Tehero, Remy; Aka, Emmanuel Brou

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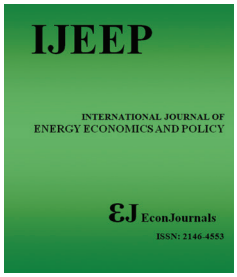

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Drivers of the Quality of Electricity Supply

Remy Tehero*, Emmanuel Brou Aka

[1]Department of Economics, Felix Houphouët Boigny University, Côte d'Ivoire. *Email: tehero_remy@yahoo.fr

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ABSTRACT

Although electricity quality is an important input for development and growth, the literature about its determinants quality is scarce. Therefore, this article is the first proposing a cross-country analysis identifying the determinants of the quality of electricity supply at a global level. In this analysis, 138 countries at different development stages have been considered and data are sourced in the Global Competitiveness Report (2016-2017), Worldwide Governance Indicators (WGI) and the World Development Indicators (WDI). The Findings confirm the importance of institutional infrastructures such as regulation quality, government effectiveness and rule of law, but also other parameters such as, Foreign Direct Investment and Technology Transfer, Availability of Latest Technology, the income of the population (gdp per capita) and the quality of the workforce (quality of education). The coherence of this empirical result is confirmed by the performances of developing countries which are lower than those of developed countries.

Keywords: Electricity Quality, Institutions, Investment, Technology
JEL Classifications: O30, Q40, Q48

1. INTRODUCTION

Energy has always been a major input of economic dynamic of countries particularly because major processes rely on it. According to the BP Energy Outlook (2017:p7), two-third of the increase of consumed energy is related to the power sector. Indeed, electricity is the form of energy which has the highest growth rate and it will account for 40% of the additional final energy by 2040 (IEA, 2017). Also, developing countries should play a key role in the demand of global energy beyond 2035. It is an important product of people daily activities i.e. cooking, communication, security and transportation (electric vehicle) without forgetting education. It should be noted that impacts of its disturbances for customers may be immediate or not, and the effects may be mechanical and financial. In general, impacts of power outages are in reality underestimated due to the systemic effect. Furthermore, according to the Emerging Market Private Equity Association (EMPEA, 2015), the increasing demand of household and firms in a context of insufficient infrastructures is requiring heavy investments. This is also an important point since in many countries, power infrastructures are facing aging and they are not performing well in term of quality.

Despite its importance, the literature about determinants of electricity quality supply is scarce. Therefore, this paper aims at presenting an analysis of the quality of electricity supply based on the World Competitiveness Report 2016-2017, and concerning 138 countries at different development stages at the image of the empirical study proposed by Boolaky et al. (2013). It analyses relative impact of institutional, economic and training infrastructures by exploring determinant factors of the quality of electricity supply and focusing strategic drivers for improving the efficiency of the sector. The question of interest can be formulated as follow:

"What are the Determinants of the Quality of Electricity Supply?"

In addition, this paper will highlight the place of investment for improving power infrastructure quality. Indeed, the paradigm

adopted by the government of Côte d'Ivoire is suggesting attracting private investments for developing the sector, proposing efficient regulatory environment and an innovative inclusive policy. In 2012 as in 1990, the Ivorian government intended significant institutional and legal reforms to attract private investments to accompany the country in its objective of becoming sub-Saharan locomotive of power energy market by 2030 (Shearman and Sterling, 2012).

Data used for empirical analysis are extracted from World Development Indicators (WDI), Worldwide Governance Indicator (WGI) and the Global Competitiveness Report (GCR). Also, by using Ordinary Least Squares (OLS) regression technique and correlation analysis, this analysis will put into evidence the importance of institutional infrastructures such as government effectiveness or regulation quality as well as investments, the gdp per capita or the expertise of the workforce. The possible existence of indirect effects should not affect the conclusion of this study which is supported by the economic theory.

The analysis will be structured into five steps. First, the importance of power energy which motivates this dissertation will be highlight before suggesting in a second step prior studies about determinants of electricity supply and outages. In a third step, the variables of interest and the estimation technique will be described before discussing results of econometrical estimates in a fourth step. The following discussion in the final step will establish in what extent institutional framework, workforce, investment and technology are relevant factors contributing to improve electricity quality.

2. THE NECESSITY OF HAVING A HIGH QUALITY OF ELECTRICITY SUPPLY

2.1. Power Energy is Important for Development and Growth

Electricity is an essential good, even vital, which should be accessible at an affordable price for the population. The literature about the impact of its quality on development and growth indicators is vast and a positive correlation has been proven. Authors like Chakamera and Alagidede (2018) have demonstrated a positive short and long-run effect of the quality of power infrastructures on growth. Others, like Pourbeik et al. (2006), explain that power energy outages represent a real threat for development from its economic consequences. They backed this assertion up by evoking social and political influences and describing the causes and the dynamics of blackouts. More specifically, equipment constructors, firms, household and services require a good quality of electricity supply. The high numbers of power outages or electricity rationing are examples of reliability problems in many countries.

Indeed, electricity quality problems have a direct impact on all the social categories of the population by affecting heating, communication (internet, telephone…) or even for perishable goods (Kosa et al., 2011) with consequences on health. It also implies equipment called priority receivers such as lighting, computers, and security of persons in hospitals, airports, buildings and in public services that welcome the public in general. In emergencies, a well-functioning of elevators and escalators is vital.

Although quantifying the real extent of power outages impact is difficult, peer literature has tried to assess economic consequences in some countries. As an example, according to Forkuoh and Li (2015), in Ghana, frequent electricity outages represent annual losses by many hundred thousands of US$, and it also generated extra costs related to self-generation of electricity. In addition, some organizational adjustments may become necessary (Abbas, 2016). In the same approach, Amadi et al. (2016) assessed the impact of electricity quality problems around 2.26% of the GDP in Nigeria of the year 2014. Uzorh and Nnanan (2011) defend that weak electricity quality probably remains a handicap for the development of the manufacturing sector.

According to the Department of Health (2007) the United Kingdom, infrastructure service of power energy is most important than the others since they will not be functioning without it. As an example, consequences of electricity outages for the public health system in term of surveillance, medical service functioning and emergency management can be dramatic (Kile and Skowronski, 2005). Hospitals, health centers and medical equipment i.e. dialysis treatment, as well as the preservation of many health products, require the proper functioning of electricity. In the same context, Klinger et al. (2014) propose an article analyzing the systemic impact of electricity outages in the health sector. They reported that from January 2013 to March 2013, over one million person have been affected by power outage which can comcern appointment cancellation of patients (Stamp, 2012), affect vaccination program (Fishbane and Kist, 2012), prehospital cares and reluctance to get into the hospital (Ardagh, 2012), victims of electrocution (Schmidlin, 2011), etc.

