Modern Economy, 2023, 14, 122-162
https://www.scirp.org/journal/me
ISSN Online: 2152-7261
ISSN Print: 2152-7245

Electricity Consumption Determinants and Investment Opportunity: A Prospective Analysis Based on the Context in Côte d'Ivoire

Remy Tehero*, **Emmanuel Brou Aka**

Department of Economics, Felix Houphouët-Boigny University, Abidjan, Côte d'Ivoire
Email: *tehero_remy@yahoo.fr, e.aka-brou@hotmail.fr

How to cite this paper: Tehero, R., & Aka, E. B. (2023). Electricity Consumption Determinants and Investment Opportunity: A Prospective Analysis Based on the Context in Côte d'Ivoire. *Modern Economy, 14,* 122-162.
https://doi.org/10.4236/me.2023.142010

Received: November 5, 2022
Accepted: February 25, 2023
Published: February 28, 2023

Abstract

In many countries, governments anticipate energy consumption. In the electricity sector, heavy investments are required for improving and extending infrastructure quality in order to satisfy demand. Therefore, many governments, especially those of developing countries, are soliciting private investments in order to face contemporary challenges. This paper contributes to a scare literature about investment opportunity in the power sector but is relatively abundant about determinant of electricity demand. It aims to examine 1) The relationship between private investor and the government; 2) Electricity consumption on the one side and population size and GDP on the other side in Côte d'Ivoire. The analysis commenced by showing how far the return on investment, so the price level, is a determinant factor for the investor's decision to enter or reinvest in the electricity market. From an empirical point of view, the cointegration test confirmed the used of the Vector Error Correction Model (VECM). It shows a long-run relationship between, electricity consumption and the GDP and population. The Wald test indicates a causal relationship of electricity consumption on GDP. Moreover, an overview of demand forecast lets envisage business opportunities for investors through economic and regulatory perspective suggestions.

Keywords

Electricity, Game Theory, Investment, Prospective, Regulation

1. Introduction

The Importance of electricity is undeniable. Indeed, it can be used for varied needs such as lighting, cooking, water cooling or heating, electronic or telecommunication devices, transportation (electric vehicles)...The relatively low quality of electricity in Africa, mainly due to limited production capacities and the degraded state of transmission, distribution and production infrastructures, caused up to 4.9% loss of sale for firms and 2% on average GDP loss (Scott, 2015). Therefore, the need for power energy planning in order to satisfy demand is of great importance for countries, especially developing ones (Trotter et al., 2017).

However, despite unreliable electricity and losses on the grid, high operational costs and low purchasing power of consumers lead among others to reluctance to invest (UNCDF, 2018). Yet, investment needs are colossal. As an example, the African Development Banque estimated, in constant 2005 dollars, at US$ 547 billion, to ensure universal access to reliable electricity in Africa, by 2030 at the latest (BAD, 2008). In addition to the proposal of Sagan & de Muison (2008) for an incentive regulatory framework, the challenge for governments is to highlight the economic strengths of countries. Very high investments requiring the participation of private players are essential in developing countries (Taale & Keyremeh, 2015). Muzenda (2009) noted the lack of funds to ensure production diversification investments in sub-Saharan Africa while Mariwah et al. (2010) justified its need by rapid population growth.

Faced with the observation of the lack of incentives for investment in the electricity sector, the attention of energy economists focused, first, on the design and operation of spot markets, and, second, tried to limit the risks of exercising market power. The aim was to facilitate the entry of new operators by removing barriers to entry, limiting vertical "production-supply" integration, long-term "production-supply" contracts and dominant positions, etc. At the same time, the entry of foreign importers and buyers has been facilitated through the transparency of rules and the development of interconnections. In this vein, the competitive dynamic has gone through several stages from access to the network with vertical separation between generation and network, and the authorization of independent producers until the gradual and total opening of the end market to competition.

In Côte d'Ivoire, the 2014 electricity code requires the liberalization of all branches of the sector, from production to commercialization. This liberalization has been in effect since the end of 2020 and could encourage market entry for new players and new professions depending on technologies. In addition, the Transmission-Production Master Plan[1] for the electricity sector, which concerns both production, transmission and distribution infrastructure, and rural electrification, initially amounted to more than XOF 9000 billion, has been set (CI-ENERGIES, 2014). This plan begins by analyzing the existing infrastructure before setting the planning on the basis of demand forecasts and different scenarios taking into account the uncertainty of this demand. To carry out this plan, a significant contribution is expected from the private sector (ANARE-CI, 2019). The challenge of this article consists in pointing out determinants of energy de-

[1]In French this plan is known by: "Plan Directeur Production Transport".

mand and criteria supporting investment decision for investors and the economic and regulatory factors to be taken into consideration in the analysis of the perspective in terms of demand for electrical energy.

Indeed, access to affordable and reliable energy requires synergy between governments and the private sector in order to benefit from private investments. The private investor questions his adhesion to a project in a regulated sector or the process of liberalization by analyzing the risks linked to the attitude of the regulator and the outlook in terms of demand. This is a question of understanding the economic rationality related to investments required in power infrastructures by considering different scenarios of market development. In addition, the investor's position (decision) will be analyzed through game theory and a prospective analysis will be done on the basis of scenarios.

Therefore, anticipated demand and population size considerations as determining factors of the investment will condition the scope of the study. Data used in the analysis are provided by the World Development Indicators and national players (CIE). Moreover, Vector Error Correction Model (VECM) has been used as analytical approach in order to appreciate both the long run and the short run relationship, before suggesting demand forecasts. First, this paper will present private sector involvement via Public Private Partnerships (PPP) in infrastructure development mainly in the power sector and profitability as strategic factor conditioning investor's decision. Second, since perspectives in terms of consumption are envisaged by the private investor, an analysis of the determinants of electricity consumption in Côte d'Ivoire will be proposed. Finally, through a discussion, a prospective analysis considering possible scenarios for the evolution of demand according to economic and regulatory factors should be suggested.

2. Logic of Private Players

2.1. The Public-Private Partnerships as the Preferred Path for the Development of Electricity Infrastructure

The quest for greater efficiency in the delivery of public services, budgetary difficulties of many governments and the debate on market regulation have led to an increasing number of association forms between the public and private sectors (Savas, 2000). The acronym Public-Private Partnership (PPP) designates any form of agreement or association of the public sector and private organization (company or foundation) with the aim of implementing all or part of a service of general interest. The PPP is the result of a questioning of the form of ownership (privatization, nationalization) in a context of persistent budget crisis and socio-economic demands gradually crystallizing around concerns about the effectiveness and efficiency of public action (Mazouz, 2009). This cooperation between the public and private sectors reflects a win/win relationship for the provision of public services, ensuring a good distribution of roles and effective risk management (Salambéré, 2019). In absolute terms, convenient as they are, the literature on PPPs teaches that they do not do justice to the extraordinary diversity of observable institutional structures (Mazouz & Leclerc, 2008). The main challenge remains the successful implementation and management of projects, while safeguarding the *public interest*, which is understood to be the *common good*, i.e. the search for individual happiness (or satisfaction) for all.

Asquer (2014) shows that several factors including the historical and institutional context as well as the political characteristics enter into account in government's motivations. The State assumes that the contribution of the private sector will cover the requirements in order to meet changing demand. The literature, based on scenarios, also shows that recourse to private financing only reinforces the advantages of consolidation if the lenders have enough expertise to assess project risks (Iossa & Martimort, 2012). For the sake of efficiency, it is important to control the cost-benefit ratios, especially since the private partner's objective is to make a profit. Commercial and financial arrangements can appear to be complex in the long term in regulated sectors (Delmon, 2010: p 108), especially since, according to Bougrain et al. (2005) the seek for a perfect balance would be utopian.

The State of Côte d'Ivoire launched its first master plan, initially proposing around 66 major projects and looking for a contribution from the private sector to increase production capacity through the granting of licenses to independent power producers, as well as the extension and modernization of the network[2]. In addition, in most West African countries, private investments in the energy sector are made in accordance with the specificities of PPP. Indeed, many African countries have opted for "concession" for grid development because they benefit from the financing capacities and the know-how of the private sector. This partnership is formalized by a Public Service Delegation (DSP) contract or a Partnership Agreement (PA) and aims to improve the quality and performance of the service, reduce the financial burden borne by the consumer and improve the quality of the service.

Therefore, the choice of the private partner remains important. In the case of a DSP, the operator is paid according to the result. The company bears risks related to management and work availability, income and, in the case of a concession, construction. In the PA, risks related to income are limited by public payment capacities. The State therefore bears the financial (payment) risks and the private entity bears risks of the works. Thus, the responsibility for investments is defined by contract. In a "management contract", the operator has no investment obligation; his remuneration is defined *ex ante* and consists of a fixed part and a variable part depending on performance. The second type of contract is a "lease contract" under which the operator has investment obligations.

In general, the assessment of PPP remains mixed depending on the country and the type of contract. Most of the time, the challenge is to make a diagnosis in order to define a legal and regulatory framework favouring the establishment of

[2]The estimated cost of this plan is XOF 9293 billion including nearly XOF 1577 billion in additional investments in the mining sector.

PPPs and their evaluation. Also, although most African countries have great potential in terms of natural resources, many public infrastructures were financed by debt and deteriorated due to maintenance problems. Recourse to the private sector made it possible to alleviate financing difficulties and compensate for the deficit in transport and electricity production infrastructure, but also to provide technical and management know-how as well as an incentive to results (BM, 2017).

Private companies finance all or most of the new investments in electricity infrastructures. If the participation of the private sector in the production of electricity in Africa is known, it is less so when it comes to the transport of this form of energy, considered to be a natural monopoly but which accounts for little in the total value chain cost of the entire industry. Yet, in addition to the fact that investments in transmission infrastructure allow the producer-consumer connection, they also allow the integration of intermittent renewable sources and the satisfaction of growing demand by ensuring security of supply.

The recourse to the private sector for the financing of infrastructure in the power sector is quite well known. Indeed, in Côte d'Ivoire, PPP is requested for the financing of the Energy Development Plan [2013-2030] of Kenya for the construction of transmission infrastructure, estimated at US$6.5 billion. In addition, network infrastructures very often require substantial investment, as is the case of the West African power line corridor, estimated at 2000 km, connecting Nigeria to Guinea, amounting to approximately US$1.2 billion. However, the contribution of the private sector in the development of transport infrastructure can take different forms depending on the option chosen. As an example, the privatizations observed in 1991 in the United Kingdom, of three transmission companies, made it possible to obtain £5.6 billion between 2013 and 2016 out of the £16.6 billion envisaged before 2021. The total network concession obtained by the National Grid Corporation of the Philippines will have enabled it to inject US$1.9 billion. Thus, there are many other cases of projects carried out within the framework of PPP (BM, 2017). It should also be noted that, in all the case studies, the use of calls for tenders created strong competitive tension and exerted downward pressure on prices.

2.2. Investor's Decision under Uncertainty/Risk

While making the decision, the investor must face risks or possible uncertainties depending on the quality of the information available to him, which may be partial or imperfect. Depending on the reliability of information and data, the context might be qualified of certain or uncertain, and risky situation between these two extremes (Taha, 1992: p 412). Indeed, some economists distinguish risk from uncertainty. They consider that "risk" relates to probable events, whereas in a situation of "uncertainty", agents do not have a valid basis to fully identify the different possibilities and assign them a probability of occurrence. In other words, a decision under uncertainty evokes situations in which the probability is unknown (or cannot be determined) but where the possibilities for the investor are not totally ignored.

The approach adopted focuses on the analysis of the strategic relationship between two (or more) players driven by the maximization of their "profits" and to highlight the conditions that can promote investment. It requires:

- In a first assumption that the two players are rational and independent, each player acts by considering his interests;
- In a second assumption that the agent has the necessary funds;
- A third assumption that would hardly be feasible: the contract is complete and signed *ex ante*, i.e. no private information at the time of signing the contract (contingencies could be anticipated and therefore stipulated by contract, payment schedule, quantity, quality; the technologies are known by the State and the agent who has access to them).

In the principal-agent relationship, dealing with imperfect information on costs (adverse selection) or efforts of the company (moral hazard) is an important aspect for the regulator. Indeed, the maximization of social welfare is further under its responsibility. This is the reason why any reform of economic policy takes into account the geographical scope of the reform and the degree of independence of the regulator. Thus, in its relationship with the company, the regulator has the authority assigned by the State in order to facilitate the necessary investments in infrastructure, by taking into account the location of production and consumption zone. These requirements in terms of financing need make the regulator or institutional players vulnerable to the pressure groups.

For the regulator, knowing the strategic attitude of the company allows it to anticipate. For this reason, Scholz (1991) compares the relationship between the firm and the regulator to a prisoner's dilemma. Indeed, the game theory is handling a typical case of decision-making under uncertainty of two "intelligent" opponents willing to optimize their advantage. In the same way, for the firm there is an uncertainty concerning the sectoral orientations impelled by the public authorities to the renegotiation of the contracts or opening of markets. Either the regulator or the firm is willing to take the best possible decision amongst possible choices called *strategies* which can be qualified of mixed or pure.

The general case deals with the possibility of honesty or not between players. In each cell of the following matrix (**Table 1**), the first letter is the utility perceived by the player 1 (the principal) and the second that of the agent. The assumption of the rationality of the players is admitted.

