Research on Assessment of Electric Energy Demand in the Republic of Benin

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Abstract— **for decades, Benin's economy has been fuelled by abundant inexpensive hydropower. The country has been experiencing an increase in frequency of power cuts over the last ten years. This paper analyses the growing demand of energy in the Republic of Benin. We adopted the time series model to assess and build the energy demand function from which we have successfully forecasted the demand for next coming eight years and found that the energy demand function increases exponentially every two years, while the energy supply function increases slightly in the same time. This reveals that Benin has to diversify its generation capacity by investing in the renewable energy, and finally promote the public-private partnership to ensure and secure sustainable electricity supplies.**

Index Terms—**Energy Demand, Energy Demand Assessment, Energy Demand in Benin, Electricity Supply**

I. INTRODUCTION

Energy is one of the essential factors for Benin's qualification to be a country with an emerging economy. In fact, access to energy products in sufficient quantity and at a lower cost is one of the necessary conditions for the development of economic activities and the creation of jobs; improving the living conditions of the population and the fight against poverty. This is the whole issue of the development of energy services and its close relationship with the development of other sectors of activity.

Benin's electricity has recorded, in a cyclical manner and particularly during the last ten (10) years, more or less significant crises. These crises are no longer seasonal or episodic events, according to their duration, frequency and generalization throughout the territory. They are mainly due to chronic shortages of electrical energy, resulting in regular power cuts now known as "load shedding", which seriously affect all socio-economic activities. To appease the population, political declarations and promises of definitive solutions are made, but the engine is slow to take. Benin's energy situation is characterized by low energy consumption and marked by a predominance of traditional uses of biomass energy contributing to the degradation of forest cover; low access of people to electricity, particularly in rural areas. In 2014, the national electrification rate is 31%, with 58% in urban areas and 6.7% in rural areas. Electricity consumption per capita, which is also very low, is around 110 kWh / inhabitant / year [1]. National electricity production is essentially made from thermal power plants and represents 8.45% of total demand in 2015 [2], while Benin has great potential for renewable energy, especially solar energy and biomass.

This study will briefly examine a general research question. It consists in make a comparative study analysis between the current total Energy Production (GWh) and the Total energy Supply by Benin, focusing more on analyzing the difference between the Total Energy Supply and the total energy Demand by the population.

This paper consists of six sections. First section presented the introduction of the paper. The next section reviews the literature pertaining to the subject. It focuses on Definition and importance of Electric Energy, Statement of Benin's Electric Energy and also Energy Potential of Benin. Third section proposes the Research Methodology. Fourth section presents the expected results. Fifth section concludes the research and the sixth section presents the limitation of study.

II. LITERATURE REVIEW

A. Definition and importance of Electric Energy

Electrical energy is available energy in the form of an electron current (electricity). This energy is used directly to produce light or heat [3]. Electrical energy is produced by the transformation of another form of energy. Today, several kinds of energy are used for the production of electricity for example, hydraulic energy, solar energy, wind energy And so on…

According to Pierre Jacquet (2010), energy, and in particular electricity, is a crucial resource for economic and human development. The availability of electricity underlies the provision of essential services such as education, bringing light to schools and homes, food safety through refrigeration, access to communication technologies, and Improve the productivity of agricultural and economic activities.

Pablo Del Río (2006) shows that electrification can make a substantial contribution to the achievement of the Millennium Objectives for Development (MOD). The following table summarizes each of these eight objectives and summarizes the role that could play in achieving them [4].

TABLE (1): Role of electrification in achieving the MOD

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1	Reducing Extreme Poverty and Hunger: Electricity is essential for job creation and industrial activities.
2	Ensure universal primary education: In order to attract teachers in rural areas, homes and schools should have electricity. Good lighting conditions are needed to study over night.
3	Promoting gender equality and empowering women: Lack of access to electricity contributes to gender inequality because it does not free women from domestic chores.
4	Reduce Infant Mortality: Air pollution in homes due to traditional fuels and stoves causes disease.
5	Improve maternal health: Pollution in the home, lack of electricity for medical-social centres, lighting up for night births and heavy physical burden of memory contribute to maternal ill health.
6	Fighting HIV / AIDS, malaria and other diseases: Electricity for radio and TV communication can help disseminate useful information about public health.
7	Ensuring a sustainable environment: The production, distribution and consumption of conventional energy have negative effects on the local, regional and global environment.
8	Establishing a global partnership for development: The 2002 Johannesburg Summit on Sustainable Development called for associations between public entities, development agencies, civil society and the private sector. This involves the promotion of viable and reliable energy services at reasonable prices.