The opportunity cost of electricity outage has averaged 2% of the GDP for more than 30 African countries. This situation justifies the importance of electricity for better productivity of small and medium-sized enterprises as evoked by Doe and Asamoha (2014) while analyzing the context in Accra (Ghana). Accordingly, a better reliability of power energy has contributed to improve the productivity of firms in Ethiopia (Arlet, 2017 from Dollar et al., 2005). Since the ambition of governments is to ensure a fair and balanced development, public electricity services guarantee a fair balance between the constraints of economic development, spatial planning and solidarity.

2.2. Electricity Quality and Efficiency

The quality of the electric power depends on several players: the producer, the distributor, equipment manufacturers and the end customer. Its efficiency is a matter of strategic interest for all the players [electricity companies, operating personnel, households, industries and services, and equipment manufacturers] for many reasons such as firm competiveness, the generalization of sensitive equipment and the opening up of electricity market (Ferracci, 2001 and RTE reports).

Indeed, electricity outages may occasion losses for industries since it may affect the proper functioning of industrial processes and occasion extra charge related to opportunity cost of idle resources

(workforce, capital and land eventually). Disturbances – outages such as voltage dips, interruptions, atmospheric surges, harmonic - of electrical energy can have various consequences in terms of lack of production, quality of production, delay in delivery, etc.

The Graph 1 reflects losses in terms of sales suffered by firms for countries (or groups of selected countries) in 2016. Groups of least developed countries are facing the highest loss rates. As an example, Sub-Saharan countries have a rate of 8.26% and countries of South Asia 10.90% are facing the highest loss rates. In 2016, losses in terms of percentage of sales due to electricity outage was 9.9% in Cameroon and 9.7% in Benin, this value moved from 7.7% in 2013 to 4.3% in 2016 in Egypt.

This situation has an immediate consequence on the attitude of firms to acquire as far as possible private facilities to remediate this situation. It generates extra costs related to self-generation of electricity and organizational adjustments may become necessary (Abbas, 2016). The following table shows that owning a generator remains important for firms in developing countries. Indeed, in Sub-saharan Africa, though 28.3% of firms owned a generator, electricity constraint represented a very severe obstacle for 29% them and a major obstacle for 24.5% while in South Asia it represents a major obstacle for 38.4% of firms and a very severe obstacle for 27.3%.

The tendency of owning self-generation capacities that is indicated in Table 1 can be explained by the fact that firms become less vulnerable and have low electricity outage costs (Adenikinju, 2005).

Moreover, the end of the 20th century and the beginning of the 21st century saw the emergence of sensitive equipment such as variable speed drives, computer systems, automation, fluo-compact lighting, etc. These equipment require high-performance electrical power both in terms of supply continuity and others quality aspects (Ferracci, 2001). Any failure could result in the shutdown of the equipment and consequently an interruption of the entire chain of production or services. For instance, there are many hyper sensitive production tools in the petrochemical industry, in printing, steel, water treatment… and services whose coordination requires the greatest vigilance such as telecommunications and banks.

Finally, in the context of liberalization, quality may be perceived as a criterion of competitiveness. Thus, consumers, mainly industrialists considering production requirements pay great attention to the reliability of electric power.

2.3. Efficiency of Electrical Infrastructures

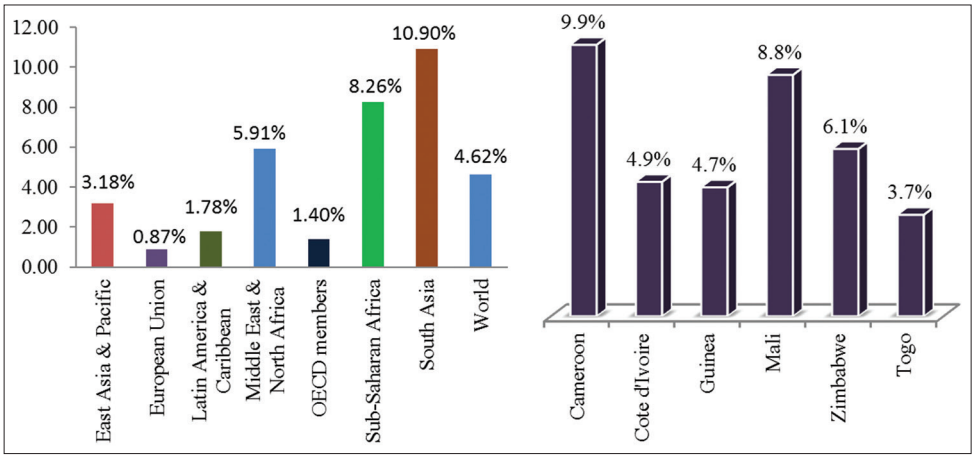
Electricity losses represent a handicap for an efficient functioning of the network in so far as it reduces the available quantity for final use. As an example, in 2010, power energy losses in developing countries varied between 11.6% and 20.7% and in 2016, OECD country was facing a transmission and distribution losses of 6.3% while that rate was 11.7% in Sub-Saharan Africa.

Examples of grid performances presented in the Graph 2 shows that in 2018, transmission and distribution losses in African countries were very high, i.e. in Côte d'Ivoire is 22.2% or Ethiopia 17.3%. However, performances of countries like Mauritius, Namibia or South Africa were relatively good.