In the case treated in the table above, benefits are classified as follow $A^+ > A > B > A^-$. The character "honest" is important because it determines the quality of the information. Theoretically, the situation between the regulator or public institution and the firm is not always characterized of perfect information. For that reason, as defended by (Sagan & de Muison, 2008), incentive regulation can be recommended in developing country wher the low purchasing power of population is low and investing in new technology which can occasion tariff increase that may be delicate.

Table 1. Profits analysis of the game between the regulator and the investor (source: author).

		Player 2 (Agent)	
		Honest	Not honest
Player 1 (Principal)	foreseeable	A, A	A^-, A^+
	Not foreseeable	A^+, A^-	B, B

Note: A and B stand for profit level. As an example, in the couple (A^+, A^-), the first letter (A^+) indicates the profit level of player 1, in the same way, A^- is used for player 2.

For the principal, being an "honest" agent mean that the agent is declaring its real cost, avoiding *Averch-Johnson effect*[3] (Averch & Johnson, 1962) and making cost reduction effort that limiting moral hazard. For the Principal, being honest is meaning no surprise in the regulatory decisions, and to propose framework limiting effects of capture theory and the price decided is supposed to be optimum based on the information in its possession. The agent can be deprived (of a part) of his earnings by the regulator of an unverifiable investment (internal training, etc.) before signing a contract, which would reduce the incentive and could lead to underinvestment.

Different scenarios can be appreciated. When the information is not simultaneous, the regulator defines a tariff on the basis of production or operating costs presented by the firm. The institution will have to adjust on the basis of determined costs realized *a posteriori*. The possibility for a regulator remains unlikely, therefore, with a low probability of occurrence, insofar as the State is plaintiff remains engaged by its signature. Thus, **Table 2** describes the game between the principal and the agent in terms of investment level depending on the tariff level.

In **Table 2**, "W" represents the social Welfare, and P the price or the tariff value. Inequalities are established as follow $W^+ > W > B > W^-$ and and $P^+ > P > B > P^-$. When the tariffs decided by the government are low, the investment is also low, the game couple between the government and the company is (W, P). The investor would not have much interest in investing a lot of money even though he might decide to enter the market. When the government chooses a low tariff while the level of investment necessary to meet the quality requirements is high, the working couple is (W^+, P^-) because social welfare is high but the profit of the investor is low or close to zero. The incentive to invest in such a situation is low. Therefore, the investor has no interest in entering the market or applying for a new project. In addition, the existence of a psychological cost would be such as to encourage the investor, in order to avoid penalties, to respond to the challenge of an adequate investment, that is to say, able to achieve the objectives set. The equilibrium in this case "high price for high investment" is a pareto optimal; the regulator offering high tariffs to ensure return on investment.

From his side, the investor has the choice between a low or high level of investment. Without government or regulatory intervention through incentives,

[3]The *Averch Johson effect* designates a risk of overinvestment, i.e.in order to maximize its profits, the firm tends to substitute capital for labor when it is sure that its incurred costs will be recovered.

Table 2. Tariff level and investment level in the relationship Principal-agent (source: author).

		Player 2 (Agent)	
		Low investments	High investments
Player 1 (Principal)	Low tariffs	W, P	W^+, P^-
	High tariffs	W^-, P^+	B, B

the level of investment will be low when the level of tariffs is low. In such a case, it is not certain that the objectives in terms of quality will be achieved. Assuming that people in developing countries have low purchasing power, for the investor, the temptation to invest is low. These countries are naturally not very attractive for the deployment of more efficient technologies (generally more expensive). Therefore, it seems essential to introduce incentive systems or mechanisms to reduce disparities arising from the income level of the populations.

Kearney (2011) explains that company's DNA encompasses different parameters ranging from macroeconomic or regulatory environment, demand structure of the sector, to technology. In this context, the challenge for the investor could be related to predictability and adaptation in relation to (Taha, 1992: pp 413-422):

- Profits or expected losses based on income or utilities;
- Value of the expected variance for "long-run" analysis and "short-term" decision adjustment based on risk aversion by considering random variables, as well as aspirations in terms of profit maximization and cost minimization of the investor into a reasonable period of time;
- Most likely value by supposing a deterministic approach considering highest favorable probability replacing random value.

The network manager, mainly in developing countries, takes into account demand trends, congestion cost and investment costs. In the electricity sector, the regulatory framework and the demand level are some examples of random variables.

Figure 1 shows how important is the demand level as well as the possibility for the investor to having a clear idea of the incidence of the regulation. Decision theory recalls that the consideration of subjective probabilities makes it possible to define criteria consistent with likelihood assessment of possible consequences of decisions. As evoked by Kearney (2011), it also shows how important the predictability within a horizon of time and the potentiality of the firm [ability, desire and need] might be. Furthermore, the regulatory framework is very important for the investor as long as the certainty [or uncertainty] of his expectation is based on the reliability of the public decision without consideration of changes in political regime. For the firm, evolving within a predictable and clearly established regulatory framework helps to foster the attainment of the necessary investment needs (depending on expected income). At the regional level, the opportunity to invest must include the uncertainty of [cross-border] trade.

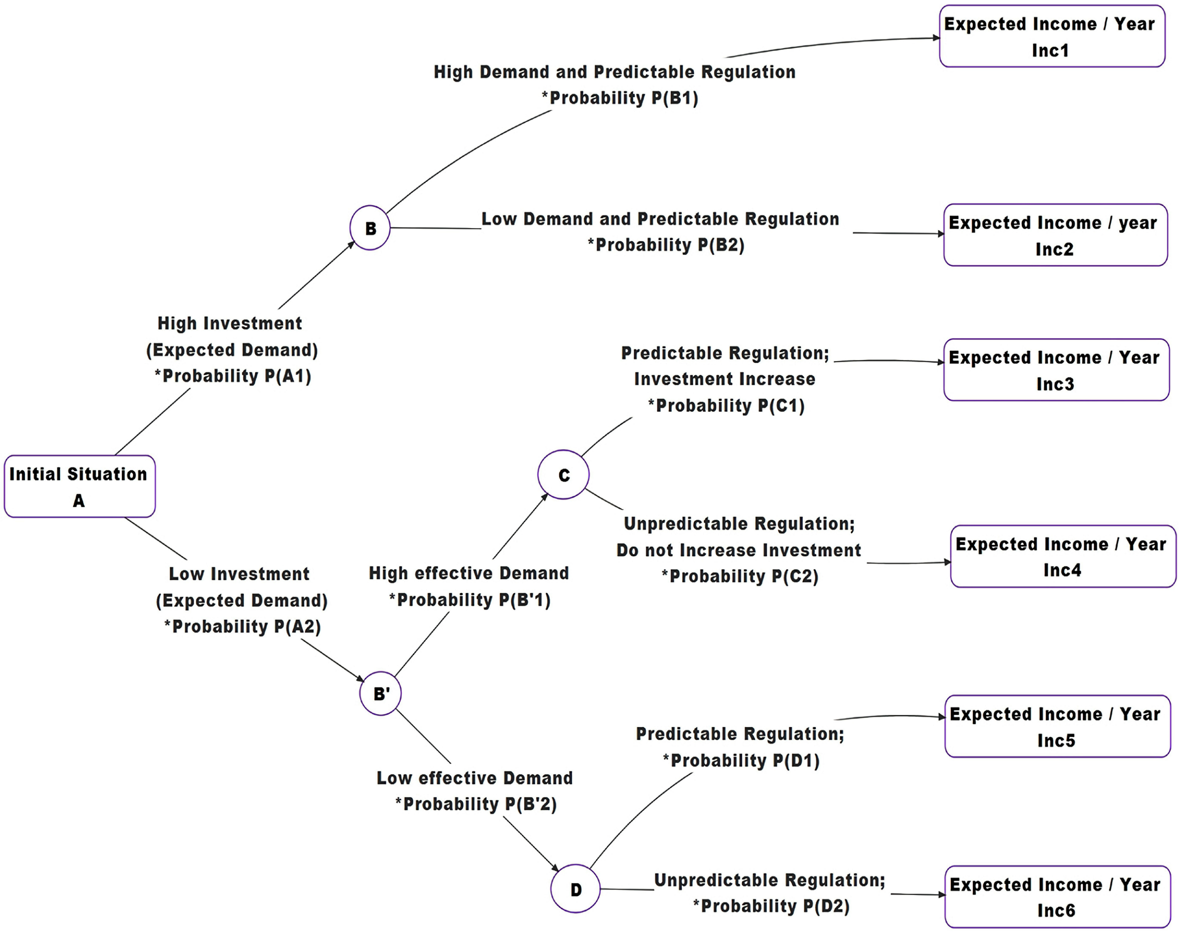


Figure 1. Decision tree for the investor.

2.3. Profitability of Investments

As a reminder, the cost structure of network industries is characterized by an economy of scale which also represents a barrier to entry and the needs in terms of civil engineering associated with the location of network infrastructures. The recovery concerns the CAPEX [investments] and OPEX [operation and maintenance]. The duration of depreciation varies depending on the nature of the assets. However, an average of 30 years is considered for Depreciated Replacement Cost.

$$R_e = R_f + \beta_e \left(R_m - R_f\right);$$

$$\begin{cases} R_e, & \text{return on equity} \\ R_f, & \text{risk-free rate observed in the market} \\ \beta_e, & \text{the correlation between equity risk and general market risk} \end{cases}$$

R_m the return on the market portfolio, then the difference (R_m – R_f) represents the risk premium of the market.

The firm willing to invest has equity [*CP*] to which is added a share of indebtedness [*D*]. The "Weighted Average Cost of Capital" (WACC) is defined as follow:

$$\text{WACC} = R_d \cdot \frac{D}{D+CP} + R_e \cdot \frac{CP}{D+CP};$$

$$\begin{cases} R_d, & \text{the nominal cost of the debt} \\ R_e, & \text{the nominal cost of equity (own fund)} \end{cases}$$

Nominal after-tax WACC:

$$\text{WACC}_{\text{after-tax}} = w = R_d \cdot (1 - T_c) \cdot \frac{D}{D+CP} + R_e \cdot \frac{CP}{D+CP};$$

with T_C the corporate tax rate.

The real pre-tax WACC takes into account the inflation rate i:

$$\text{WACC}_{\text{pre-tax}} = \frac{1 + \frac{w}{1 - T_c}}{1+i} - 1$$

The maximum allowed Income (MAI) for the year n would be:

$$\text{MAI}_n = \text{RAB}_n \cdot \text{WACC} + \text{annuity}_n$$

with RAB the Regulated Asset Base

From the investor's perspective, the difference between the before and after-tax methods lay in the time profile of income. Obviously, the after-tax method appears to favor the regularity of after-tax profits and therefore, to some extent, dividends. It highlights the needs for financial stability despite practical difficulties of an *ex ante* calculation of tax charges. About the pre-tax method, it gives a regular profile of "pre-tax" profits, and can mean a much after-tax profits on the most recent assets that benefit from exemptions and/or tax depreciation rebates.

The network operator (or even the government) could use the indebtedness with its financial partners to finance its projects according to the quota for which it did agree to. Let C_i be the cost of the project i and L_{ij} the loan contracted for the investment project i from the financial partner j at the rate R_{ij} for n years. Let P_k be the number of possible projects and P_L the possible number of lenders or financial partners likely to grant a loan to the network operator or to the state, n the number of years of repayment and $Amax_j$ the maximum amount that the financial partner j (a bank for example) is ready to grant. The mathematical modeling can be translated as follows:

$$\min \sum_{j=1}^{P_l} \sum_{i=1}^{P_k} L_{ij} \frac{R_{ij}}{1 - (1 + R_{ij})^{-n}} \tag{1}$$

$$\begin{cases} \forall i = 1, \cdots, P_k : \sum_{j=1}^{P_l} L_{ij} = C_i & (2) \\ \forall j = 1, \cdots, P_L : \sum_{j=1}^{P_k} L_{ij} \le Amax_j & (3) \\ \forall j = 1, \cdots, P_L, \forall i = 1, \cdots, P_k : L_{ij} \ge 0 & (4) \end{cases}$$

The objective function (1) proposes an optimized commitment for the realization of the infrastructures by minimizing the sum of the annuities ($L_{ij}\frac{R_{ij}}{1-\left(1+R_{ij}\right)^{-n}}$) to be paid. The total of the amounts borrowed to finance each project i must be equal to C_i (constraint 2). Constraint 3 recalls that the financial partner j does not finance more than $Amax_j$; all the variables being positive (constraint 4). The payback time (return on investment) is a criterion to which many investors are sensitive, mainly in developing countries where the political context can appear relatively unstable. Likewise, when it comes to dealing with cases where the dual variables are interpreted as marginal costs, this method (linear programming) helps to minimize an operating cost while respecting, for each output, the demand constraints.

3. Empirical Interest of Researchers for Electricity Consumption Path

Electricity consumption level has always been a determinant factor for investors. Several models have been used to address determinants of electricity consumption. Also, as explained by Yeboah et al. (2013), the interest in the consumption of electrical energy, it must be admitted, is reflected in the literature by the relative abundance of studies. In their article, these authors recall many empirical studies contributing to the body of existing knowledge in the field of energy consumption. It shows that, even if the main determinants of electrical energy consumption are many, electricity demand is influenced by variables such as real GDP per capita, price of electricity, population size, but also air temperature as well as variables related to financial, industrial development and energy efficiency.