B. Statement of Benin's Electric Energy

The use of electricity is limited to 2.9 million people or nearly 29% of the population in 2013[5]. Access to electricity in urban areas is 56.4%; it accounts for only 5.5% in rural areas. The national electricity production is essentially made from thermal power plants and represents 8.45% of the total demand in 2015 [2]. The self-generated energy produced by all the national production units in 2015 amounts to 102662, 613 MWH against 30450,925 MWH in 2014 with a contribution of 1125,349 MWH from the YERIPAO mini hydroelectric power station [2]. This significant increase is due to the production of new rental groups to face the energy crisis at the national level. Over the last twenty years, demand for electricity has been steadily increasing, at a rate of 7% per year, mainly due to household consumption [6]. In the industrial sector, the use of electricity is limited to a few industries (agri-food, cotton, textiles, pharmaceuticals and cement).

The demand for electric energy in Benin is growing steadily by more than 8% (2008-2012) to respond to the country's economic development. It is growing faster than supply, dominated by imports. Most of the electricity demand is concentrated in the three southern departments: Littoral, Ouémé and Atlantique. In terms of power, the maximum peak of the interconnected grid reached 191 MW in 2013 (compared with 186 MW in 2012), highlighting a significant slowdown compared to the last few years because of the limited supply demand. The deficit currently recorded at the peak is greater than 50 MW for Benin; excluding the additional power provided by the SBEE. In order to reduce this deficit, the Government has made urgent arrangements for the rental of generators.

To meet the demand of the population Benin is highly dependent on the outside for its energy supply. Benin uses the following sources supply: GHANA Volta River Authority (VRA) for a guaranteed power of 60 MW and a guaranteed annual energy of 500 GWh until 2012; NIGERIA Transmission Company of Nigeria (TCN) for a guaranteed power of 75 MW and a guaranteed annual energy of 300 GWh for a contract period of ten (10) years; Ivorian Company of Electricity (CIE) of Ivory Coast for a guaranteed annual energy of 100 GWh for a contractual period of three (3) years expired since 2010; Electricity of Niger for the supply of the city of Malanville in Benin (2.4 GWh in 2009) [7]. This decline is linked to a beginning energy crisis with a higher internal production.

C. Energy Potential of Benin

Benin has an interesting potential in renewable energies such as hydro power, biomass, solar, wind power.

Benin's hydropower potential is characterized by a large network of rivers, low heights, low slopes, high infrastructure costs (civil engineering developments) and a pronounced low-flow regime (very low flows in dry season) [5] with an official list of 85 micro-hydropower sites with a total capacity of 50 MW (between 7 and 4436 kW) and a total output of 200 GWh / year. While traditional biomass energy is now the main source of energy used in Benin. But there is a wide range of other biomass resources that can be upgraded in order to increase domestic production capacity and thereby reduce imports of fossil fuels and electricity [8]. These include residues from agricultural production, agro-processing waste, household waste, wood processing residues. However Solar energy for heat and power generation is the best known renewable energy technology in Benin, various studies carried out for the determination of the solar field reveal that the monthly average daily irradiation for a duration of 7 hours per day of sunlight varies from 3.9 kWh / m² in the South to 6.1 kWh / m² in North; Which is an important potential that can be valued.

These potentials remain under-exploited overall, though they can be used for improving electricity supply security in Benin.

III. Research Methodology

Documentary research consisted of gathering and selected books and reviews appropriate to the subject by using the internet tools. The documentation consulted is composed of the archives of Benin Electric Energy Company (SBEE).

We adopted the time series model in this paper. First, we constructed a table based on energy demand data and from this table we extracted the graph that explained the time series plot of energy demand. We then analysed and determined the moving average of the energy demand.

Second, we used the deseasonalized data as the Y variable and we make a simple linear regression of this variable on the period t. The model that we got in the form of $y_t = \beta_0 + \beta_1 x_1$, has been used as the energy demand function and from this model, we have successfully forecasted the demand for the next coming seven years.