2.3.1. Improving the reliability of electricity supply

The vulnerability of firms, services and households is related to perishable products, effects on electrical devices and sensitivity of information. As a reminder, quality remains a strategic

Graph 1: Value lost due to electrical outages (percentage of sales for affected firms) in 2016

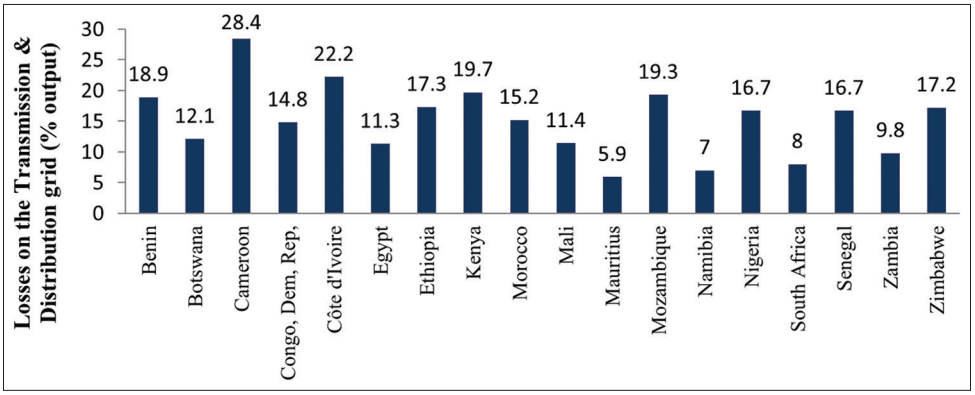


(Source WDI, 2018)

Table 1: Firm facing electricity constraint and owning a self-generator (Geginat and Ramalho, 2015)

	No obstacle (%)	Minor obstacle (%)	Moderate Obstacle (%)	Major obstacle (%)	Very severe obstacle (%)	Owning a generator (%)
Sub-saharan Africa	17.5	15.4	13.6	24.5	29.0	28.3
South Asia	8.1	9.4	16.7	38.4	27.3	33.0
Latine America and Caribean	29.7	17.9	15.0	15.2	22.3	26.1
Eastern Europe and central Asia	39.4	14.9	12.0	14.9	18.8	6.9
East Asia and Pacific	20.7	24.0	14.9	14.4	5.9	23.1

Graph 2: Transmission and distribution losses in African countries (GCR, 2018)



performance indicator which is improved by technical progress, allowing detection and control of system faults. The impact on the number of minutes of interruptions can be significantly reduced as well as losses on the grid.

2.3.2. Cost-effectiveness of electricity

Electricity cost structure is highly dependent on energy mix. Also, technological progresses lead to reduce production costs. In practice, the real cost of electricity is difficult to be determined given existing subsidies and strong dependence on raw material. This configuration presupposes a cost-effect of raw materials on the energy bill of the countries.

In addition, tariff setting remains very important since it can influence consumer's attitude and firm's performances in developing countries (Scott and Darko, 2014). Unfortunately, the cost of power energy can affect financial statement of firm as it has been the case in South Africa and even be (partly) responsible for the closure of factories in Nigeria depending on the price-elasticity (Akuru and Okoro, 2014).

In an aim of efficiency, the economic theory is suggesting a marginal cost pricing as the path to reach the "social optimum". The cost structure of the firm and the price-elasticity of different types of consumers (residential, firms, commercial) may remain low and different or unknown. This interpretation has to be put in parallel with earlier empirical studies evoking price or income-inelasticity of electricity. In practice, marginal cost is rarely implemented for many reasons such as the existence of sunk costs (Vickrey, 1948; Léautier, 2015) or information problems (Depoorter and Ben 1999). Several other pricing approaches have been defined and in many countries, reforms are necessary. However, it is difficult to suggest tariff reforms when the quality of electricity remains low (Kojima and Trimble, 2016. p39). The cost of electricity in Africa is among the highest in the world while observed losses often represent double of the losses experienced elsewhere (IEO/AEO, 2014).

3. THE QUALITY OF POWER ENERGY SUPPLY: A RELEVANT LITERATURE

Determinants of the quality of electricity supply in its full aspects are not studied enough in the literature. Thus, the ambition of analyzing them is suggesting browsing determinants of power energy supply on the one side with the adjunction of determinants specifically identified to occasion power outages on the other side.

First of all, the literature reveals an interest of many researchers for the determinants of power energy supply. Indeed, available articles identify different types of impacting factors which can be institutional, economic, technological or depending on the state of infrastructures. One example is the study of Ubani (2013) asserting that urbanization rate, population density, distance between generation plants and consumption areas, access rate and industrialization rate have an effect on the electricity supply in Nigeria. To defend this assertion, the author used ordinary least square approach for analyzing data covering a period going from 1985 to 2005. The same methodology has been used by Ubi and Effiom (2012) analyzing the electricity supply in Nigeria from 1970 to 2009 to include technology, government funding and power losses as determinants factors of power supply. They mentioned that a significant part of the energy which was transported (40%) where lost. Still in Nigeria, Akinyemi et al. (2014), for their part, evoke the vulnerability of the power sector to climate change and use Vector Error Correction econometrics method to analyze the related effect during the period going from 1971 to 2011. These authors concluded a positive effect of climate change, quality of institutional infrastructures and the GDP per capita as positive impacting factors, and, power losses, poor technology to negatively affect electricity supply. Furthermore, the results of the study of Nababan (2016) in Indonesia put into evidence grid size, generation capacity, tariff level and investments to have an impact on the supply of energy. The author proposed a panel of available data from provinces fohr the years 2009-2014 analyzed under a fixed effect.

Secondly, the state of the grid and its efficient functionality can affect the quality of power energy supply to the end user as defended by Jufri et al. (2017). Indeed, the authors explain that the optimum functioning of the network depends on its durability and flexibility, exposure, extreme events such as exceptional weather or earthquake conditions and vulnerability. They propose different formulas to assess impacts on performances of the grid depending on the parameter of interest. The vulnerability can possibly be calculated by the "conditional cumulative probability" of the ratio of damage by the intensity of the weather condition; the exposure would be

indicating the number of exposed components and impact in the network of extreme circumstances, by multiplying the intensity of the extreme event by the grid exposure and by the network vulnerability. These authors also proposed many methods to avoid outage and improve the resilience of the grid such as underground cable, prevention of inundations, sensor technology, efficient maintenance planning management, etc. Other authors remind that a large amount of electricity generated is lost. For instance, by analyzing the context in Ghana, Kwakwa (2018) observed that at least 20% of electricity produced were lost. By using time series analysis for annual data from 1971 to 2013, this author has come to the conclusion that many factors such as income level, education, electricity price, investment, population and manufacturing have a significant effect on electricity losses. He also recommends more capital investment and public education for improving the situation.