In Jordan, Alawin et al. (2016) proposed an ARDL model to analyze determinants of electricity demand from data over the period 1985-2006. They showed that, contrary to the energy price index and industrial efficiency, population and GDP growth positively influence electricity consumption. Issa & Bataineh (2010) also had interest for determinants of electricity demand in Jordan. These authors used data for the period 1979-2008 and the technique of ordinary least squares. The explanatory variables in their model were real GDP per capita, real electricity price and efficiency in the industrial sector. Real GDP per capita has been found to have a positive effect on energy consumption while real electricity price and efficiency variables negatively affect energy consumption. These results indicate that as income increases, energy consumption also increases. These findings, say the authors, are consistent with the theory.

In Turkey, Halicioglu (2007) examines how energy demand in the residential sector has been influenced by price and income. The author notes that income positively influences the demand for electricity and accelerates purchases of electrical goods and services, just as urbanization has a positive effect, as it provides better access to electricity. Conversely, the price of electricity negatively influences the demand for electricity. Dilaver & Hunt (2011) criticized the models used so far for Turkey which, in their opinion, had ignored important economic variables such as income and the price of electricity. Their study proposes a structural time series analysis on data covering the period 1960-2008. These authors note a positive effect of GDP, a negative elasticity of average real electricity prices and the effect of factors relating to the underlying trend of energy demand such as consumer behavior.

In Pakistan, Zaman et al. (2015) examined the relationship between electricity consumption and the main factors related to it. Based on Alfred Marshall's demand function, they analyzed the effect of economic growth and the price of electricity over a period of 41 years (1972-2012). The results via the VECM model showed a positive effect of economic growth with two-way causality and the number of customers on electricity consumption, and a significant but small negative effect of electricity price and electricity shortage on electricity consumption. Still in Pakistan Khan & Qayyum (2009), for their part, use the ARDL technique over the period 1970-2006 to analyze and confirm the long-term and short-term [positive] effect of price and income on the consumption of electricity from agriculture, industry and households. Jamil & Ahmad (2010) rather considered a longer period to analyze electricity consumption in Pakistan (1960-2006). Their study shows a unidirectional causality of GDP on electricity consumption, i.e. that an upward trend in economic activity has a knock-on effect on consumption. On the other hand, Alter & Syed (2011) empirically analyzed the electricity demand in Pakistan over the period 1970-2010 using time series data via the cointegration test of Johansen (1991). The analysis shows statistically significant (at 1% and 5%) but low short-term income and price elasticities, which the researchers say indicates that consumers view electricity use as a basic necessity in short-term, but long-term luxury, then necessity in the end.

Latif (2015) provides a study of electricity consumption in Canada through panel data analysis over the period from 1983 to 2010. Using dynamic and modified ordinary least squares techniques, he demonstrated a positive effect of GDP per capita on electricity consumption per capita; but, an insignificant negative effect of real electricity prices on electricity consumption per capita. A study conducted a few years earlier by Ndiaye & Gabriel (2011) analyzed the electricity consumption of 62 dwellings in Oshawa. Data was collected from energy audits, telephone surveys and smart meter readings and processed via the latent root regression technique of Hawkins (1973) to solve the problem of multi-collinearities between predictors and at the same time reduce the number of predictors needed. Unlike other variable selection techniques such as the stepwise method, the technique used allows easy identification of alternative subsets. It is an approach that determines low eigenvalues and suggests possible alternative sub-regressions. The author notes that the type of fuel used to heat the swimming pool, the heating system, the domestic water heater, as well as the type of air conditioning and the number of air changes per hour at 50 Pa have a positive effect on electricity consumption. On the other hand, the average number of weeks that the family goes on vacation and the existence or not of an air conditioning system have a negative effect on electricity consumption.

In Portugal, Wiesmann et al. (2011) examine the relationship between per capita electricity consumption and housing characteristics among consumers. The econometric study based on municipal and survey data on consumption expenditure collected between 2005 and 2006 concludes a weak direct effect of income. However, they mention that the future demand for electricity in Portugal will be strongly influenced by the evolution of socio-economic factors as well as by the evolution of the building stock.

In South Africa, Inglesi & Pouris (2016) reviewed and summarized the issue of energy consumption. These authors were motivated by a severe crisis in the energy sector which had a negative consequence on the whole economy (Inglesi, 2010). They mention about twenty studies, ten of which analyze and summarize the causal relationship between energy demand and economic development, and ten others dealing with factors that characterize energy consumption. Economic growth and the price of electricity are considered among the main determinants of electricity consumption in South Africa.

Udo et al. (2011) used the ARDL model and annual time series data over the period 1970-2008 to study the dynamics of aggregate electricity consumption in Nigeria. Real GDP per capita, electricity price, population and industrial sector production were the explanatory variables. The study shows a statistically significant long-term income elasticity, which is consistent with the theory defending that an increase in income stimulates an increase in demand for goods and services including electrical. Short-term income elasticity, also significant, is lower than that of long-term value. The values of the elasticity of the "population" variable were 0.89 and 0.86 in the long and short term, respectively, and are statistically significant. This means that, based on the proposed model, the increase in population leads to an increase in the demand for electricity, all other things being equal. The study by Ubani (2013) confirms this diversity of socio-economic and physical factors by dealing with the case of Nigeria via data covering the period 1985-2005 and using the method of multiple linear regressions. These factors are population density, urbanization, number of manufacturing industries, employment rate, distance between production centers and number of households served. The results of Ubani (2013) are partly shared by Ekpo et al. (2011), particularly with regard to population, industry and the price of electricity. These authors consider data from 1985 to 2008 and include in their model the approach of Pesaran et al. (2001) on the level relations according to the stationarity in trend or in first difference of the regressors.

In Delhi (India), Tewathia (2014) conducted a survey to find out the determinants of electricity consumption. The author's aim was to analyze the effect of household income, the number and use of electrical appliances, the size of the house, the size of the family, the time spent away from home and the higher level of education on monthly electricity consumption in all seasons. The author relied on a questionnaire addressed to 350 households selected via random sampling. Among other things, it appears that the level of education has a negative effect because the most educated families tend to consume less electricity, and electricity consumption is higher in the hot season (summer) for different reasons such as air conditioning, etc. In the same vein, Filippini & Pachauri (2004) analyze electricity demand in Indian urban households. Three electricity demand functions were estimated from monthly data for three seasons (winter, monsoon and summer). The results show that electricity demand is income and price inelastic regardless of the season. In addition, household, demographic and geographic variables are important in determining electricity demand, which cannot be determined using only macro-aggregate models.

Kumarasinghe & Gunathilake (2010) examined the link between electricity demand and its determinants in Sri Lanka using data for the period 1977 to 2005. Income (GDP), population, percentage of electrified households, energy intensity and implemented rural electrification programs have been found to have positive effects on long-term electricity demand and, on the other hand, the average price of electricity has a negative effect on the demand for electricity. The estimated regression coefficients were statistically significant at the 1% level. The analysis followed standard econometric principles in evaluating the unit root properties of the variables in the model.

In the United States, Sanquist et al. (2012) based their research on data from the Residential Energy Consumption Survey (RECS), in 2005. They claim that air conditioning, the number of times the washing machine is used, personal computers, the climatic zone of the dwelling and the duration of television use significantly (positively) influence electricity consumption. For their part, Kavousian et al. (2013) examine the residential electricity consumption of 952 dwellings in the United States in terms of daily maximum and minimum. Minimum daily consumption is influenced by weather conditions, location, size of dwelling and number of refrigerators. The maximum daily consumption is influenced by the use of high consumption devices and the number of residents. In the summer consumption model, the main factor influencing electricity consumption is the degree of cooling (air conditioning) per day.

Thus, the journey of literature is rich in lessons. It should be noted that each country may have its own distinctive factors that describe electricity demand in addition to GDP and electricity prices. A synthesis study by Khanna & Rao (2009) establishes that electricity demand is a function of GDP, prices, incomes, the level and characteristics of economic activity, urbanization and seasonal factors. The authors indicate that the magnitude of their effects differs between countries, periods and studies, including for the same country. They also note that some demand studies suffer from a number of limitations, including data availability and price distortions that limit the responsiveness of demand to price signals. Similarly, Jones et al. (2015) offer a broad review of the literature to investigate the factors that influence or do not influence domestic electricity consumption. They studied 62 factors as possible determinants of electricity consumption. With regard to socio-economic factors, they find that electricity consumption increases with the level of household income and the number of occupants in a house and the time spent there. About housing factors, the age of the dwelling, the number of rooms, the number of bedrooms and the floor area influence electricity consumption. With regard to household appliances, the number of appliances, the existence of a desktop computer, a television, an electric oven, a refrigerator, a dishwasher, a dryers and higher use of washing machines have a positive effect.

4. Data and Methodological Approach

Consistently, the literature highlights production (GDP) and population as determining factors of electricity consumption. The data related to the variables considered in **Table 3** are annual and cover the period 1985-2020. These are secondary data. These variables are provided by the World Bank database (WDI) and the Ivorian Electricity Company (CIE), the latter being the monopolist in charge of distribution (and billing) to the end consumer. Thus, the list of variables that will be used for the econometric analysis is presented in the following table (**Table 3**).

In this section, it is a question of verifying the effect of the population and the gross domestic product (in the long term) on electricity consumption in order to anticipate demand forecasts. The approach by vector error correction models (VECM), which is a dynamic model adopted in this study, has the advantage of providing information on the long-term relationships by possibly adding the short-term dynamics. This theoretical framework highlights various aspects:

- The existence of an autoregressive character, i.e., in dynamic models where, among the explanatory variables, the endogenous variable itself and the shifted values (its past values) appear.

Table 3. List of variables.

Variables	*Signification*	*Scale (units)*	*Sources*	*Expected effect*
enc	*This is the **dependant variable**, reflecting the energy actually consumed, therefore billed to consumers in Côte d'Ivoire. It is to be distinguished from the quantity of energy produced which is higher but which undergoes losses…its logarithmic expression is **lenc.***	*GWh*	*CIE*	
pop	*This variable reflects the size of the population of Côte d'Ivoire. Son expression logarithmique est **lpop.***	*Numerical*	*WDI*	*Positive*
gdp	*This is the gross domestic product. Its logarithmic expression is lgdp.*	*US$*	*WDI*	*positive*

Source: WDI & CIE.

$$Y_t = f\left(X_t, Y_{t-p}\right)$$

- The existence of lags underlies a distinction between a possible short-term effect distinct from a long-term effect. These are models with exogenous variables $\left[X_t\right]$ and its past or lagged values. In general, their functional form is:

$$Y_t = f\left(X_t, Y_{t-q}\right)$$

- The extensive analysis of the models combines the two previous characteristics:

$$Y_t = f\left(X_t, Y_{t-p}, Y_{t-q}\right)$$

Thus, in the dynamic model, the endogenous variable is explained by its own lagged values and the present and past values of the explanatory variables (X_t):

$$Y_t = \lambda + \sum\nolimits_{i=1}^{p} a_i Y_{t-i} + \sum\nolimits_{j=0}^{q} b_j X_{t-j} + e_t \quad (1)$$

In Equation (1), b_0 indicates the short-term effect of the explanatory variable under consideration on the variable to be explained, and $e_t \sim iid\left(0,\sigma\right)$. The explicit structural representation of a stationary process with *p*, the number of lags, can be reformulated as follows:

$$Y_t = \lambda + a_1 Y_{t-1} + a_2 Y_{t-2} + \cdots + a_p Y_{t-p} + b_0 X_t + \cdots + b_q X_{t-q} + e_t \quad (2)$$

Equation (1) or (2) takes into account the autoregressive character of the model:

$$Y_t = a_0 + \sum\nolimits_{i=1}^{p} a_i Y_{t-i} + \varepsilon_t \quad (3)$$

Moreover, the possible existence of a long-term effect of the variable can be drawn from the long-term relationship $Y_t = k + \gamma X_t + v$ as follow:

$$\gamma = \frac{\sum a_j}{1 - \sum a_i} \quad (4)$$

In the analysis of time series, the problem of spurious regressions (high coefficient of determination and low Durbin Watson) linked to the non-stationarity of the variables has been raised (Granger & Newbold, 1974). In the analysis of time series, spurious regressions problems (high coefficient of determination and low Durbin Watson) linked to the non-stationarity of the variables has been raised (Dickey & Fuller, 1979, 1981; Fuller 1976, 1996; Phillips, 1987). However, authors such as Engle & Granger (1987) indicate that the stationarization of the variables by their use in first difference makes the series lose its long-term properties because the model captures only the short-term dynamics. These researchers therefore suggest adding long-term dynamics to the short-term stationary model by using a so-called error-correction model, the estimation of which assumes the existence of a long-term equilibrium relationship (cointegration) between variables (Maddala & Kim, 1998). When all the variables are stationary, the estimation of the parameters can be made by the OLS method. If the variables are integrated of the same order but are not cointegrated, it is appropriate to differentiate the variables before estimating by the OLS method. Moreover, if in addition to being integrated of the same order, variables are cointegrated, then either OLS method is applied to the variables in level in order to obtain the long-term equilibrium relationship, or it is necessary to estimate the error correction model (by OLS) which analyses the short-term dynamic between variables. Finally, when the variables are not integrated of the same order, some are integrated of zero order while others are of order 1, the long-term relationship and the short-term dynamics must be estimated simultaneously (for example by the ARDL method).

Furthermore, classical multi-equation econometric approaches have been much criticized (Granger, 1969; Sims, 1980) because predictions made using these models have turned out to be rather poor (Gossé & Guillaumin, 2011). The generalization of autoregressive (AR) models to the multivariate case provides a statistical response to all of these criticisms. The essential contribution of autoregressive processes is to allow better forecasting of macroeconometric models (Gossé & Guillaumin, 2011).