IV. Results and Discussions

The various data collected were analyzed using statistical tools. But before presenting the results concerning the two specific problems of our study, it is essential to first of all make a comparative study analysis between the current total Energy Production (GWh) and the Total energy Supply by the company. Afterward analyze the difference between the Total Energy Supply and the total energy Demand by the population. This analysis will finally lead us to determine the energy function that could be used as a tool to forecast the needs of the population for any coming year. To this end, we approached a resource person at the Benin Electrical Energy Company (SBEE) General Management.

Table (2): Total Energy Production (GWh)

	2012	2013	2014	2015	2016	2017
Nangbeto	172	180	174	219	185	202
Tags CEB	94	95	1	10	36	44
ContourGlobal	0	0	0	0	5	62
SBEE	74	55	12	68	66	0
CEET	22	9	1	16	29	1
Total	362	339	188	313	321	309

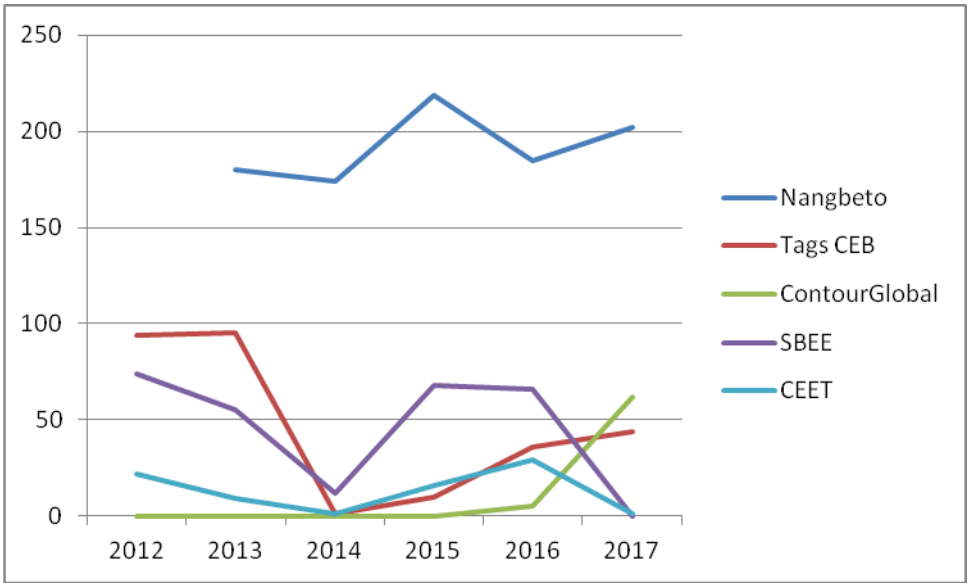

Fig (1): Total Energy Production

The energy produced in Benin mainly comes from five sources that are Nangbeto, CEB, ContourGlobal, SBEE and CEET. The graph shows that energy production is not a stable function but instead has fluctuated over the time for any of the five sources.

Table (3): Total energy Supply

	2012	2013	2014	2015	2016	2017
Imports	1025	1009	1319	1563	1636	3499
Production	362	339	188	313	321	309
Total Supply	1387	1348	1507	1876	1957	3808