Thirdly, the influence of weather conditions on the quality of electricity supply have been highlight by many authors. Indeed, Campbell (2012) shows that difficult weather condition i.e. rainy season, wind or storms (as the most damaging cause) with the adjunction of falling trees can explain supply interruptions to many customers by damaging the grid. The author focused on two indicators of reliability that are SAIDI and SAIFI[1] to evoke the context in some developed countries. He defends that outages related to weather conditions can be reduced and the reliability improved by implementing several approaches such as underground lines, smart technologies, and maintenance planning. In addition, the evidence from a trend analysis seems to show that outages related to weather conditions was in an ascendant phase, i.e. between 1992 and 2010 in United States. In the same vein, the methodological approach of Klinger et al. (2014) is quite original since during the three 1st months of the year 2013, they registered power outages due to weather conditions in 19 countries. They enumerated 52 power outages during that period and identified storms, cyclones, Tornado, earthquake, heavy rain, bushfire, high winds etc. as risky weather conditions.

Moreover, electricity theft[2] in addition to being an economic crime negatively affect the quality of electricity supply. Also, though the literature about this matter is undeniably vast, very few analyze such corruption in power energy sector empirically. Indeed, the theft of power energy is affecting the quality of electricity supply by occasioning many consequences such as overloading of distribution networks, damage to network equipment, burning cables, exploding transformers, melting fuses, poor quality of voltage and repetitive breakdowns. For all these reasons, Olaoluwa (2017) explains that electricity theft does not only affect equipment, but it also causes outages. The author identifies various factors at the origins of this phenomenon such as, unemployment, immoral attitude, weakness of the law and the weak billing system. In the same vein, Smith (2004) reminds that fraud on metering by bypassing normal circuit with security risks, billing irregularities or unpaid bill can affect quality of electricity and the income of the firm. By using correlation and comparative analysis, the author defends that this situation can be explained by low income of population then the price of electricity; failure of institutional framework related to government effectiveness, regulation, corruption etc. and can considerably be reduced by technical progress and stronger coercion. Furthermore, Arango and Deccache (2017) achieved simulations to analyze the impact of electricity theft on the quality of electricity, especially voltage drop, following different network configurations. They too, defend that coercive measures against fraud by setting penalties improve the quality of power energy.

Ultimately, the management of electricity reliability is a real concern for countries and new policies are encouraging or imposing the deployment of equipment with more advanced technologies to improve fault detection repairing. An evidence of new technologies proposed by Taneja (2017) analyzing the accuracy of the fault location data as well as smart meters on the resolution time of outages in Nairobi (Kenya). During 1 year starting from October, 2014 to September 2015, electricity outages have been reported by using SAIDI, SAIFI or Revenue Loss indicators, and compiled. The methodology considers outages reported by customers by phone or on social networks of customers, recorded and weekly compiled only after the fault has been resolved. The author concludes that new technology can improve electricity reliability.

4. DATA AND METHODOLOGICAL APPROACH

4.1. Data Sources and Description of Variables

The following variables described in the Table 2 are sourced in (i) the Global Competitiveness Report (GCR: 2016-2017) which is a survey conducted by the World Energy Forum, (ii) the World Development Indicators (for the year 2016), and, (iii) the last data source is the Worldwide Governance indicators (for the year2016).

The following analysis is proposed by taking into account in the descriptive analysis countries at different development stages by splitting the sample into three groups, based on the subdivision established by the Global Competitiveness Report (2016-2017, p38) :

- Groupe 1: "Factor driven countries" (FDC) with a per capita income of less than $US 2,000 as it is the case for most of west African countries such as Côte d'Ivoire with an economy based on agriculture [coffee, cocoa, oil palm and to a lesser extent oil and mineral resources], but also other countries such as Ethiopia…;
- Groupe 2: "Efficiency driven countries" (EDC) are classified at stage 2 of development and have a gdp per capita between $US 3,000 and $US 9,000 such as South-Africa;
- Groupe 3: "Innovation driven countries" (IDC) with a per capita income above US$ 17,000 is the third and last group of the analysis; [3]

1 SAIDI "system average interruption duration index" ; SAIFI "system average interruption frequency index".

2 Power energy theft includes fraud which is "meter tampering", "irregular connection", unpaid bills or other irregularities.

3 *Nota Bene*: *<<Transition economies>>* are normally classified between two consecutive stages. However, for this analysis, they will be considered as belonging to the previous stage. For instance, countries with gdp/capita between $US 2,000 and $US 3,000 such as Algeria, Azerbaijan and Gabon will be considered as factor driven economies. Idem, countries in transition between stage 2 and 3, with a gdp per capita between $US 9,000 and $US 17,000 such as Turkey and Argentina are included into efficiency driven economies. This decision seems to be the most adequate because these countries did not reach the following development stage and the economic structure does not depend only on the income per capita.

Table 2: List of variables

Variables	Meaning	Numerical values	Source
Qes	"Quality of electricity supply" as dependent variable;	From 1 for extremely unreliable to 7 for best performances;	GCR
Het	"High education and training," indicating the quality of graduated from university and training contribution to quality improvement. It demonstrates the level of development and the labor force skills and takes into account the ability for the educational system to meet economic challenges;	1 for inadequate educational system and 7 for best performances;	
fdi_tt	"Foreign direct investment and technology transfer," to appreciate the extent in which FDI is representing a canal to bring new technologies in a country;	1 for not all and 7 for a lot;	
Alt	"Availability of latest technology;"	From 1 for less available to 7 while strongly available;	
Ms	"Market size" is giving an idea of the real potential of the market in terms of access to domestic and foreign demand, which are very strategic for investors in their analysis of parameters such as economies of scale;	From 1 for weak market size to 7 when it is more attractive;	
Etii	"Effect of taxes on incentive to invest;"	From 1 when the incentive to invest is low to 7 when it contribute to a great extend;	
Elfcr	"Efficiency of Legal Framework in Challenging Regulations" provides the ability for private actors to challenge government decision and regulatory system by using legal tools;	From 1 for an extremely difficult environment and 7 for an extremely easy one;	
Bgr	"Burden of Government Regulation" that indicate how tedious regulatory requirements might be for firms ("permits, regulation, reporting");	From 1 for very heavy requirement to 7 for not at all;	
Sars	"Strengh of (financial) Auditing and Reporting Standard;"	1 for very weak and 7 for very hard;	
Ji	"Judicial institution" describes how far judicial institution might be influenced by firms, individual or government;	1 when is not independent and 7 for fully independent;	
Polstab	"Political stability" of the country including terrorism or other kinds of violence with political motivation;	(−2.5; +2.5)	WGI
Goveff	"Government effectiveness" is related from the one side, to the performance of public and civil service and their autonomy vis-à−vis political pressure; and from the other side, the government credibility to "formulate and implement" efficient policies;	(−2.5; +2.5)	
Regq	"Regulation quality" to qualify the resilience of regulation policies and the promotion of private sector;	(−2.5; +2.5)	
Rulaw	"Rule of law" is the variable which assess the confidence in the rule, police and justice to assume contracts, property rights, violences.	(−2.5; +2.5)	
Corrup_cont	"Corruption control," or the control of corruption, describes how State tools are used illegally for private purposes, by describing corruption as evoked in the theory of "capture" by "elites" and "private groups;"	(−2.5; +2.5)	
gdp_cap	GDP per capita variable which neperian logarithm (lgdp_cap)	USD ($US)	WDI

By considering this subdivision, the sample is composed of 52 counties belonging to FDC, 49 to EDC and 37 to IDC.