The optimal number of lags p is important because an insufficient number of lags causes the process under study to lose information; its memory not proving to be long enough. Conversely, too many delays increase the number of parameters to be estimated and reduce the degree of freedom of the process accordingly. The analysis proposed in this section favors information criteria, i.e. the number p of lags minimizing the AIC (Akaike Information Criterion) and BIC[4] (Bayesian Information Criterion) criteria, which are the most commonly used in economics. To a lesser extent, the Hannan and Quinn (HQ) criterion appears. However, other criteria exist (Deniau et al., 1992) and the works of authors such as Bruneau & De Bandt (1999) or Bruneau & Jondeau (1999) help, in the event of divergence on the number of lags to be considered, to make a choice.

$$\text{AIC}(p) = \ln(\det \hat{\omega}) + 2\frac{k^2 p}{T} \tag{5}$$

$$\text{BIC}(p) = \ln(\det \hat{\omega}) + \frac{k^2 p \ln(T)}{T} \tag{6}$$

$$\text{HQ}(p) = \ln(\det \hat{\omega}) + \frac{k^2 p 2 \ln(T)}{T} \tag{7}$$

with $\hat{\omega}$ an estimator of ω and remembering that k is the number of system variables, and, T the number of observations.

Let L be the lag operator and ε_t satisfying the properties of a white noise:

$$Y_t\left(I - \theta_1 L - \theta_2 L^2 - \cdots - \theta_p L^p\right) = \theta_0 + \varepsilon_t \tag{8}$$

Let

$$\theta(L) Y_t = \theta_0 + \varepsilon_t \tag{9}$$

with $\theta(L) = I - \sum_{i=1}^{p} \theta_i L^i$

[4]BIC est aussi connu dans la littérature en statistique par Schwarz Information Criterion (ou SIC, SBC, SBIC).

Several lessons emerge from these equations, two of which are obvious. First, different models with a large number of equations can be estimated. Then, the number of observations available and the number of lags condition the size of the model. Thus, the quality of the estimate depends on the arbitration capacity of the modeler while preserving the degree of freedom.

An autoregressive process can be performed via ordinary least squares (OLS) or maximum likelihood. Indeed, Hamilton (1994) noted that the maximum likelihood method is increasingly used because OLS are no longer valid when there are constraints on the parameters (Lardic & Mignon, 2002). Indeed, the likelihood at t, conditional on past values, is expressed as follow:

$$L\left(Y_1,\cdots,Y_T\right)=\prod_{t=1}^{T}L\left(Y_t \mid \underline{Y_{t-1}}\right) \tag{8}$$

In Equation (8), $\underline{Y_{t-1}}$ denotes the memory up to date $t-1$ included. The likelihood is deduced:

$$L\left(Y_1,\cdots,Y_T\right)=\prod_{t=1}^{T}\frac{1}{\left(\sqrt{2\pi}\right)^n\sqrt{\det\omega}} \cdot\exp\left[-\frac{1}{2}\sum_{1}^{T}\left(Y_t-\theta_1Y_{t-1}-\cdots-\theta_pY_{t-p}\right)'\omega^{-1}\left(Y_t-\theta_1Y_{t-1}-\cdots-\theta_pY_{t-p}\right)\right] \tag{9}$$

The estimates $\hat{\theta}_1,\cdots,\hat{\theta}_p$ of the parameters $\theta_1,\cdots,\theta_p$ as well as the variance-covariance matrix ω related to the error term (ε_t) can be obtained via the maximization of the log-likelihood which is:

$$\log L\left(Y_1,\cdots,Y_T\right)=-\frac{nT}{2}\log 2\pi-\frac{T}{2}\log\omega-\frac{1}{2}\sum_{t=1}^{T}\varepsilon_t'\omega^{-1}\varepsilon_t \tag{10}$$

Thus consider the following estimate:

$$Y_t=\hat{\theta}_0+\hat{\theta}_1Y_{t-1}+\hat{\theta}_2Y_{t-2}+\cdots+\hat{\theta}_pY_{T-p}+\varepsilon_t \tag{11}$$

The number of delays p is determined according to the criteria mentioned above (Equations (5), (6), (7)) and the parameters $\hat{\theta}_0,\hat{\theta}_1,\hat{\theta}_2,\cdots,\hat{\theta}_p$ as well as the variance-covariance matrix associated with ε_t are estimated. The forecast of the process at a horizon h is then written:

$$E\left[Y_{T+h}\mid Y_T\right]=\hat{\theta}_0+\hat{\theta}_1Y_T+\cdots+\hat{\theta}_pY_{T-p+h} \tag{12}$$

Similarly, VECM processes appear to be an interesting alternative for embarking on forecasting models. In addition to this, the cointegration test of Engle & Granger (1987) is only valid for two integrated variables of the same order, but remains less efficient for multivariate cases. Although the Johansen test overcomes this concern and is based on vector autoregressive error correction modeling (VECM), it also requires that all the variables be integrated of the same order, which is the case of this study. The present econometric analysis is conducted on energy demand using the cointegration model of Johansen & Juselius (1990). Demand forecasts can be analyzed on the basis of trends related to socio-economic development (industrial production, GDP), changes in residential demand (population growth, increase in electricity consumption, electrification of non-electrified areas, improving electricity supply services), evolution of the transition from independent energy sources and connection to networks, etc.

The basic empirical function analyzed in this study is as follows:

$$\text{Consumption} = f\left(pop, gdp\right)$$

$$\begin{aligned}\Delta enc_t = {} & A_0 + \sum\nolimits_{i=1}^{p} A_{1i}\Delta enc_{t-i} + \sum\nolimits_{i=0}^{q} A_{2i}\Delta pop_{t-i} + \sum\nolimits_{i=0}^{q} A_{3i}\Delta gdp_{t-i} \\ & + B_1 enc_{t-1} + B_2 pop_{t-1} + B_3 gdp_{t-1} + e_t\end{aligned} \quad (13)$$

Δ operator indicates the first difference of considered variable; $A_1, \ldots, A_4$ express the short-run effects; $B_1, \ldots, B_4$ quantify the long-run effect; e_t is the error term which has the characteristics of a white noise ($e \sim iid\left(0, \sigma\right)$). The cointegration relationship between variables conditions the short and long run estimation between variables. As mentioned earlier, several tests are possible for this purpose (Engle & Granger, 1987; Johansen & Juselis, 1990; Pesaran et al., 2001).

The existence of cointegration between variables will be deduced from an error correction model carried out according to the procedure of Pesaran et al. (2001):

$$\begin{aligned}\Delta enc_t = {} & A_0 + \sum\nolimits_{i=1}^{p} A_{1i}\Delta enc_{t-i} + \sum\nolimits_{i=0}^{q} A_{2i}\Delta pop_{t-i} + \sum\nolimits_{i=0}^{q} A_{3i}\Delta gdp_{t-i} \\ & + \Phi u_{t-1} + e_t\end{aligned} \quad (14)$$

where Φ is called the error correction term, adjustment coefficient or the cointegration relation's adjustment coefficient. First, the degree of integration of the variables (stationarity test) will be determined using tests such as those of Dickey-Fuller Augmented/ADF and Philippe-Perron/PP. Then, it will be necessary to check the possible existence of a cointegrating relationship between variables.

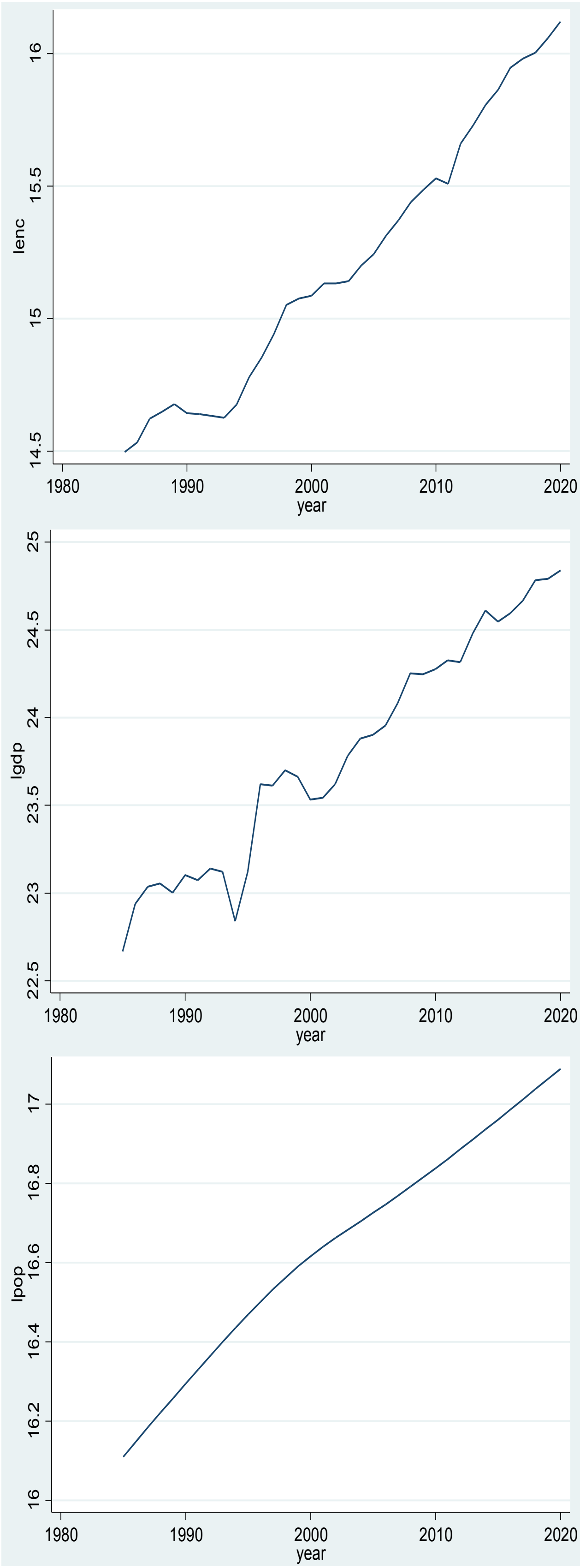
5. Results and Prospective Approach

5.1. Descriptive Analysis

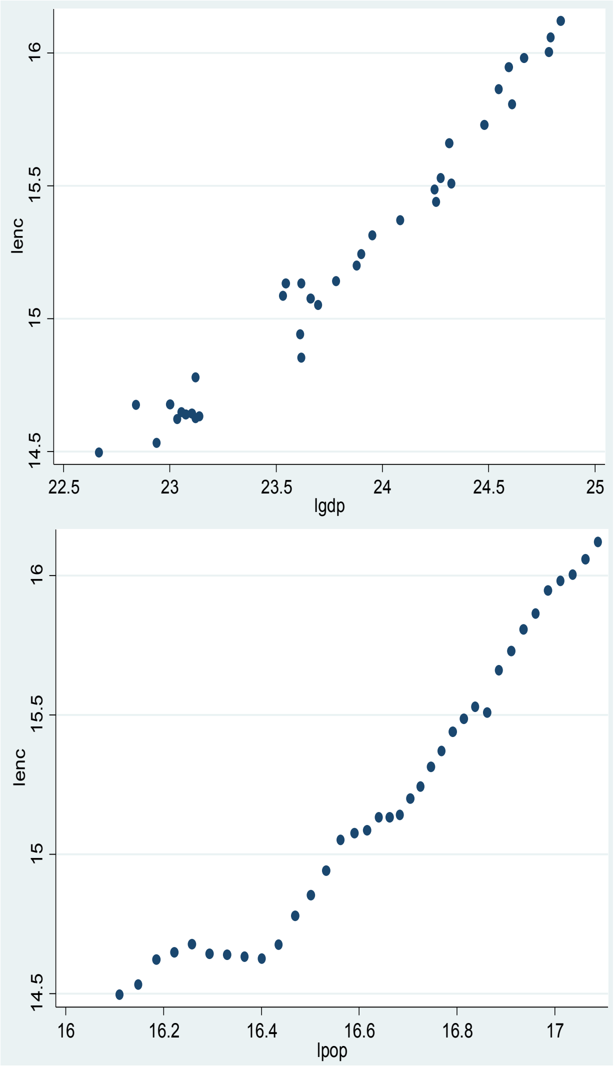
The associated graphical analysis (**Graph 1**) provides a visual of the series and highlights contrasting performances over the analysis period. In **Graph 1**, the two figures above, from the left to the right show respectively the evolution of energy consumption (*lenc*) and GDP (*lgdp*). The third graph is related to the evolution of the population (*lpop*).

Indeed, the graph above recalls, through the shape of the GDP curve, various economic performances (periods of recession or growth) such as the devaluation of the CFA Franc which occurred in 1993 or the military-political crisis which started in 2002 and ended in April 2011. Thus, the 1990s and 2000s were marked by a combination of both economic and political crises. Moreover, the shape of the curve relating to the size of the population (*lpop*) does not seem to present any particular disturbance.

Graph 2 illustrates the relationship between GDP and the level of energy consumption on the one hand, and the size of the population and the level of energy consumption on the other hand. It makes it possible to assume a positive correlation and the possibility of analyzing the effects of these variables on the



Graph 1. Graphical overview of series. Source: author, from the data.



Graph 2. Relationship between the endogenous variable and the exogenous variables. Source: author, from the data.

dependent variable via a linear approach. **Table 4** summarizes some descriptive characteristics of the series considered. Among other things, it indicates that gross domestic production (*lgdp*) has the highest volatility.