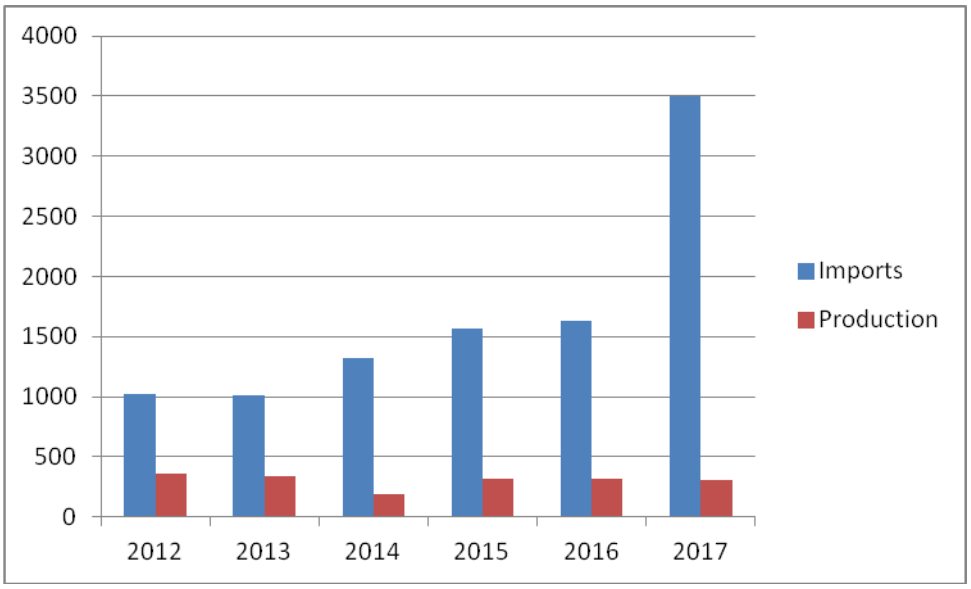

Fig (2): Total Energy Supply

For any of the years considered, the energy imported is more than three time higher than the one produced, proving that the energy consumed in Benin mainly depends on the imports from other countries namely, Ghana, Cote d'ivoire, Nigeria, Niger.

Table (4): Total Energy Supply and Demand

Total Energy Supply and Demand(GWh)						
	2012	2013	2014	2015	2016	2017
Total Suppy	1387	1348	1507	1876	1957	3808
Total Demand	4005	4020	5006	5122	5502	5603
Gap	2618	2672	3499	3246	3545	1795

Fig (3): Total Energy Supply and Demand

Energy demand is almost four times higher than Energy supply. As a result, the gap between supply and demand is significant. In order to meet this challenge, huge efforts in terms of energy investment are necessary.

To determine the energy demand function, we developed the time series model using some data provided by the CEB, the main energy body in Benin. The function that will thus be determined could be used as a tool to forecast the needs of the population for any coming year.

Table (5): Determination of energy function

		aka Yt			Yt/CMA		Yt/St	
t	Year	Demand (GWh)	MA(2)	CMA(2)	St, It	St	Deseasonize	Tt
1	2012	4005	4012.5	4262.75	0.94	0.98	4103.37	4466.98
2	2013	4020	4513	4788.5	0.84	0.95	4223.88	4673.37
3	2014	5006	5064	5188	0.96	0.98	5128.95	4879.76
4	2015	5122	5312	5432.25	0.94	0.95	5381.77	5086.16
5	2016	5502	5552.5	5592	0.98	0.98	5637.13	5292.55
6	2017	5603	5631.5	5646.5	0.99	0.95	5887.16	5498.95
7	2018	5660	5661.5	5670.25	1.00	0.98	5799.01	5705.34
8	2019	5663	5679	5693.5	0.99	0.95	5950.21	5911.74
9	2020	5695	5708	5731.75	0.99	0.98	5834.87	6118.13
10	2021	5721	5755.5	5782.75	0.99	0.95	6011.15	6324.52
11	2022	5790	5810					6530.91
12	2023	5830						6741.16
13	2024							6943.65
14	2025							7150.04
15	2026							7356.43