4.2. Hypotheses and Analytical Approach

Four main hypotheses out of five related to institutional infrastructures, investment, technology, income and education will be tested. Indeed, they are based on structural distinction between posited countries, the literature review and the availability of data as well as the expectation vis-à-vis the workforce, investments and technological concerns:

Hypothesis 1: Variables related to institutional framework, regq and goveff, bgr have a significant and positive effect on the quality of electricity supply.

Hypothesis 2: Economic variables such as the income per capita have a significant and positive effect on the quality of electricity supply.

Hypothesis 3: Technological progresses (alt) and Foreign Direct Investment and technological transfers positively affect qes.

Hypothesis 4: The quality of the workforce has a positive effect on the quality of electricity supply.

Hypothesis 5: The quality of electricity supply is lower in FDC than in EDC and IDC.

The basic model is a cross sectional data established as follow by a deterministic approach:

$y_i = c + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} + \varepsilon_i$; with $k \in N$ for country "I."

Y_i, is the endogenous variable and, $X_{i1}, X_{i2}, \ldots, X_{ik}$, are exogenous variables.

$\beta_1, \ldots, \beta_k$, are the partial regression coefficients reflecting the effect of a 1-point variation of the exogenous variable considered on the endogenous variable.

Vigilance over sources and methods of data acquisition make it possible to reduce the errors of simultaneity or redundancy between the intentions sought through the formulation of variables, whether

they are institutional or not. Thus, the correlation coefficient will be used as support in the choice of variables in order to avoid multicollinearity likely to compromise the results. Also, the use of a large number of countries should aims to minimize that risk by providing good estimators.

The cross sectional countries analysis approach is scientifically recommendable to support or contest assumptions. The required time depends on the number and the quality of the variables and the countries selected. It may defend many fields of research and be accepted to support a new theory. However, it may not be helpful to appreciate behavior over a period and the selected period might not necessarily be representative over time. Although the global competitiveness report is one of the best references in the world in terms of credibility, as mentioned by Boolaky et al. (2013), the analysis above is using secondary data. Many variables have not been defined specifically for electricity sector but are more general, i.e. based on country's potentialities. Therefore, the quality and the experience of national and international institutes in charge of collecting the data as well as the number of selected countries at different development stages are in favor of the validity of the approach.

5. RESULTS AND INTERPRETATION

The economic logic and previous empirical results will be helpful for establishing a causal analysis between variables. Also, the software of analysis is Eviews version 7.

5.1. Descriptive Analysis of the Performances of Group of Countries

The following Table 3 aims at presenting a descriptive analysis for selected variables in order to put into evidence performances of groups of countries.

Based on the results indicated in the Table 3, it is possible to defend that globally, IDC perform better than EDC and FDC. Likewise, the volatility between countries of a same group is more accentuated in FDC than in EDC and IDC.

Indeed, by considering the vector of average values (qes, reg, goveff, corrup_cont, fdi_tt, het) for performance of each group of countries, the quality of electricity supply is better in IDC (6.31, 1.36, 1.37, 1.32, 4.97, 5.46) than in EDC (4.79, 0,.8, 0.18, −0.02, 4.46, 4.38) which is better than the one in FDC (3.25, −0.59, −0.62, −0.66, 3.78, 3.41). Likewise, with an average score of 3.41 out of 7 for het variable, performances of FDC is indicating how much significant effort is needed in terms of education and training. The same observation should be done about institutional framework (−0.59 for regq and −0.62 for goveff) in this group of countries.

Like in many developing countries, the score of Côte d'Ivoire (3.6, −0.36, −0.67, −0.54, 4.5, 3.4) seems above the average value of FDC even though scores of goveff and het is indicating that the performance of the country in these particular points are lower than the average value of FDC.

Table 3: Descriptive analysis of variables

Variables	Groups of countries	Average	Min.	Max.	Standard deviation
qes	FDC	3.25	1.2	5.8	1.117
	EDC	4.79	1.7	6.2	1.01
	IDC	6.31	4.8	6.9	0.5
regq	FDC	−0.59	−2	0.59	0.48
	EDC	0.18	−1.23	1.37	0.55
	IDC	1.36	0.09	2.18	0.53
goveff	FDC	−0.62	−1.82	1.07	0.54
	EDC	0.18	−0.95	1.09	0.467
	IDC	1.37	0.21	2.21	0.50
corrup_cont	FDC	−0.66	−1.67	1.14	0.56
	EDC	−0.02	−0.97	1.32	0.559
	IDC	1.32	−0.26	2.3	0.74
fdi_tt	FDC	3.78	2.4	4.8	0.57
	EDC	4.46	3.1	6	0.54
	IDC	4.97	3.9	6.3	0.54
het	FDC	3.41	1.9	5.1	0.77
	EDC	4.38	3.3	5.3	0.49
	IDC	5.46	4.3	6.3	0.47

In many areas, electricity quality problems can be explained by many factors such as lack of maintenance and in 2015, it was representing between $50 and $80 of additional cost to the consumer by considering generation, transmission, distribution and supply pace (IEA/AEO, 2014. p41). Also, many localities in developing countries are living without electricity and many of electrified regions are experiencing aging grids without improvement programs since more than 25 years. Therefore, there is a need to take into account the issue of effective preventive maintenance and care about the overload and aging of the installation which increases the risk of breakdown.

5.2. Interesting Correlation Values

Correlation analysis is providing very meaningful information about the influence of variable as indicated in the Table 4. For instance, the correlation analysis shows high correlations between regq and many other variables that may probably be determinant and interesting for the analysis. The very high correlation coefficient of 0.93 between regq and goveff is of nature to perturb the model and lead to an inadequate interpretation due to risk of collinearity. The same remark can be done for the correlation between rulaw and goveff (0.95). This correlation value between regq and goveff is logical since regulation may appear to be a direct consequence of the "formulation" and the implementation of government policy.