The *lenc* and *lgdp* series are abnormally distributed with a Jarke-Bera value less than 5%. Similarly, at the 5% threshold, the variable *lpop* can be considered to follow the Gaussian.

The linear correlation matrix (**Table 5**) shows very high values. Indeed, the correlation between *lenc* and *lgdp* is 0.98, and that between lenc and lpop is 0.97. These associations are high and could be a factor of multicollinearity. Population and GDP growth may drive (upward) energy consumption.

5.2. Stationarity and Optimum Lags

The stationarity of series must be verified in order to avoid spurious regressions, and therefore biased results. Thus, stochastic characteristics of a time series are

Table 4. Descriptive statistics of analysis variables.

Variables	*Mean*	*Min*	*Max*	*Standard error*	*Jarque-Bera (pvalue)*
lenc	15.11	14.34	16.12	0.54	6.92 (0.03)
lgdp	23.67	22.64	24.83	0.69	10.49 (0.00)
lpop	16.56	15.89	17.08	0.34	5.13 (0.07)

Source: author, from the data.

Table 5. Matrix of correlations.

	lenc	*lgdp*	*lpop*
lenc	1		
lgdp	0.98	1	
lpop	0.97	0.97	1

Source: author, from the data.

only identifiable if it is stationary. The null hypothesis is that of non-stationarity i.e. the existence of a unit root; and the ADF (Dickey & Fuller, 1979) and Phillips & Perron (1988) tests will be preferred for this purpose. Unit root tests make it possible to detect whether the stochastic process is affected by a trend or a seasonality and elements of response on the type of non-stationarity of the series. There is the TS (Trend Stationary) process which presents a deterministic non-stationarity, and the DS (Differency Stationary) process for random non-stationary processes. These two types of processes are respectively stationarized by deviation from the trend and by the filter to differences. In the latter case, the number of difference filters makes it possible to determine the order of integration of variables.

As shown in **Table 6**, the series are integrated of order 1. Thus, since all series are made stationary after differentiation, the next procedure consists in determining the optimum number of lags. As a reminder, the model of interest considers *lenc* as dependent variable and the exogenous variables are *lgdp* and *lpop*.

In **Table 7**, the optimal number of lags, according to the BIC (Bayesian Information Criterion) criterion as well as most of the other criteria such as HQIC (Hannan-Quinn Information Criterion) is 3. About the AIC criterion, this number is 4. For the coming steps of the study, the choice to consider this number of lags [3] seems reasonable given the relatively small size of the sample.

5.3. Cointegration and Error Correction Models

The series being integrated of order 1, it is appropriate to analyze the cointegration between them and to verify the existence of a long-term relationship. The results of the Johansen cointegration test (Johansen, 1991) are shown in **Table 8**.

At the 5% level of significance, the results of the cointegration tests presented in **Table 8** indicate the existence of a cointegration relationship between electricity consumption, GDP and population size. Indeed, the trace statistics (λ-trace) and

Table 6. Stationarity test.

Variables	*Level*		*First difference*		*Integration order (unit root)*
	ADF	*PP*	*ADF Z(t) (pval)*	*PP*	
lenc	1.12 (0.99)	−1.65 (0.76)	−3.4 (0.01)	−5.33 (0.00)	I~(1)
lpib	0.23 (0.93)	0.33 (0.97)	−5.50 (0.00)	−5.43 (0.00)	I~(1)
lpop	−2.95 (0.14)	−6.79 (0.00)	−2.84 (0.050)	−3.584 (0.03)	I~(1)

Source: author, from the data.

Table 7. Number of model optimum lags.

Lags	*0*	*1*	*2*	*3*	*4*
AIC	−3.617	−14.001	−17.1137	−20.2663	−20.329*
BIC	−3.480	−13.452	−16.1518	−18.892*	−18.5433
FPE	5.4e−06	1.7e−10	7.6e−12	3.4e−13*	3.5e−13
HQIC	−3.572	−13.819	−16.794	−19.810*	−19.737

Source: author, from the data.

Table 8. Results of Johansen cointegration test.

Hypothèse nulle [Rank]	*R = 0*	*At most 1 (R ≤ 1)*	*At most 2 (R ≤ 2)*
Trace statistics	83.19	25.96	0.04*
Critical value (5%)	29.68	15.41	3.76
Max Eigenvalue statistics	26.38	25.91	0.04
Critical value (5%)	20.97	14.07	3.76

Source: author, from the data.

maximum eigenvalue (λ-max) reject the null hypothesis of the non-existence of a cointegrating relationship. Thus, in the event of the existence of a shock in the short term, the possibility of a convergence in the long term of the series can be envisaged. This observation is consistent with previous studies, including those of Ngutsav & Aor (2014), in Nigeria, which identified a cointegration relationship between electricity consumption, income, electricity prices, population and industrial production, and Zaman et al. (2015) proving a cointegration between electricity consumption, GDP and electricity price in Pakistan.

The long-term relationship between electricity consumption and its determinants by the VECM approach is as follows (**Table 9**).

The values shown in **Table 9** express long-term information. Any deviations from the long-term equilibrium are gradually corrected by the error-correction term through a series of short-term partial adjustments. The coefficients (−0.51 and −1.04) are statistically relevant to predict developments or changes in the trajectory of energy consumption. Thus, the interpretation of elasticities suggests that a variation (increase) of 1 point of *lpib* occasion an increase of 0.51 point of

Table 9. Result et vecm estimation.

Long-run relationship
$lenc = 1.000 lenc_{t-1} - \underbrace{0.51}_{\substack{(0.058)\\[-8.73]}} \cdot lgdp_{t-1} - \underbrace{1.04}_{\substack{(25.91)\\[-7.34]}} \cdot lpop_{t-1} + 14.81$
Short-run relationship
$\Delta lenc = \underbrace{-0.25}_{\substack{(0.11)\\[-2.31]}} ECT_{-1} + \underbrace{0.22}_{\substack{(0.17)\\[1.30]}} \Delta lenc_{-1} + \underbrace{0.04}_{\substack{(0.18)\\[0.24]}} \Delta lenc_{-2} - \underbrace{0.06}_{\substack{(0.06)\\[-0.97]}} \Delta lgdp_{-1}$ $+ \underbrace{0.027}_{\substack{(0.05)\\[0.49]}} \Delta lgdp_{-2} - \underbrace{0.33}_{\substack{(9.12)\\[-0.04]}} \Delta lpop_{-1} + \underbrace{3.32}_{\substack{(9.24)\\[0.36]}} \Delta lpop_{-2} + \underbrace{0.07}_{\substack{(0.03)\\[1.98]}}$

Note: ( ) represents standard deviations; [ ] represents the value of the T-statistic. Source: author's estimates.

lenc. De même, une augmentation de 1 point de *lpop* occasion une croissance de 1.04 point de *lenc*. The negative and significant value of the error correction term (−0.25) implies that there is a long-term causality of *lpop* and *lgdp* on *lenc*.

Table 10 highlights an overall short-term causal link of GDP on energy consumption. However, energy consumption has a short-term causal effect on GDP.

5.4. Model Stability

Stability tests ensure the validity of a model for legitimate interpretation. The results indicated in Table 11 translate the stability indicators of the model. The normality test confirms that the errors relating to the different models follow a normal distribution.

Similarly, the null hypotheses of non-autocorrelation and homoskedasticity of the residuals are accepted at the 5% threshold. Also, as illustrated by Graph 3, the CUSUM squared test is carried out to check the stability of the model parameters and the reaction following a shock. It shows that the model is [globally] stable.

Thus, despite the possibility of disturbances probably linked to the economic, management or even socio-political context, the model tends to find a relative balance so that the line of residuals is [re]located inside the standard deviation lines.

5.5. Forecasting

The model having passed the diagnostic tests, it is possible to perform a [an attempt to] forecast in order to anticipate the evolution of demand.

The forecasts, as depicted in Graph 4, indicate an upward trend in each of the variables. The consumption forecast values are presented in **Appendix**.

5.6. Prospective Analysis

According to Godet & Roubelat (2003), prospective is a matter of focusing on long-term concerns. Analyzing the future cannot claim to remove doubts and uncertainties, but rather establish a set of choices among a set of possible futures.

Table 10. Short-run causality (Wald test).

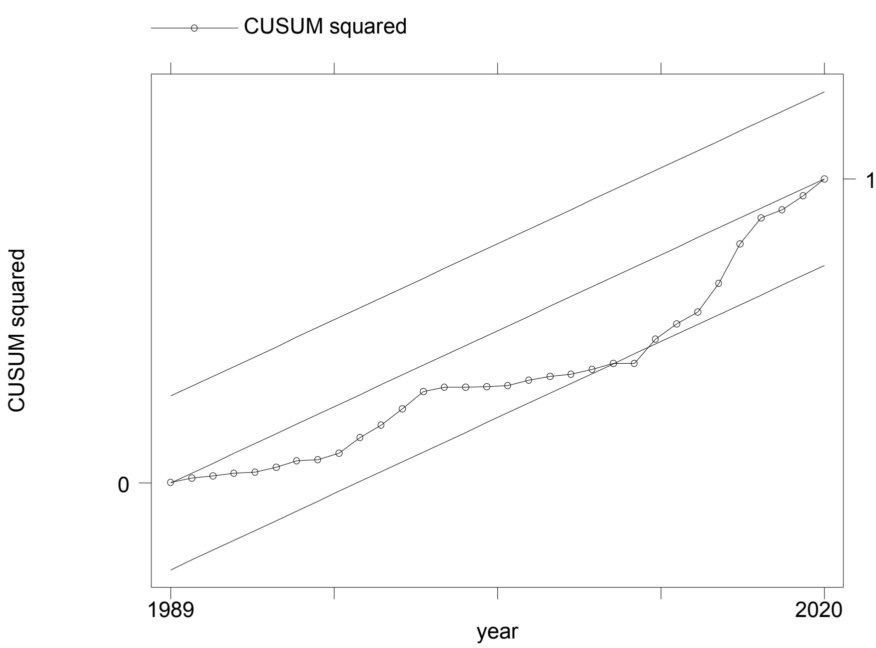
Causality/Directions			Results
lgdp	=>	*lenc*	One-way causality
lpop	-	*lenc*	Causality not proven

Source: author, from the data.

Table 11. Résultats des tests diagnostiques.

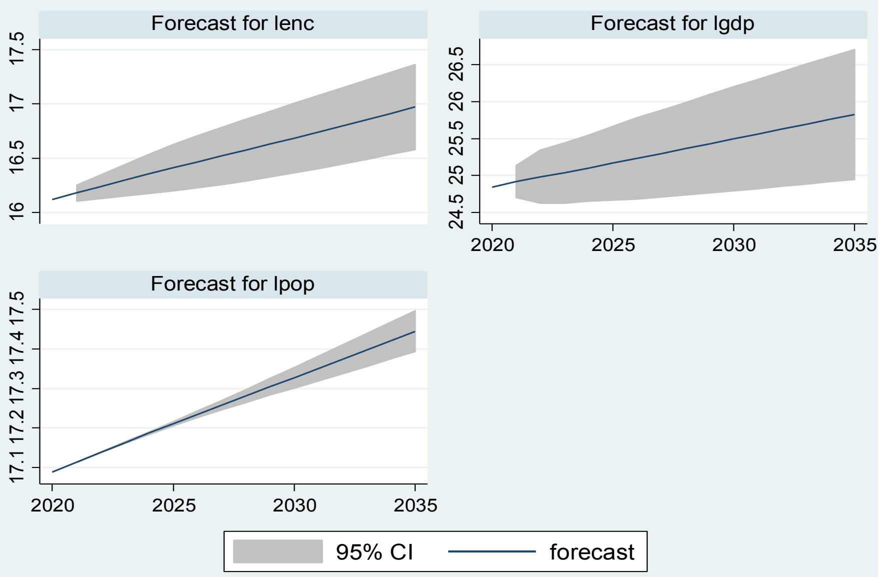
Test Hypotheses	***Tests***		***Chi-square value (probability)***
Heteroskedasticity	*White*		*4.62* (*0.46*)
	Breusch-Pagan/Cook-Weisberg		*0.27* (*0.60*)
Normality	*Jarque-Bera*	$\Delta lenc$	*1.998* (*0.36*)
		$\Delta lgdp$	*0.080* (*0.96*)
		$\Delta lpop$	*0.011* (*0.994*)
		ALL	*2.089* (*0.91*)
Autocorrelation	Lagrange-multiplier test	Lag 1	10.122 (0.340)
		Lag 2	16.651 (0.055)
Stability			The VECM specification imposes 2 unit moduli.

Source: Author, from data.



Graph 3. Cusum square test for stability. Source: author, from the data.

As a reminder, forecasting must be distinguished from foresight which is a proactive and pre-active conduct (attitude). In fact, forecasts almost always fail to come true. Therefore, prospective foresees the desired future by envisaging



Graph 4. Forecasts 2020-2035. Source: author, from the data.

scenarios and decisions, as well as informed actions to achieve that desired future while anticipating and causing change (Godet & Roubelat, 2003). The prospective paradigm considers a heuristic school and a rational school based on complementary scenarios.

Since the future is inherently uncertain, the scenario approach was chosen in order to analyze implications of various potential development paths rather than predicting them. Nowadays, long-term policy and vision are needed to adapt to the social and economic trajectory (which is rapidly changing) and to technological progress (dynamic). Statistical considerations have limits insofar as they are linked to overestimation or underestimation, to the inertia of "structure" and "conduct" in the SCP (Structure-Conduct-Performance) paradigm.

