While, the MESSAGE model is used to optimize the supply system and quantify GHGs emitted. 2012 was chosen as the base year, with an overall electricity consumption of 5 TWh. Results shows that in 2035, electricity demand could reach 35 TWh, 19 TWh and 17 TWh for High, Intermediate and Low scenario respectively. Hydro, Thermal (GAS, HFO, LFO), Biomass, Solar and Wind power plant projects have been considered in the study, with different implications based on countrypolicy. Results show that GHG emissions constraints can be met if appropriate investments are made.

1. Introduction

Energy is required in every human activity. The close link between electricity and the country's economic development makes it a strategic resource. It should therefore be generated in sufficient quantities in order to satisfy demand. Maintaining the balance between generation and consumption of electricity is a permanent challenge for which planning is critical. However, generation of electricity is a greenhouse gas producing activity as demonstrated in the work of [1–5], which is harmful to the environment. Studies have shown that the power sector contributes about 40% of the total carbon emissions [1]. These GHG produced in great quantity, play a dominant role in climatic change [6]. The impact is significantly negative on natural and socio-economic systems [7–9]. Today, global warming, long ignored, is at the forefront in the development of many countries' policies. As a result, electricity production falls under the category of activities that should be closely monitored for the benefit of life on Earth. In this context, it is imperative to develop and promote alternative energy sources that can lead to sustainable energy systems. Research on how to reduce greenhouse gas emissions is a priority. Many countries have oriented their development strategies towards more sustainable energy systems. The objective of the National Energy Strategy in Morocco is to establish 42% of total installed capacity from solar, wind and hydropower by 2020 [10]. Since 2005, the European Union has made significant progress and is gradually attaining her 2020 renewable energy target [11]. In their studies in the Palembang city of India, Sarah Colenbrander et al. [12], indicate that a proactive investment of USD 405.6 million in low-carbon development will reduce emissions by 24.1% in 2025 and reduce by USD 426.8 million the expenditure on energy of the city.

Abbreviations: CAPP, Central Africa Power Pool; CAR, Centre Africa Republic; DRC, Democratic Republic of Congo; ECCAS, Economic Community of Central Africa States; ENEO, Energy of Cameroon (National Electricity Company); GHG, Greenhouse Gas; HFO, Heavy Fuel Oil; IAEA, International Atomic Energy Agency or IAEA; IMF, International Monetary Fund; LFO, Light Fuel Oil; MAED, Model for the Analysis of Energy Demand; MESSAGE, Model for Energy Supply Alternatives and to their General Environment Impacts; na, not available; NIS, National Institute of Statistic of Cameroon.

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Cameroon's electricity production is characterized by a considerable imbalance between demand and supply. Since the early 2000s, Cameroon fell into an electricity crisis which is characterized by frequent brownouts and blackouts. From 2000 to 2009, the hydroelectric plants have not changed. The installed hydroelectric power has been constant and equal to 719 MW with an energy production of 3892 GWh in 2006. A slight increase of the installed power was observed between 2003 and 2006 following the installation of a new thermal plant in Limbe (85 MW), the increase in installed capacities of existing plants (Oyomabang I, Logbaba) and the increase in the number of private electricity producers. The thermal power plants installed by the national utility company in 2006 was 206 MW for an energy production of 255 GWh. As for the private production of electricity, the installed capacity in 2006 was up to 275 MW for an energy production of about 960 GWh. In 2013, an additional power of 216 MW from the Kribi gas fired plant was introduced to the network. Despite all this power generated, in 2015, Cameroon still faced outages in the distribution of electricity because of the ever existing gap between demand and supply.The electricity generation in Cameroon exploits non-renewable sources (i.e., fossil fuels), which has a negative environmental impact (i.e., pollution, climate change). This study is particular with the simultaneous management of energy demand, energy production and greenhouse gas control.