From the correlation matrix can also be observed very meaningful values between qes and institutional infrastructures such as regq and goveff, which are respectively 0.81 and 0.85. The role of the government and a performant institutional framework is to impulse credible policies and sector articulation efficiency. Likewise, the relationship is good between qes and het (0.81) as well as the one between lgdp_cap and qes (0.82).

The correlation between het and qes is high (0.81). Idem, correlation is very high between the income and the educational level (0.87) since the highest is the educational level, the better is the income (salary) as well as the correlation between lgdp_cap

Table 4: Matrix of correlation between variables of the sample

	etii	fdi_tt	Qes	regq	goveff	het	ji	innovpot	lgdp_cap	rulaw	sars	ms	elfcr	bgr	alt
etii	1														
fdi_tt	0.46	1													
qes	0.35	0.70	1												
regq	0.41	0.74	0.81	1											
goveff	0.37	0.73	0.85	0.93	1										
het	0.26	0.63	0.81	0.81	0.86	1									
ji	0.48	0.65	0.65	0.74	0.78	0.62	1								
innovpot	0.34	0.66	0.68	0.76	0.80	0.74	0.75	1							
lgdp_cap	0.36	0.64	0.82	0.82	0.87	0.87	0.64	0.68	1						
rulaw	0.37	0.71	0.81	0.93	0.95	0.80	0.82	0.78	0.82	1					
sars	0.41	0.67	0.66	0.70	0.74	0.66	0.69	0.68	0.68	0.71	1				
ms	0.04	0.39	0.36	0.29	0.36	0.44	0.23	0.43	0.44	0.28	0.29	1			
elfcr	0.57	0.61	0.56	0.64	0.65	0.52	0.89	0.75	0.49	0.71	0.63	0.21	1		
bgr	0.70	0.43	0.29	0.37	0.33	0.20	0.55	0.45	0.15	0.37	0.33	−0.07	0.71	1	
alt	0.38	0.81	0.85	0.87	0.89	0.82	0.74	0.81	0.84	0.87	0.77	0.38	0.67	0.34	1

and qes (0.82). The good correlation between rulaw and qes most probably means to prevent fraud.

The results of the multivariate regression will confirm correlation results (Table 5). The basic functional model is:

qes = *F* (*elfcr*, *bgr*, *het*, *alt*, *lgdp__cap*, *fdi__tt*) or, translated from an econometric point of view by a multivariate linear equation.

Considering all countries, the results of the OLS regression are as follow:

Indeed, a further analysis by multivariate regressions shows interesting values of R^2 (0.78 and 0.76). From these models, technologies (alt), the income level (lgdp_cap) and the human resources (het) have a positive effect on qes. Likewise, as defended by Khennas (2012), they confirm that the variable het with a slope of 0.36 and 0.42 respectively in model 1 and 2 is important to maintain the high level of infrastructure quality, to plan and improve maintenance intervention as needed for developing countries, and after-sale services. The workforce variable also shows that training level can provide a high level of expertise to design or maintain a service of good quality. The goal is to be able in quality and quantity to provide human resources able to face contemporary challenges related to the balance between the supply and the demand of electricity of which there are various solutions (tele-metering, storage technologies, interconnections, the management of dispatching, erasures of clients when it is necessary) requiring high competences. Only a qualified workforce can choose the best options based on economic and environmental issues.

Furthermore, technological progresses and their availability through alt variable represent a factor that positively affects the reliability of electricity. The correlation coefficient between alt and qes is 0.85 and the slope from the model 1 is 0.76. The technology helps for an immediate detection and location of fault as well as dispatching or transactions, and environmental concern. In the same way, the model 2 shows the positive effect of fdi_tt on qes.

Table 5: Effects of variables on qes

qes	Model 1	Model 2
	Dependent variable	
Constant	−3.06 (0.00)	−1.789 (0.03)
regq		0.32 (0.02)
het	0.36 (0.00)	0.42 (0.00)
lgdp_cap	0.248 (0.01)	0.309 (0.00)
alt	0.76 (0.00)	
fdi_tt		0.418 (0.00)
elfcr	−0.07 (0.53)	
bgr	0.16 (0.19)	
	R square : 0.78	R square : 0.76
	Std of residuals: 0.72	Std of residuals: 0.749
	Sample size = 138; Fisher prob = 0.000	

P values are in parentheses

The ability of country to implement an efficient regulation has a positive effect on qes. For Poudineh et al. (2014) the existence of heterogeneity is requiring incentive regulation for encouraging innovation and (optimum) investments. Nevertheless, many economists are requiring vigilance about that "optimum" in order to avoid a risk of over-investment (Averch and Johson, 1962, Besanko and Spulber, 1992). As a reminder, the regulator is expecting in a dynamic approach of its relationship with the firm, a management effort and technical improvement, for output in quantity and quality at lowest cost as possible for consumers. The goal is to become as closer as possible of the efficiency frontier of production that reach the social optimum.

Moreover, with a slope of 0.248 in the model 1 and 0.309 in the model 2, the level of gdp per capita supports the cost of recent technologies needed to encourage research and innovation. The improvement of production and network infrastructures is requiring heavy investments which should be supported by consumers.

6. FURTHER DISCUSSION

6.1. A Strategic Role of Institutional Infrastructures

Institutional infrastructures are very important because they propose a convenient framework for the management of economic

activity sector and encourage investments. Indeed, the literature is also very detailed about the evident importance of political and legal impulsion that is necessary (Salter and Doupnik, 1992). Therefore, reforms offering an attractive and efficient framework are necessary to meet the challenge of development (AEO, 2017). Also, the economic literature highlights a link between market structure and complementarities or institutional arrangement for solving sectoral problems.

This objective of a complementarity between institutions makes the sector attractive with regard to the availability of financing. According to Saunders and Besant-Jones (1993, p14), the regulatory framework should have as basic criteria:

- Transparent and open;
- Clearly defined and understood by players;
- Reforms including tariffs must be consistent.