Figure 2 summarizes fairly well the synergy necessary for the effectiveness of prospective action. Any scenario necessarily contains subjective elements and is open to various interpretations. A scenario is not a prediction of the future to come, but a coherent description of a future state or trajectory that is as complete as necessary for the purposes of analysis.

Thus, for attracting investments, it seems adequate to analyze the factors that may influence the level of demand. This will be examined from the energy system assessment material of the International Atomic Energy Agency (IAEA, 2009: p 3) which is the Model for Analysis of Energy Demand (MAED). The MAED is schematized by Figure 3.

The objective is to map the trends and evolution of energy needs, especially since these correspond to alternative socio-economic development scenarios. This tool has the advantage of being flexible and specially designed to estimate future electricity needs for the production and consumption of goods and services. In the analysis, this approach takes into account technological innovation (including the technological performance of household appliances), infrastructure,

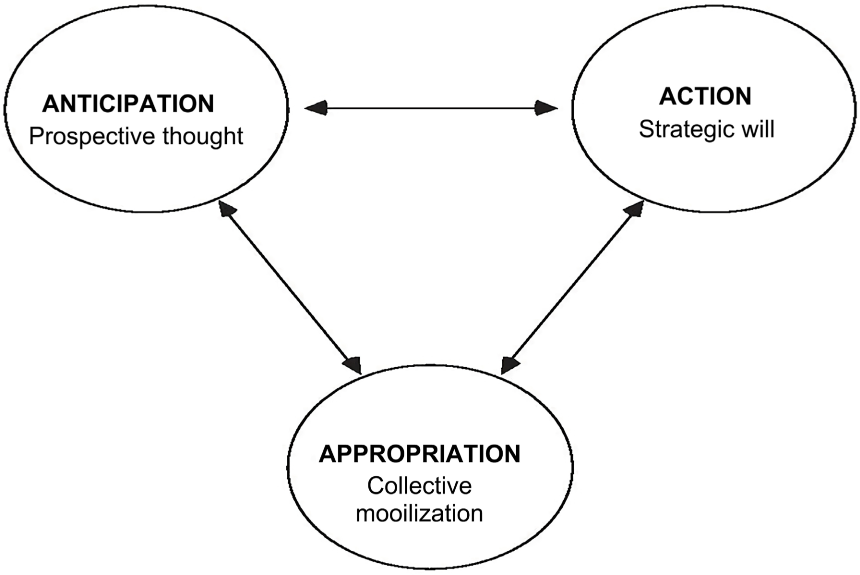


Figure 2. The Greek triangle (Godet & Roubelat, 2003).

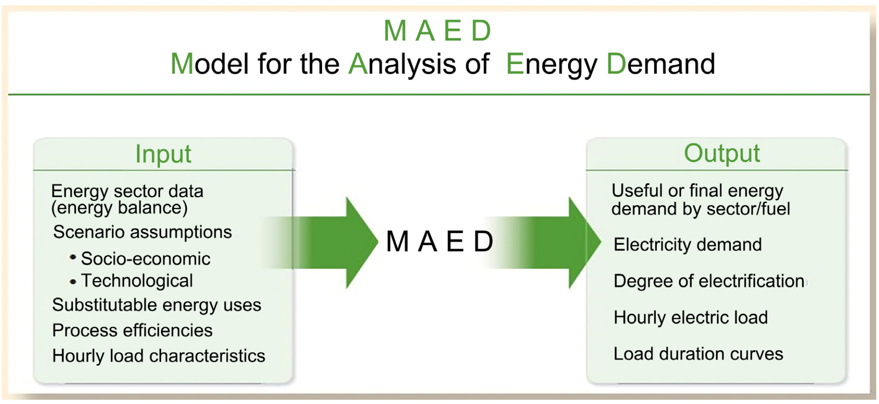


Figure 3. The main Inputs and Outputs by MAED (IAEA, 2009).

changes in lifestyle, per capita income, etc. However, deep mutations are difficult to imagine in the development of energy systems inclined to rapid changes and very often can be discontinuous. Indeed, lifetimes of technologies in the power sector can be very long, from several years (household appliance equipment, photovoltaic systems, etc.) to several decades (power plants, transmission and distribution networks, and dams). Therefore, many of the technologies that will be put into service will remain so over the next decade and possibly beyond, as new and improved technologies emerge and begin to compete with each other. As well, planning, preparation and construction periods for infrastructure are important to be taken into account, since they may depend on the nature of the decisions in the implementation of projects (from 5 to 15 years between the initiation of the project and its achievement), for example, power plants, hydropower projects, transmission lines and interconnections.

There are relatively few data on the future evolution of the population in Côte d'Ivoire. The International Monetary Fund (IMF) makes its own forecast by considering a growth rate of 3% (Fonds Monétaire International, 2008). In addition, two studies carried out by American offices. The first forecast comes from the University of Denver (Colorado)-International Futures (IFs) forecasting system, and Pardee Center for International Futures at the University of Denver. The second forecast was made by the US Census Bureau, International database. The announced growth rate is around 1.7% per year in the short term, very similar to the estimated current growth rate. In the longer term, the growth rate considered decreases to 1.4%. Based on the past, this forecast seems low, even for a low scenario.

As a reminder, various elements are found in the background of the development of this master plan. First, a sharp increase in consumption is expected concomitantly with economic development, rural electrification and mining development (in the west of the country). In the same vein, the increasingly important role of Côte d'Ivoire within the West African Power Pool should be taken into account. Furthermore, some challenges must be addressed including the heavy dependence on thermal electricity, which is also causing the accelerated depletion of domestic natural gas resources, the low reliability of supply and the low efficiency of the electricity grid. Indeed, production, transmission and distribution losses were expected at 13%, including 10% on the distribution network and 3% for the transmission network. However, these losses on the transmission and distribution network were over 20% in 2020. Finally, the popularization of smart meters remains essential for monitoring demand in real time. This type of meter has a low operating cost but also contributes to the reduction of fraud.

As early as the 1980s, given the economic crisis, Côte d'Ivoire undertook a broad reflection on the policies of the economy towards industrialization, the privatization of state companies and diversification. The objective was that the agricultural sector is no longer the only one on which the economy is based by promoting the development of other sectors (mining, oil, industry and tourism). The socio-political crisis (from 1999-2010), certainly contributed to slowing down the realization of the projected visions. However, the country launched, from April 2012, reconstruction programs and infrastructure development projects according to the National Development Plan 2012-2015, then 2016-2020 valued at US$50 billion, and for which the private sector is highly solicited (up to 60%). More specifically, the 2020-2030 Renewable Energy Development and Energy Efficiency Sector Policy document (PSDEREE) supplementing the 2014 Energy Policy document, defines the main orientations in the electricity sector.

The challenge for investors remains to have elements of analysis that reduce uncertainties and help to define their investment choices. The objective is to propose an analytical framework taking into account purely economic, sectoral and social variables. These uncertainties can be reduced by the macroeconomic environment depending on the evolution of various variables (GDP, inflation, employment, literacy rate, population density, urbanization rate, energy policy, etc.). This approach is all the more important as the CI-ENERGIES report

(CI-ENERGIES, 2019) highlighted the discrepancy between demand level forecast from 2017.

The GDP and the GDP/capita have a direct impact on the modernization of the network (low GDP growth rate, high GDP growth rate, alternating and moderately low growth) because the positive effect of income on the quality of infrastructure is demonstrated (CNUCED, 2017; Tehero & Aka, 2020). Likewise, interest in the unemployment rate is borne by the income of workers. The higher the unemployment rate, the less investment needed to improve the quality of electricity can be supported.

- Case 1: a slight reduction in the unemployment rate (economic growth has no impact and cannot reduce job insecurity).
- Case 2: significant reduction in the unemployment rate, close to structural unemployment with great disparity.
- Case 3: strong reduction in unemployment and deep reflection on "inequality and redistributive justice"…

The level of education and training, which presupposes a high literacy rate, allows better control over technological developments and indirectly employability (therefore the level of income). It facilitates technological assimilation and their stability. Many hypotheses are possible regarding the future:

- Assumption 1: the level of education is not efficient, and universities and polytechnics do not have sufficient financial resources for research…and the few existing elites are not recognized or are used in an environment of clientelism or nepotism.
- Assumption 2: the literacy rate remains constant or without a subsequent "boom", with the same geographical distribution. The impact in terms of improving the expertise of the workforce is not sufficient to face development challenges with internal human resources, i.e. the expertise would exist but not in sufficient quantity to meet the contemporary challenges from a local workforce.
- Assumption 3: better prospects are envisaged, the level of education reached international standards and the training of the workforce is adapted to the challenges of development according to the needs of the country.

The industrialization process requires greater demands on energy. Conversely, the development of the energy industry constitutes a great business opportunity for foreign industries, encouraged to set up branches. As Côte d'Ivoire is a country dependent on factors of production, there is an immediate need for the processing of raw materials and agricultural products such as coffee, cocoa, palm oil, etc. which would lead to an increase in energy consumption, hence a need for modernization of infrastructure, and greater demands in terms of quality. Different scenarios are possible:

- A low industrialization rate, meaning that the destination "Côte d'Ivoire" or country's methods of seduction are not attractive enough for private investors. The reasons may vary, i.e. the property right is not guaranteed...or the political situation is not likely to inspire confidence.

- An average change in the level of industrialization with a transformation rate of agricultural raw materials between 50% and 75%. This approach assumes the implementation of serious policies but for which the result is not fully in line with expectations.
- A high industrialization rate of around 80% to 100% of the transformation of raw materials. This approach should be the result of a persistent economic policy, which encourages and favors the creation of local subsidiaries of multinationals through advantageous incentives via attractive fiscal policy and the development of infrastructure in terms of mobility, communication and energy. Local savings in the context of developing capital markets can stimulate the propensity for local private investment, etc.

Urbanization is an interesting argument for the development of countries and can influence the quality of electricity supply to consumers. Indeed, the urban development model is also an important factor in the evolution of the quality of the supply knowing that the electrical energy decreases in intensity with the distance. The higher the urbanization process is, the better it is. In 1960, the ratio of rural to urban population was 3 for 1. In 2010, this ratio rose to 1.07 for 1, therefore 48.37% of the population living in urban areas, i.e. 51.63% in rurality. In 2019, according to World Bank data (World Development Indicators), 51.2% of the population lived in urban areas. Urban development is accompanied by an increase in energy demand, therefore, urban development will have to be done in a controlled and planned manner. The lifestyle and the increasing concentration of the population in large cities influence energy consumption patterns and could promote changes from one form of energy to another and in terms of technological solutions. This means that the evolution of infrastructure would follow these changes. Urban development can be strong, medium or weak, with a concentration of population around urban centers:

- Case 1: the urbanization rate continues from an irrational perspective and objectives without a respected urbanization plan.
- Case 2: this scenario considers an increasing number of urban areas by considerably reducing the rural population. The approach assumes being able to provide a minimum public service, including free access to electricity, such as public lighting.
- Case 3: this eventuality imagines a total urbanization rate of one hundred percent respecting the minimum planning standards with the preliminary economic and administrative infrastructures and a balance between the vertical and lateral extension of cities.

Simplistic assumptions about changes in the structure of electricity supply and demand can be suggested. Thus, with regard to the evolution of production capacities and the size of the network, the following cases can be formulated:

- Case 1 would reflect an investment slowdown in production infrastructure which may be explained by economic difficulties and then by a modest contribution of the country in the development of infrastructure and a lack of private investment, especially in FDI. Many factors can explain this hypothesis, such as political instability, resulting in the postponement of investments, an unsatisfactory agreement for the investor, a grid in poor condition …

- Case 2 would aim moderate estimates of the production capacity linked to limited investments (including in renewable energies). Probably, an effort of maintenance or even rejuvenation should be done, the perpetuation of the current efforts and the execution of the planned projects, as well as the major investments required.
- Case 3 would describe a strong evolution of production capacities, including the development of renewable energies, associated with the improvement and development of transmission and distribution facilities, a more efficient network, largely buried, investments in smart technologies, etc. This situation should have an impact on prices and is concomitant with an increase in consumption per capita (more services, more industries, etc.). This assumption suggests that challenges related to the quality of electricity such as obsolescence of infrastructure, blackouts etc. need to be resolved as soon as possible and the mini-grids management system improved.

Population density is also an important factor for population coverage, network deployment efficiency and scale effect. Several factors must be taken into account in the analysis, including the evolution of housing costs, the deployment of administration and services, or the development of new large urban centers, such as the effectiveness of the transfer of the capital in Yamoussoukro, a town located in the center of Côte d'Ivoire (as well as the grouping of villages or campsites). Indeed, the relocation of institutional infrastructures (ministerial departments or administrations), from the economic capital (Abidjan) to the political one (Yamoussoukro), has a significant impact on the economic and political dynamics. Thus, the coming years could see a slight increase of population density in Abidjan and in large urban centers, but remain stable in the small towns which now have better infrastructure and employment opportunities. Demographic dynamics are accentuating the pressure on electricity demand, which poses financing problems for the electricity sector and opens up prospects for the promotion of energy efficiency and the development of non-hydraulic renewable energies, in complementing what is traditional energies (thermal and hydraulic). The strong demographic growth is driven by a relatively high fertility rate estimated at 4.9 children per woman in 2017 and a significant migration of populations from the West African region which represents more than 24.2% of the total population, according to the outcomes from the General Census of Population and Dwellings (INS, 2014).