Cameroon is located in Central Africa, between latitudes 1° and 13°N, and longitudes 8° and 17°E. Her geographical location gives a good predisposition for renewable energies; Solar energy, Wind and Biomass. Cameroon has the possibility of producing clean energy through the exploitation of her potentials in renewable energy. Biomass, mainly used in the residential sector for heat production, dominates the energy mix of Cameroon. But its usage for electricity production remains marginal [13]. Whereas, Cameroon's biomass potential is enormous, resulting from domestic waste, forest products and their waste, and from agricultural waste. This potential is so enormous that if sufficiently exploited, the biomass could contribute 40% of the demand for electricity in Cameroon [14]. Concerning solar energy, there is a great potential estimated at 3491 h of sunshine per year with a solar radiation of 1934 kW h m^{-2} per year in the Far North Region of the country [15]. The average national theoretical power production capacity is estimated at2327.5 TWh, or about 20 times the hydroelectric potential [16]. Wind technology can be developed because studies have shown that the wind potential is considerable in the West and North-Centre (Adamawa) regions and on the coastal zone [17]. With these new sources of electricity production, new projects can be developed to add to the already well-established and underexploited technologies such as hydroelectricity, whose potential is up to 20 GW. Only 3% of this potential is being exploited [17]. The greatest barrier to the expansion of renewable energies may be investment cost.

The hydro potential of Cameroon is distributed in 5 main hydrological basins. The Sanaga basin covers a great portion of the entire country. The Lom Pangar dam was recently built to regulate the flow rate of the Sanaga which is the main river of the basin. It has been proven that more infrastructure could be deployed in this basin to produce up to 6 GW of electricity in the medium term, including the existing installations [17]. The exploitation of the four other basins for hydroelectricity is regulated by regional organizations.

Cameroon has enormous economic potential and has developed a strategy towards emergence by 2035. This should lays emphasis on the increase in electricity generation in the country to solve the problem of electricity supply by long-term planning. Environmental protection has not been left out in this ambitious program. The development of the electricity sector in Cameroon must take into account the protection of the environment.

Forecasting future energy demand and optimum allocation of energy resources are requirements for a rational energy policy. The main objective of energy management systems is to reduce the costs associated to the exploitation of the energy network, to reduce the environmental impact caused by the production of energy and to satisfy the energy demand.

This article brings solutions to 4 fundamental questions for the sustainable development of Cameroon in the electricity sector:

- ✓ What will be the electricity demand in the next 20 years following the various scenarios and socio-economic presumptions?
- ✓ What will be the effects on the environment in terms of GHG emitted?
- ✓ Which resources can be used to meet future demand while respecting strict limits of GHG emissions?
- ✓ What are the impacts on the cost production of electricity if the limitation of GHG is taken into account?

In Section 2 of this article, a discussion of the broader regional context and how it affects the outlook for Cameroon is presented. Section 3 presents the methodology used in this study. It describes some key new electricity production technologies. The contribution of these technologies in electricity production and for GHG mitigation in Cameroon is analyzed. In this section, two different model frameworks are described. Section 4 presents results of the models and discussions.

2. Regional context of electricity trade: what impact on Cameroun outlook

Central African countries have some common characteristics:

(i) A huge hydroelectric potential, representing about 57% of Africa's potential, mainly distributed between the DRC and Cameroon.
(ii) A low access to basic energy services. Nearly 95% of the rural population has no access to electricity. There is a significant energy deficit, which is a contrast to the energy resources in the region.
(iii) A high economic growth rate. During the period 1999 to 2009, the region recorded an average growth rate of about 6.2%; 7.3% on average in the six oil-producing countries (Angola, Cameroon, Congo, Gabon, Equatorial Guinea and Chad) and 4.7% in the other countries. This growth can only be sustainable if it is accompanied by an adequate energy production.
(iv) Considerable mining and agricultural potentials which are underexploited. Strategic development documents produced by each country of the sub-region generally suggest a significant increase in the development of mineral resources, but the implementation of these guidelines is slow and ineffective.
(v) In addition, the region has the poorest infrastructure networks in the continent, including transport and energy, with a negative impact on production, regional trade capabilities and social conditions (high rates of poverty, health scourges).

Important energy resources are available in the region. But investment practices related to energy production and energy