The analysis from the study of Hesseling and Sari (2006) in Netherlands recommending setting up ex-ante and ex-post a "q-factor" (quality factor) is very interesting. The authors are probably right when they do not envisage price regulation without affecting quality and esteem that not only output should be concern, but input and processes as much as possible. In this prospect, regulation plays a key role with environmental challenges, or as defended by Huyang and Van Hertem (2018), through tariff setting responsibility or project approval. They also underline that other factors such as raw material prices, inflation, and political risks can increase uncertainties. Zugravu (2009) is the one who underline the delicate role of regulation by evoking a positive impact but also negative on the FDI, particularly by imposing very high and inconvenient standards.

The literature about the importance of the necessary political and legal impetus is very rich (Salter and Doupnik, 1992). Poudineh and Jasmab (2013) questioned about the determinants of investment in the regulated natural monopoly of electricity network and recommended to watching out the response of the firm vis-à-vis incentive. The positive correlation between regq and fdi_tt variable is then testified by this empirical result whatever the development stages [also the bgr is singularly significant]. This point of view should absolutely include a trust in the insurance that the judicial institution and auxiliaries (police) to defend a full and fair respect of contracts and property right.

Furthermore, investments are enclosed in a dynamic game between the firm and the regulator to continuously update infrastructures to technical progress (Poudineh et al., 2014). The sars is an important indicator of the state of the financial market and remains determinant for capital mobility (Frank and Mayer, 1992). Stronger auditing dispositions and reporting standard are required as long as the capital market is becoming sophisticated (Boolaky et al., 2013).

6.2. The Necessity to Improve the Expertise of the Workforce and the Purchasing Power of Population

Despite its importance, the expertise of the workforce remain a challenge for developing countries and possible initiative should encourage the creation of high level schools or partnership between schools of different countries for experience sharing. In Côte d'Ivoire, the investment code of 2012 (Ordinance N° 2012 - 487 Of June 07, 2012 declaring The Investments Code), in its articles 23 and 26, as much as possible, encourages the investor to recruit the local workforce first and foremost. Also, in 2012, UPDEA (Union of Producers and Distributors of the Electric Power of Africa) has instigated the establishment of regional centers of excellence to counter the deficit of experts then seen in the pooled electricity market, and identified national training centers eligible to becoming regional pole of excellence (ANARÉ, 2012 : p32). Nigeria is a good example in Africa insofar as "the National Power Institute of Nigeria" has been created in 2009 to provide in quantity and quality workforce for developing the sector and enhance research centers.

These initiatives are the prolongation of Van Huffel's (2001) viewpoint defending that firms use to train their workers, or the mere advent of new technologies could lead to a need for a new design of the educational and training system. In the short and long-run thinking, the "het" variable ensure providing qualified labor force in order to innovate and use efficiently the technologies that would have been transferred and reducing risk of failure. Also, it provides the necessary expertise for regulating efficiently the sectoral market (Boolaky et al., 2013) which is a significant parameter for attracting foreign capital as testified by the correlation between sars and het variables. Michaels et al. (2001) declare in their book "The war for talents" that firms (but not only) that systematically recruit talents at all the stages of the organization are performing better. Not only that, for foreign investors engaged in the country and soliciting local expertise, it is a "good deal" which remains generally less expensive, especially in developing countries. Furthermore, the importance of the workforce explains the strategy of States for attracting and keeping talents. It is also proven that the level of education is correlated to the income level.

One of the main handicap for the development of infrastructures in many countries is the purchasing power of population. Indeed, depending on the technology, the price of one kWh of electricity varies and is generally higher for electricity produced from renewable energy than those produced by using hydrocarbons also called fossil energy, or nuclear energy. Therefore, in many cases, population in rurality and even in some urban areas cannot afford electricity by different solutions (mainly in "off-grid" context) which are generally more expensive. In addition, developing countries are facing high population growth rate and low income per capita. The empirical study of Easterly and Levine (2001) shows that the covariance between the income per capita and the Total Productivity Factor is positive. It means that the living standard and the level of wages and return on investment in physical and human capital is lower in developing countries and explains the reason why financial flows are concentrating toward developed countries.

Definitely, an important parameter would be the market size "ms" which is important because the investor is being interested by the local and foreign market which will be accessible by investing in a

country. This result is testifying the assertion defended by BCEAO (2013) pretending that the isolation of some States, the low market sizes etc. as well as the quality of infrastructures (electricity, water, telecommunication …) and legal and judicial challenges are crippling factors to foreign investment. In this consideration, regional (supra-national) market that is cleared of any barrier may surely have a positive impact.

6.3. Focus on Investment in Infrastructures and New Technologies

Investments in infrastructures are a key argument to sustaining growth and development. According to Energy Technology Perspectives 2017, the electricity sector requires coordinated long-term investment planning. Indeed, the efficiency and reliability of electrical systems will be guaranteed by the acquisition of quality infrastructure via a set of investment. Also, in the power sector, investment decision once commenced is irreversible, especially in transmission and distribution because of heavy fix costs. Therefore, uncertainties about costs or price level may become significant barrier for investors and technology deployment.

According to Bhattacharyya and Palit (2016), finding the relative investments may sometime remain the principal barrier for many African countries. Hence, the attractiveness of foreign direct investment and technology transfer seems to be an approach of high interest as long as FDI had been a significant catalyst for improving the quality of infrastructures mainly in telecommunication (following the liberalization process during the 2000's decade) and in the mining sector. This is an important and a real option for developing countries since they are not performing well in term of technical progress due to a lack of research and development means)well-equipped laboratories, universities…).

By taking the example of Africa, transmission and distribution grids are also facing aging context, and congestions. In order to face overstress and aging, the study of ETSAD and published in 2014 affirms that 40% of the planned investments around US$ 7.2 trillion for the period 2012-2035 will be allocated to the renovation of existing infrastructures and 60% to build new infrastructures (Vaillancourt, 2014). In Nigeria, an "Investment Promotion Commission" (NIPC) was created for looking and proposing an efficient business climate and assisting investors. Many developing countries are proposing tax holidays to attract investors mainly for renewable energy promotion. In general, the decision of many African countries to promote private investment is a response to attract private capital by encouraging investors who estimate the environment complex and non-advantageous due to low purchasing power compared to others economical spheres. Nevertheless, it should not be forgotten that private investor establishes his business model on constraints often varied and based on (i) the offer of service, (ii) the technological architecture, the financial structure [what cost structure for what profit?] and, (iv) organizational arrangements related to the network structure of value.