Regulation framework (regional and national) has an impact on the attractiveness of investments depending on the probability of occurrence of the evolution assumptions (macroeconomic environment, organization of the sector, level of tariffs). The regulation variables are generally organizational (linked to the structuring of the transmission and distribution activity) or economic.

The regulator and the government will provide the necessary incentives to the operator to encourage investment in better quality electricity. In addition, network infrastructures can remain State property which remunerates the service of the operator. The investment decision becomes more complex because it will take into account political factors...In this case, the government bears investment risks and sometimes uses the loan. In addition, the ownership or organization of electricity transmission and distribution may fall under a national or local monopoly (local authority). Therefore, several options are possible:

- The State takes over or modifies the structuring of the sector following insufficient performance in terms of quality;
- Regional commitments require a national restructuring of the sector;
- No major change.

Composition and pricing structure

- Pricing options:
  - Maintaining the regulated tariff and definition of a regulatory review period;
  - Conservation of the current tariff regulation model with the possibility for the government to revise tariffs if necessary;
  - Questioning of the current approach for various reasons, mainly political or ideological.
- Composition of the tariff:
  - Introduction of an additional tax to take into account externalities such as environmental impacts (for example, CO_2) in order to respect international commitments;
  - Status quo on the billing model and taxation;
  - Changes in billing choices based on customer category or social reference for social justice reasons.

Financial assumption:

- Strong attractiveness of capital due to the development of the financial market; a low discount rate, a favorable security index, political stability, an attractive interest rate;
- Medium attractiveness despite political stability and growth, but with a persistent relative fear for various reasons, attractiveness of capital mainly dependent on investor confidence and guarantees provided by the State;
- Low attractiveness inherited from fears of instability and political crises; anxious players; high corruption, etc.

5.7. Example of Business Opportunity

Like many developing countries, demand prospects from the Ivorian market are very interesting for private investors detecting business opportunities. Indeed, access to electricity is not 100%, it is necessary to distinguish the need for electrical energy from the effective demand. This context is accentuated by requirements related to the fight against climate change.

Table 12 illustrates business opportunities that may arise from socio-economic and environmental context, as well as geographical context of the area. In addition to the traditional activities of production, transport, maintenance, etc., other activities are likely to emerge or develop. These activities can be regulated or deregulated, and concern different places (rurality, cities, national, etc.). The analysis must take into account technological developments and their necessity, therefore their adoption by consumers. Similarly, it is necessary to dwell on the rapidity of growing needs in terms of production, energy transit, etc. to meet demand.

Different scenarios are possible with regard to profitability as illustrated by the example in **Table 13**[5] based on technological penetration and geographical

Table 12. Examples of business opportunities in the electricity sector.

Classical activities	New activities/New jobs	Activitiy types	Geographical context
Production	Congestion management	Regulated	
Distribution and Transmission	Storage unit management	Regulated or Deregulated	Rurality
Metering	Management of fleet of Electric vehicles	Regulated or Deregulated	Big cities
Maintenance Extension	Advisory activities Energy audit	Deregulated Regulated	National or international
Troubleshooting and Commissioning	Local dispatching of intermittent production	Regulated	

Source: author.

Table 13. Optimum technological choice adapted to the socio-economic and geographical context (source: author, inspired by Andaluz-Alcazar (2013)).

Scénarios	*Perimeter/ geographical context*			
Scenario with adapted technology (mature) [low profitability]	*Rural area*	*Citiy*	*Big City*	*Métropolis*
-Energy efficiency	## ##	##	##	##
-Decentralized Generation	##	## ##	## ##	## ##
Scenario with selective technologies [Average profitability]	*Rural area*	*Citiy*	*Big City*	*Métropolis*
-Energy Efficiency	## ## ##	## ## ##	## ##	## ##
-Decentralized Generation	## ##	## ## ##	## ## ##	## ## ##
Scenario with widespread deployment of selective technologies [high profitability]	*Rural area*	*Citiy*	*Big City*	*Métropolis*
-Energy Efficiency	## ##	##	##	##
-Decentralized Generation	##	##	##	##

[5]The increase in the number of "#" reflects increasingly strong State intervention for technological development (deployment). The fewer the "#", the higher the potential for development without special intervention from the regulator.

context. The information contained therein does not reflect an absolute appreciation. It shows how far State intervention might be required for technology deployment.

New technologies are of a structuring nature. Indeed, the adoption of a technology depends on the socio-economic factors of the populations (income, level of education, services, inhabitants of upscale or precarious neighborhoods, etc.), housing type (rental, private residence, …) and the diversity of the geographical context (large cities, rurality, etc.). Technologies are mature when they do exist for "a long time". If they are supposed to be widely disclosed, it is not inappropriate to consider them as being of low profitability. The intermediate approach suggests adapting the technology to the "type of consumer according to the above-mentioned criteria". The scenario with high profitability for the investor considers newer, more efficient technologies, therefore supposed to present a higher level of profit. According to Arthur (1988, 1989), the adoption of a technology depends, among other things, on *learning by use*, describing that, the increasing use of a technology favors its subsequent diffusion and its improvement; *informational increasing returns*, because the more a technology is known, the more it is used for detection; and *interrelations* between technologies to express the need for technologies to be compatible and therefore communicate with each other.

6. Conclusion

Through this article, it was about assuming the economic outlook in terms of opportunities for investment vis-à-vis electricity demand outlook. Thus, the approach adopted proposed an analysis of the private investor's attitude vis-à-vis risks and uncertainties. It presented the different possibilities in the cooperation between the investor and the regulator. The analysis shows that the attitude of the regulator in the adoption and implementation of the announced economic regulation decisions helps the private investor to minimize external uncertainties and influences his choice to enter or not, or to invest more in the power sector. Indeed, the decision to invest depends on the economic, institutional, regulatory and social environment. This observation is consistent with those of Riccardi (2009) and Andaluz-Alcazar (2013) regarding the criteria of interest for the investor. As proved by Easterly & Levine (2001), the relatively limited level of private investment indicates that, in addition to factors related to political stability and corruption, the economic profile of Côte d'Ivoire, like developing countries, given the low level of the income per capita, makes the return-on-investment low. The institutional and regulatory framework includes, inter alia, national legislation, technical and commercial standards, harmonized rules, and the promotion and protection of investments.

It is about improving production capacities and the quality of grid infrastructures (largely aging). Thus, the prospective analysis shows how well future demand level in terms of perspectives can be attractive for investors even though technologies that will be implemented will depends on many parameters such as the purchasing power, tariff level and subsidies, eventually. It is admitted that increasing production capacity is a priority for action that may require structural transformation. The empirical analysis which used the VECM approach confirms long run effect of population and GDP on electricity consumption. The planning process should orient the energy mix towards a progressively more diversified and balanced set of energy sources adapted to the country's resources and future needs, by taking into account the technical and economic specificities, and environmental and social impacts of the different technologies. Obviously, primary resources of fossil origin will continue to play an important role in the production of electricity. However, production from renewable sources can, in this context of strong increase in demand, be a significant contribution. This is why the prospective analysis seems to be an interesting approach that can help the decision-makers to orient policies and put forward arguments in order to attract private investors.

According to UNCDF (2018), creating an environment conducive to private investment to accelerate the transition to sustainable energy would amount to putting in place equal and transparent competition rules, building capacities for project preparation, technical assistance and service provision as a means of unlocking investment. This should not be without the risk management culture and controlling the various incentives throughout the energy value chain. This point of view is shared by the BAD (2008) recalling the urgency of facing the growing demand by accentuating the development of clean energies and capacity building. Also, an appropriate regulatory framework dealing with pricing in order to improve performance in terms of quality and attract investment seems to be a major concern. In Côte d'Ivoire, the 2014 Electricity Law and various decrees adopted in 2016 give more independence to the regulation agency (and other public players), allowing it to carry out its task more efficiently.

Moreover, in addition to improving the performance of the grid, at the same time, the production capacity should be able to meet demand and congestion should be reduced for the benefit of consumers, although they are not necessarily very enthusiastic about supporting necessary investments via the price level. Regulator's contribution should consist in defining an adapted quality-cost model, capable of supporting production capacities and grid deployment while improving the performance of the existing infrastructures. To this end, it seems essential to set up technical, economic and financial databases in order to help measure achieved progress.

Finally, the debate continues as to the equalization of prices (as a measure of solidarity) and setting rules for defining tariffs that bear the *cost of service* obligations insofar as the cost of producing electricity differ from renewable to thermal sources. In addition, the low purchasing power of populations, mainly in rural areas, justifies the establishment of subsidies or *take-or-pay* contracts to support investments. Furthermore, the societal context is an important aspect that must be taken into account in the deployment of the project. Indeed, the populations are concerned about the progress of projects, in terms of affected assets (plantations, land, etc.), compensation mechanisms and results. Interactions with these populations are necessary for the acceptability of projects. Disputes can be resolved amicably between the population and the project promoters, or by an administrative or judicial mechanism in cases where the compensation would not be satisfactory.

Since the prospective analysis proposed in this study in suggesting an analytical framework, future research should consist of a quantitative approach in order to estimate impacts considering different assumptions and paths. Also, as suggested by CNUCED (2017) the development of renewable energies by encouraging investment and setting up regulatory framework in other to promote them.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Alawin, M., Al-Hamdi, & Alomeri, M. (2016). Determinants of Electricity Demand in Jordan. *Iranian Journal of Science and Technology, 9,* 1-7. https://doi.org/10.17485/ijst/2016/v9i15/88578

Alter, N., & Syed, S. H. (2011). An Empirical Analysis of Electricity Demand in Pakistan. *International Journal of Energy Economics and Policy, 1,* 116-139.

ANARE-CI (2019). *Rapport d'Activité.* https://anare.ci/documents/rapports-dactivites/

Andaluz-Alcazar, A. (2013). *Choix d'investissement sous incertitude des gestionnaires des réseaux de distribution (GRD) en Europe à l'horizon 2030.* Thèse de Doctorat, HAL—Economies and Finances.

Arthur, W. B. (1988). Competing Technologies: An Overview. In G. Dosi et al. (eds.), *Technical Change and Economic Theory* (pp. 590-607). Pinter Publishers.

Arthur, W. B. (1989). Competing Technologies, Increasing Returns, and Lock-In by Historical Events. *The Economic Journal, 99,* 116-131. https://doi.org/10.2307/2234208

Asquer, A. (2014). Explaining Partial Privatization of Public Service Provision: The Emergence of Mixed Ownership Water Firms in Italy (1994-2009). *Annals of Public and Cooperative Economics, 85,* 11-30. https://doi.org/10.1111/apce.12027

Averch, H., & Johnson, L. L. (1962). Behaviour of the Firm under Regulatory Constraint. *American Economic Review, 52,* 1059-1069. https://doi.org/10.7249/P2488-1

BAD (2008). *Cadre d'Investissement dans l'Energie Propre en Afrique: Rôle du Groupe de la Banque Africaine de Développement.* Tunis.

BM (Banque Mondiale) (2017). *Connections: Partenariats Public-Privé dans le Secteur du Transport d'électricité en Afrique.* Washington DC.

Bougrain, F., Carassus, J., & Prout, M. C. (2005). *Partenariat public-privé et bâtiment en Europe, quels enseignements pour la France? Retour d'expériences du Royaume-Uni, d'Italie, du Danemark et de France.* Presse de l'école nationale des ponts et chaussées.

Bruneau, C., & De Bandt, O. (1999). La modélisation VAR structurel: Application à la Politique Monétaire en France. *Economie et Prévision, 137,* 67-94.

https://doi.org/10.3406/ecop.1999.5948

Bruneau, C., & Jondeau, E. (1999). Long-Run Causality, with Application to International Links between Long-Term Interest Rates. *Oxford Bulletin of Economics and Statistics, 61,* 545-568. https://doi.org/10.1111/1468-0084.00143

CI-ENERGIES (2014). *Plan Directeur des ouvrages de Production et de Transport d'Energie Electrique de la Côte d'Ivoire Pour la Période 2014-2030.* https://rise.esmap.org/data/files/library/c%C3%B4te-d'ivoire/RE/RE_8_2Plan%20Directeur%20Production%20et%20transport%20Energie-Resume.pdf

CI-ENERGIES (2019). *Diagnostic du Secteur de l'Energie en Côte d'Ivoire—Rapport Final de l'Etude de collecte des Données relatives au Secteur de l'Energie Electrique*. Rapport Final.

CNUCED (2017). *Rapport 2017 sur les Pays les Moins Avancés: L'Accès à l'Energie comme Vecteur de Transformation*. United Nations. https://unctad.org/system/files/official-document/ldcr2017_fr.pdf

Delmon, J. (2010). *Partenariats Public-Privé dans le Secteur des Infrastructures—Guide Pratique à l'attention des décideurs Publics*. The World Bank. https://documents1.worldbank.org/curated/en/826081468188357079/pdf/99115-WP-FRENCH-Box393188B-PUBLIC-Delmon-PPPsecteurinfrastructures-French.pdf

Deniau, G., Fiori, G., & Mathis, A. (1992). Sélection du Nombre de Retards dans un modèle VAR, Conséquences éventuelles du Choix des Critères. *Économie et Prévision, 106,* 61-69. https://doi.org/10.3406/ecop.1992.5315

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of the American Statistical Association, 74,* 427-431. https://doi.org/10.1080/01621459.1979.10482531

Dickey, D. A., & Fuller, W. A. (1981). Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. *Econometrica, 49,* 1057-1072. https://doi.org/10.2307/1912517

Dilaver, Z., & Hunt, C. (2011). Turkish Aggregate Electricity Demand: An Outlook to 2020. *Energy, 36,* 6686-6696. https://doi.org/10.1016/j.energy.2011.07.043

Easterly, W., & Levine, R. (2001). It's Not Factor Accumulation: Stylized Facts and Growth Models. *The World Bank Economic Review, 15,* 177-219. http://www.jstor.org/stable/3990260 https://doi.org/10.1093/wber/15.2.177

Ekpo, U., Chuku, C., & Effiong, E. (2011). The Dynamics of Electricity Demand and Consumption in Nigeria: Application of the Bounds Testing Approach. *Current Research Journal of Economic Theory, 3,* 43-52.