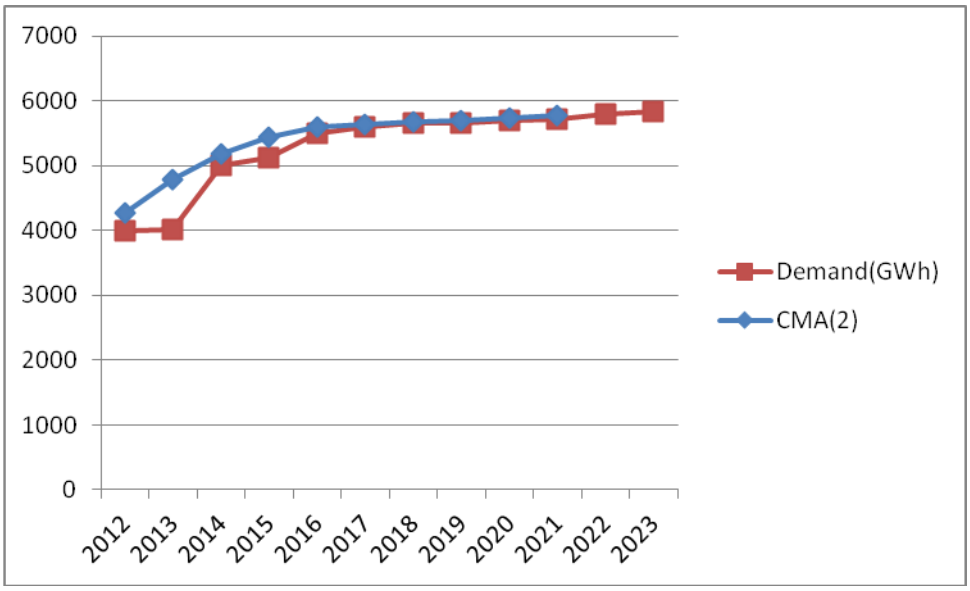

Fig (4): Time series plot of Energy demand

To determine the energy demand function, we make a simple linear regression of the variable YT (deseasonize) on the period t. The results are as follows:

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.888054
R Square	0.78864
Adjusted R Square	0.76222
Standard Error	343.1243

Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3514378.48	3514378	29.85008	0.000599
Residual	8	941874.3944	117734.3		
Total	9	4456252.875			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	**4260.582**	234.3985346	18.17666	**8.62E-08**	3720.058	4801.106	3720.05843	4801.10641
t	**206.3941**	37.77674438	5.463523	**0.000599**	119.2808	293.5074	119.280777	293.507435

The intercept and the **t** are significant and prove that the model built upon the variables is consistent.

Then we got the following model:

$y_t = 4260.582 + 206.39x_t$, where

Y_t is the demand function and X_t the corresponding period.

Using this function, we can accurately predict the total energy demand for any coming year. For example the year 2020 corresponds to the period 15, to find out how much energy will be demanded by the household, we have:

$y_{2026} = 4260.582 + 206.3941X15$ =7356.43 GWh.

* The results show that from 2012 to 2017 Benin energy production fluctuates over time and the energy consumed in Benin mainly depends on imports from other countries, the energy demand is more significant than energy supply. Consequently the total energy demand in Benin issued from the function built previously being 7356.43 GWh by the year 2026 Benin has to invest more in renewable sources of energy in order to meet this exponential demand of the population.

Due to this finding, in the short term, it is necessary that Benin increases the importation of electricity from neighbouring countries; at least what Côte d'Ivoire, Ghana and Nigeria agree to provide. And since these imports are not reliable, and the cost is very expensive, renewable energy sources are the only ones on which Benin has a certain margin for manoeuvre to increase its capacity in the present circumstances. Benin will therefore have to make a vast investment in this sector. This investment involves gradually moving from dependency to autonomy through the construction of various plants distribution which emit CO_2; the increase of hydroelectricity power plant storage all over the country, the connection of renewable electricity production sites to electric transmission networks; the injection of production into the distribution network, the increases of small scale hydro such as run river, integrate modern biomass power plant, settle various kinetic energy of wind turbines.

Moreover it is important that Benin invest in solar thermal power and flats plate collectors or photo-voltaic plants to exploit solar radiation and generate more electricity.

The government has to take the measures requested by the Technical and Financial Partners (TFPs) to open the production segment to private developers especially in the context of rural electrification. In addition the government has to grant facilities for the importation of equipment intended for rural electrification by law 2007-33 laying down the Finance Act 2008. .

Finally, in the short, medium and long term, the Benin government will have to create an association of non-bank financial institutions and the National Saving Box (NSB) for the creation of a Special Investment Fund and Development of Public Private Partnerships.

V. CONCLUSION

Benin has the potential to greatly improve the demand of energy electric by the population, which has been increasing over the years. The estimation of the energy demand by 2020 issued from the exponential function built Prove that Republic of Benin has to turn to renewable sources (biomass wind, and solar) of energy as sustainable solutions. To reduce high cost of importation of energy electric, combining the development of renewable energies and also especially involving the private partners. This electricity generation strategy has a lot of advantages for Benin., from which the most important are: First and foremost, the country will experience an increase in its electricity production, which leads to a second advantage, that of reducing dependence on the outside in terms of energy supply and third, through the development of renewable energy sources. However, a deeper study ought to be made in this sector to appreciate its advantages and inconveniences on the environment for an adequate exploitation.

VI. Limitation of Study

It should be noted that this study has several limitations. The data used for this paper come from the archives of Benin Electric Energy Company (SBEE) whose period of time are not recent, and it is not possible to make sector specific conclusions. Also, it is very difficult to access the data because Benin has problems of computerization of data.

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