As a reminder, there are pull factors of investments which are influences from destination countries or "host country" and the push factors that are those from countries of origins or "home country" (BCEAO, 2013). On the basis of statistical analysis of empirical model, Globerman and Shapiro (1999) as well as Fitzgerald (2001) can defend that international capital are highly influenced by these pull factors which are related to average income per capita, the skill level of the workforce, fiscal incentive and the political and macroeconomic stability without forgetting the market size.

Furthermore, countries and research centers are looking for innovative methods for managing electricity reliability (Taneja, 2017). The results of this study are also consistent with the assertions of Vaillancourt (2014) defending that the technology reduces losses and outages. Many authors were assuming the same conclusion with empirical analysis using parametric or stochastic approach to justify efficiency fluctuation overtime and a necessary technical adjustment required by the firm (Emvalomatis et al., 2012). In fact, technology improvement does suggest improving the billing system and payment like the use of mobile phone or other IT approaches, environmental challenge but also encourage innovative ideas etc. Elsewhere, the positive correlation between fdi_tt and alt (0.81) reminds that fdi_tt can be a good opportunity to improve technologies used in developing countries by acquiring more performing technologies. This is the reason why in Côte d'Ivoire, the investment code of 2012 (Ordinance N° 2012 - 487 Of June 07, 2012 declaring The Investment Code), in its articles 23 and 26 encourages technological transfer.

6.4. Corruption, as a Gangrene for the Development of Infrastructures

Corruption is linked to weak governance and disturbs the economy. The most commonly used indicator is the "Corruption Perceptions Index." Ugur and Dasgupta (2011) proved a negative effect of corruption on the income of population and growth. Also, investment is the main canal by which corruption affect growth (Mauro, 1997). Defending the same conclusion after a pooled analysis of OECD countries, Jajkowicz and Drobiszová (2015) (in the continuity of Mauro [1997]) conclude the negative effect of corruption on education, then on the quality of the labor force on the long-run. As a reminder, Table 3 has shown that developing countries perform worse in terms of corruption control than developed countries.

More specifically, in the power sector, corruption can make provision more expensive and lead to the deterioration of reliability (Boamah and William, 2019). Also, vulnerability to corruption lies in different stages. First, it may imply government policy which can be influenced by special interest regarding alteration of norms, licensing criteria or favoring of highest bidders, but also inefficient procedures and Power Purchase Agreements. Second, during the project definition and implementation, corruption may affect cost estimation, duration and the viability of the project, compensation and rehabilitation of persons affected by the project, the selection or supervision of contractors as well as the performance of infrastructures. The third level is about fraud or theft of electricity, which imply consumers, billing or utility staff, bureaucrats, union leaders or others cartels, etc.

7. CONCLUSION

The quality of electricity supply is important for all economic sectors and, as far as the literature have been available until this chapter is written, this is the first study proposing an analysis at a global level by considering 138 countries at different development stages. By a heterodox approach, an important outcome of this study which is inspired from the one of Boolaky et al. (2013), by using correlation and ordinary econometrics methods testifies the positive effect of regulation quality, government effectiveness, rule of law, the quality of education, the income per capita, investments and the availability of the latest technology. Also, the positive correlation of electricity quality most probably suggest a bidirectional effect on many of these determinants. As an example, the study of Aguirre (2017) in Peru reminds that electricity reliability has a positive impact on education since children have the opportunity to spend more time on studying.

First of all, the availability of the labor force in quality and quantity is an important parameter for ensuring efficiency of capital and market even though a "capture" effect can sometime be evoked since there is a risk of influence by public or private entities. In West Africa, for example, electricity regulators reported as early as 2012, the lack of a high-level training center in quantity or even quality. Furthermore, new technologies have a positive impact on performance, but the expertise of the labor force is also required to implement that technology efficiently. It is supposing an educational level of high quality and an attractiveness of the country vis-à-vis native or foreign talents. Understandably, the quality of the workforce gives confidence to investors and it is a reason why this parameter is very important for African countries (ANARÉ, 2012). Like Poloamina and Umoh (2013), this analysis defends the gdp per capita to be a very important criterion.

Besides, Fitzgerald (2001) reminds that regulatory standards can influence operating cost, and increase standards because of technico-economic progress and socio-political pressure. To attract private investors, the performance of energy projects in developing countries in general must offset the risks involved. An incentive policy, the promotion of secured loans at affordable cost, diversified banking offers can help the development of the sector. Public authorities could strengthen their role of mediation between investors and project promoters. In a favorable context, the private sector is able to offer innovative business models, able to meet the challenges of the development of the sector. Thus, the fight against corruption should be pursued by promoting good governance and access to information.

In general, industrialized countries are capital exporters while developing and transition economies are looking for investments (Fitzgerald, 2001). Various factors such as regulatory environment, internal and external economies of scale can encourage foreign investments (Blomström, 2001 from Kindleberger, 1969). The liberalization policy initiated in the electricity sector in most countries has led to the setting up of mechanisms to attract foreign capital (foreign direct investment) but also to benefit from multinational technologies and increase the performance of local firms. However, the low level of private investments in developing countries is indicating that the structure of the power energy sector is not very attractive and many reasons can explain this statement such as the level of political stability, the corruption level, and the fact that network activity is capital intensive with increasing return to scale. Furthermore, the gdp per capita is not very attractive in many developing countries as long as the return on investment is low in a context of low income (Easterly and Levine, 2001). Hence, the regional market seems to be an interesting initiative since it increases the market size, attract investment and improve the quality of infrastructures by reducing losses in the grid and enhance generation capacities.

As a reminder, this analysis put into evidence differences between groups of countries at different development stages in terms of performances. Indeed, developed countries have better scores in terms of performance of institutional infrastructures and quality of electricity supply than less developed countries. A holistic analysis of the results recommends structural and short-term policies to deal with market pooling at regional level, training of the workforce to improve the level of expertise, or economic policies for improving the income per capita of population.

Moreover, the societal context is an important aspect that should be taken into account in project deployment. Indeed, populations are concerned about the duration of the project, in terms of assets affected, compensation arrangements and infrastructure outcomes. Interactions with these populations are necessary for the acceptability of the project. Disputes can be resolved amicably between the people affected and the project holders, or through an administrative or judicial device in cases in which the compensation is not satisfactory.

Finally, complementary studies are possible about socio-economic specificities based on the development stage or geographical parameters of countries including environmental concerns and their effects on the quality of electricity. Indeed, priorities and quality challenges may be different for countries at different development stages. However, for many developing countries it seems necessary to outline the access rate to electricity while analyzing the quality of the electricity supply.

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