Engle, R. F., & Granger, C. W. J. (1987). Cointegration and Error Correction Representation: Estimation and Testing. *Econometrica, 55,* 251-276. https://doi.org/10.2307/1913236

Filippini, M., & Pachauri, S. (2004). Elasticities of Electricity Demand in Urban Indian Households. *Energy Policy, 32,* 429-436. https://doi.org/10.1016/S0301-4215(02)00314-2

Fonds Monétaire International (FMI) (2008). *Etudes Economiques et Financières—Perspectives Economiques Régionales: Afrique Sub-Saharienne*.

Fuller, W. A. (1976). *Introduction to Statistical Time Series* (1st ed.). Wiley.

Fuller, W. A. (1996). *Introduction to Statistical Time Series* (2nd ed.). Wiley. https://doi.org/10.1002/9780470316917

Godet, M., & Roubelat, F. (2003). Creating the Future: The Uses and Misuses of Scenarios. *Long Range Planning, 29,* 164-171. https://doi.org/10.1016/0024-6301(96)00004-0

Gossé, J.-B., & Guillaumin, C. A. (2011). *Sims et la représentation VAR*. CEPN Working Papers hal 00642920. Centre d'Economie de l'université de Paris Nord (CEPN) Working Papers.

Granger, C. W. (1969). Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica, 37,* 424-438. https://doi.org/10.2307/1912791

Granger, C. W. J., & Newbold, P. (1974). Spurious Regression in Econometrics. *Journal of Econometrics, 2,* 111-120. https://doi.org/10.1016/0304-4076(74)90034-7

Halicioglu, F. (2007). Residential Electricity Demand Dynamics in Turkey. *Energy Economics, 29,* 199-210. https://doi.org/10.1016/j.eneco.2006.11.007

Hamilton, J. (1994). *Time Series Analysis*. Princeton University Press. https://doi.org/10.1515/9780691218632

Hawkins, D. G. (1973). On the Investigation of Alternative Regressions by Principal Component Analysis. *Applied Statistics, 22,* 275-286. https://doi.org/10.2307/2346776

IAEA (International Atomic Energy Agency) (2009). *IAEA Tools and Methodologies for Energy Systems Planning and Nuclear Energy System Assessments*. Vienna.

Inglesi, R. & Pouris, A. (2016). On the Causality and Determinants of Energy and Electricity Demand in South Africa: a Review. *Energy Sources, Part B: Economics, Planning, and Policy, 11,* 626-636. https://doi.org/10.1080/15567249.2013.801536

Inglesi, R. (2010). Aggregate Electricity Demand in South Africa: Conditional Forecasts to 2030. *Applied Energy, 87,* 197-204. https://doi.org/10.1016/j.apenergy.2009.08.017

INS (2014). *Recensement Général de la Population et de l'Habitat*.

Iossa, E., & Martimort, D. (2012). Risk Allocation and the Costs and Benefits of Public-Private Partnerships. *The RAND Journal of Economics, 43,* 442-474. https://doi.org/10.1111/j.1756-2171.2012.00181.x

Issa, K., & Bataineh, K. (2010). The Determinants of Demand for Electricity: The Case of Jordan (1979-2008). *Arab Economic Researches Journal, 17,* 13-21. http://www.caus.org.lb/PDF/EmagazineArticles/economics_51_13-22%20khalid%20issa.pdf

Jamil, F., & Ahmad, E. (2010). The Relationship between Electricity Consumption, Electricity Prices and GDP in Pakistan. *Energy Policy, 38,* 6016-6025. https://doi.org/10.1016/j.enpol.2010.05.057

Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegrating Vectors in Gaussian Vector Autoregressive Models. *Econometrica, 59,* 1551-1580. https://doi.org/10.2307/2938278

Johansen, S., & Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration—With Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics, 52,* 169-210. https://doi.org/10.1111/j.1468-0084.1990.mp52002003.x

Jones, R. V., Fuertes, A., & Lomas, K. J. (2015). The Socio-Economic, Dwelling and Appliance Related Factors Affecting Electricity Consumption in Domestic Buildings. *Renewable and Sustainable Energy Reviews, 43,* 901-917. https://doi.org/10.1016/j.rser.2014.11.084

Kavousian, A., Rajagopal, R., & Fischer, M. (2013). Determinants of Residential Electricity Consumption: Using Smart Meter Data to Examine the Effect of Climate, Building Characteristics, Appliance Stock, and Occupants' Behavior. *Energy, 55,* 184-194. https://doi.org/10.1016/j.energy.2013.03.086

Kearney, A. T. (2011). *The A. T. Kearney Strategy Chessboard—A Broader Perspective on Strategy Development and Formulation.* ATK.0311.167.

Khan, M., & Qayyum, A. (2009). The Demand for Electricity in Pakistan. *The OPEC Energy Review, 33,* 70-96. https://doi.org/10.1111/j.1753-0237.2009.00158.x

Khanna, M., & Rao, D. N. (2009). Supply and Demand of Electricity in the Developing World. *Annual Review of Resource Economics, 1,* 567-596. https://doi.org/10.1146/annurev.resource.050708.144230

Kumarasinghe, P. J., & Gunathilake, D. K. P. U. (2010). Correlation between Long-Run Electricity Demand and Its Determinants: The Case of Sri Lanka. *Journal of Business and Economics Research, 13,* 123-134.

Lardic, S., & Mignon, V. (2002). *Econométrie des séries temporelles macroéconomiques et financières*. Economica.

Latif, E. (2015). A Panel Data Analysis of the Demand for Electricity in Canada. *Economic Papers, 34,* 192-205. https://doi.org/10.1111/1759-3441.12103

Maddala, G. S., & Kim, I. M. (1998). *Unit Roots, Cointegration, and Structural Change*. Cambridge University Press. https://doi.org/10.1017/CBO9780511751974

Mariwah, S., Kendie, S. B., & Dei, A. L. (2010). Residents' Perception of the Solid Waste Problem in the Shama-Ahanta-East Metropolitan Area, Ghana. *Oguaa Journal of Social Sciences, 5,* 21-43.

Mazouz, B. (2009). Les Aspects Pratiques de Partenariats Public-Privé de la Rhétorique Néolibérale aux Enjeux, Défis et Risques de Gestion des PPP. *Revue Française d'Administration Publique, No. 130,* 215-232. https://doi.org/10.3917/rfap.130.0215

Mazouz, B., & Leclerc, J. (2008). *Gestion intégrée par résultats: Concevoir et gérer autrement la performance dans l'Administration Publique*. PUQ—Presse de l'Université du Québec. https://doi.org/10.2307/j.ctv18pgkzv

Muzenda, D. (2009). *Increasing Private Investment in African Energy Infrastructure*. Ministerial and Expert Roundtable, NEPAD-OECD Africa Investment Initiative.

Ndiaye, D., & Gabriel, K. (2011). Principal Component Analysis of the Electricity Consumption in Residential Dwellings. *Energy and Buildings, 43,* 446-453. https://doi.org/10.1016/j.enbuild.2010.10.008

Ngutsav, A., & Aor, R. (2014). Analysis of Determinants of Electricity Consumption in Nigeria. *The Nigerian Journal for Energy and Environmental Economics, 6*. https://uchenwogwugwu.wordpress.com/2014/11/22/analysis-of-determinants-of-electricity-consumption-in-nigeria/

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Economics, 16,* 289-326. https://doi.org/10.1002/jae.616

Phillips, P. C. (1987). Time Series Regression with a Unit Root. *Econometrica, 55,* 277-301. http://www.jstor.org https://doi.org/10.2307/1913237

Phillips, P. C., & Perron, P. (1988). Testing for a Unit Root in Time Series Regression. *Biometrika, 75,* 335-345. https://doi.org/10.1093/biomet/75.2.335

Riccardi, D. (2009). *L'impact de la Régulation Economique sur l'Entrée d'un Investisseur Privé dans une Industrie de Réseau: Application aux Services Européens de Communication Mobile*. Thèse de Doctorat, HEC PARIS.

Sagan, M., & De Muison, G. (2008). *La régulation incitative appliquée au transport de l'électricité: Théorie et application au Royaume-Uni, en Espagne, en Belgique, en Norvège* *et en Italie. Pratique et positionnement de la régulation en France*. Microeconomix.

Salambéré, J. P. (2019). Le Recours au Partenariat Public Privé (PPP) par une Collectivité Locale: Le cas de la gare routière de Koudougou au Burkina Faso. *International Development Policy, Revue Internationale de Politique de Développement, 11*. http://journals.openedition.org/poldev/3144

Sanquist, T. F., Orr, H., Shui, B., & Bittner, A. C. (2012). Lifestyle Factors in U.S. Residential Electricity Consumption. *Energy Policy, 42,* 354-364. https://doi.org/10.1016/j.enpol.2011.11.092

Savas, E. S. (2000). *Privatisation and Public-Private Partnerships*. Chatham House

Scholz, J. (1991). Cooperative Regulatory Enforcement and the Politics of Administrative Effectiveness. *American Political Science Review, 85,* 115-136. https://doi.org/10.2307/1962881

Scott, A. (2015). *Building Electricity Supplies in Africa for Growth and Universal Access*. Background paper for Power, People, Planet: Seizing Africa's Energy and Climate Opportunities. New Climate Economy, London and Washington DC. http://newclimateeconomy.report/misc/working-papers

Sims, C. A. (1980). Macroeconomics and Reality. *Econometrica, 48,* 1-48. https://doi.org/10.2307/1912017

Taale, F., & Kyeremeh, C. (2015). *Households' Willingness to Pay for Reliable Electricity Services in Ghana*. MPRA Paper No. 65780. http://mpra.ub.uni-muenchen.de/65780/

Taha, H. A. (1992). *Operational Research: An Introduction* (5th ed.). Maxwell Macmillan International Edition.

Tehero, R., & Aka, B. E. (2020). Drivers of the Quality of Electricity Supply. *International Journal of Energy Economics and Policy, 10,* 183-195. https://doi.org/10.32479/ijeep.9378

Tewathia, N. (2014). Determinants of the Household Electricity Consumption: A Case Study of Delhi. *International Journal of Energy Economics and Policy, 4,* 337-348.

Trotter, P. A., Mcmanus, M. C., & Maconachie, R. (2017). Electricity Planning and Implementation in Sub-Saharan Africa: A Systematic Review. *Renewable and Sustainable Energy Reviews, 74,* 1189-1209. https://doi.org/10.1016/j.rser.2017.03.001

Ubani, O. (2013). Determinants of the Dynamics of Electricity Consumption in Nigeria. *OPEC Energy Review, 37,* 149-161. https://doi.org/10.1111/opec.12004

Udo, E. N., Chuku, A. C., & Ekpeno, L. E. (2011). The Dynamics of Electricity Demand and Consumption in Nigeria: Application of the Bounds Testing Approach. *Current Research Journal of Economic Theory, 3,* 43-52.

UNCDF (2018). *Les Financements Mixtes dans les Pays les Moins Avancés*. https://www.uncdf.org/admin/editors/ArticleItem/Index/4220?culture=fr&articleTitle=blended-finance-in-ldcs-report

Wiesmann, D., Lima Azevedo, I., Ferrão, P., & Fernández, J. E. (2011). Residential Electricity Consumption in Portugal: Findings from Top-Down and Bottom-Up Models. *Energy Policy, 39,* 2772-2779. https://doi.org/10.1016/j.enpol.2011.02.047

Yeboah, A. S., Ohene, M., & Wereko, T. B. (2013). Determinants of Energy Consumption: A Review. *International Journal of Management Sciences, 1,* 482-487.

Zaman, M., Shaheen, F., Haider, A., & Qamar, S. (2015). Examining Relationship between Electricity Consumption and Its Major Determinants in Pakistan. *International Journal of Energy Economics and Policy, 5,* 998-1009.

Appendix

Table A1. Consumption forecasts according to the econometric model carried out.

Year	*ln* (*electricity consumption*)	*Confidence interval* [95%]	
		Lower bound	*Upper bound*
2021	16.178467	16.105116	16.251819
2022	16.237458	16.129626	16.34529
2023	16.297551	16.152817	16.442286
2024	16.355359	16.172766	16.537951
2025	16.41082	16.197727	16.623913
2026	16.465729	16.226961	16.704498
2027	16.520401	16.257817	16.782985
2028	16.574667	16.290623	16.858711
2029	16.629081	16.326219	16.931942
2030	16.684203	16.364282	17.004124
2031	16.740119	16.404261	17.075977
2032	16.796822	16.44601	17.147634
2033	16.854363	16.489377	17.21935
2034	16.91268	16.533971	17.291389
2035	16.971583	16.579385	17.363782