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International Comparisons of Electricity Tariffs - A Critical Analysis of Relevant Factors.

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Abstract: *Due to the importance of electrical energy, pressure groups exert their influence on governments and regulators seeking price rules that will afford enterprises a competitive advantage. As regards civil society, low electricity prices carry a political and electoral appeal, and they also help governments combat problems related to inflation. Thus, these pressure groups have often created rankings to compare international rates, highlighting that Brazilian tariffs are among the highest in the world. The media has obviously published such studies, causing political embarrassment for the local governments.This article presents a comprehensive discussion of the various factors that may distort the results of comparisons. Yet, these results cannot be correctly interpreted without taking into account the peculiarities and complexities of each country, which are quite distinct from each other and prompt different costs and, consequently, different rates. This paper also discusses how the rates are affected by many factors, namely, natural resources, regulations, environmental issues, taxation, cost of capital, subsidies and incentives, the size, profile and concentration of the market, the quality and safety required, the geography and technological availability. Examples are also presented to illustrate the importance of these factors to set the rates in a specific country.*
Keywords: *Comparisons, Electricity, Relevant Factors, Regulation, Tariffs.*

I. Introduction

Few inputs in economics are as important as electrical energy. Its availability impacts society as a whole, either because of the need to meet its demands, or on account of the energy prices that affect the overall competitiveness of its businesses and the quality of life of families. Due to the importance of electrical energy, pressure groups exert their influence on governments and regulators seeking price rules that will afford enterprises a competitive advantage. As regards civil society, low electricity prices carry a political and electoral appeal, and they also help governments combat problems related to inflation. Thus, these pressure groups have often created rankings to compare international rates, highlighting that Brazilian tariffs are among the highest in the world. The media has obviously published such studies, causing political embarrassment for the local governments.

In Brazil, the Federation of Industries of the State of São Paulo (FIESP) and the Federation of Industries of the State of Rio de Janeiro (FIRJAN), together with ABRACE – an umbrella association of the large electricity consumers – have often published such reports. An example would be the study entitled 'What is the cost of electrical energy for Brazilian industry?' (*Quanto custa a energia elétrica para a indústria no Brasil? Firjan, 2011*).

The electricity sector is extremely complex, encompassing different processes until the final product reaches consumers. Amongst these processes are the generation, transmission and distribution of energy through networks, covering power production, transportation and delivery to the final consumer. As regards costs and revenue, the production processes are affected by the regulatory framework, which defines the energy commercialization process as well as the quality standards set forth by the regulator.

In the present article, the authors identify the key cost-determining factors that affect tariff composition and final prices for consumers. The analysis searched the international context to find differences that, while they do not justify the whole impact on the composition of the comparative rankings, they do shed a light on the rationale that may explain the key differences.

Even acknowledging the reasons that warrant the tariffs of a specific country to rank amongst the highest in the world, the final result must be dealt with pragmatically in setting forth a country´s public policies. Thus, the present article does not intend to disregard the position in the ranking as an impact on the economy and the life of families, but rather to assess the methodological effectiveness of this type of comparison.

II. Cost Formation In Electrical Energy Production

Electrical energy can be generated from several technological sources, each one of them associated with different costs of installation, operation and maintenance, which in turn, define the relative competitiveness between different projects. According to Fortunato et.al (1990) and Reis (2011), the planning and design of generation systems involve economic factors and others regarding guaranteed market supply, which reflect the choices between the quality of service obtained and its cost. The basic cost components of a power plant are as follows:

- ✓ Investment in the power plant and in the connection lines and substations: the capital used to implement the projects including civil works, equipment and industrial assembly.
- ✓ The interests during the construction of the plant: the opportunity cost of capital for the period prior to the generation of revenue.
- ✓ Power plant operation and maintenance.
- ✓ Fuel costs: fuel expenses are an important part of costs in thermal power plants. As for the hydroelectric plants, these costs may represent paying royalties for the right to use the water.

Basically, besides the initial cost forecast, the longer the maturity terms of the project and the time to build the power plant, the more likely that economic and technological changes will alter the costs initially estimated. Many other issues may also arise, either related to the power plant itself, or to the social and economic conditions surrounding the project. The environmental demands are relevant in this regard, due to the costs involved in environmental mitigation and compensation actions, which often have an impact on the schedule of the works. The resulting economic consequences of the latter are clear due to the impact the cost of capital has on production delays (Dixit, Pudyck,1994).

The economic comparison between the different types of generation projects, for example, hydroelectric, thermal or wind power plants, is a recurrent matter in the area of electrical energy generation systems. As the different projects are compared, the main issue is to use a criterion that analyzes their distinctive characteristics. Some plants require significant investments in fixed assets; yet, they may have lower operating costs, as the hydroelectric plants. The other options may have low operating costs, as for example the wind farms, but they have the disadvantage of a high uncertainty factor due to the intermittent nature of their production. Thus, a thorough analysis is paramount for a comprehensive economic assessment estimating the costs of capital and production, even those resulting from back-up systems in case of intermittent generation. Due to the complexity of the matter, it should also be highlighted that the various players involved in a project may develop different criteria for this analysis, i.e., the entrepreneur´s viewpoint may differ from that of the government or civil society. As a matter of fact, it usually does. These differences become even more relevant as public policies, involving cross-subsidies and other externalities, are considered. Besides the above-mentioned factors, others linked to the risks in contract constraints cannot be disregarded, as these are often long-term contracts with the corresponding risks involving regulation as well as financial and political stability. The following is a discussion of the key factors that condition cost formation in electrical energy and, therefore, determine the formation of regulated as well as market prices.

III. Cost-Determining Factors

3.1 Type of primary source

The type of primary source is one of the key cost-determining factors in electricity generation. Depending on the type of source (water, coal, nuclear, natural gas, fuel oil, wind), the relative level of investment and the operating costs undergo very significant changes. Some of these sources demand rather high investments, but their operating cost is not that significant, as is the case with hydroelectric plants. Other sources require less investment, but their fuel costs are extremely high, as for example, thermal plants running on light fuel oil (Maués, 2008).

3.2 Social and environmental restrictions - environmental legislation

To diagnose the impact this factor exerts on generation costs, it is necessary to analyze the environmental legislation and the licensing requirements for energy generation projects in each country, to find potentially relevant differences leading to very distinct final costs for the same type of project. An example of the above would be a thermal power plant running on mineral coal in two countries with completely different environmental legislation; i.e. the laws in one country are significantly more lenient than in the other as regards the control of greenhouse gas emissions or sulphur emissions producing acid rain. Depending on the difference in legislation, and taking into account the quality of the coal, one of the countries might build a coal-fired plant without desulphurisers while these devices would be mandatory in the other. In this case the difference in generation costs between both plants may be quite significant – over 10% - simply due to the use of desulphurisers. There may also be environmental costs involved from the indirect effects related to delays in obtaining the licenses or to the choices made in environmental policies. The latter is precisely the case in Brazil at the present time. The position taken by the environmental entities and part of organized society is directed towards building run-of-river power plants. This will increase the need for thermal plants in the immediate future, with the corresponding higher operating costs. The existence of protected areas along the route of transmission lines (areas of protected forests, indigenous lands, historical and/or archaeological sites) may lead to alterations of the optimum engineering layout for the lines. The routes may have a much more sinuous layout crossing highly rugged regions, all of which has a significant impact on the cost of the towers. There may be a need for more anchor towers as compared to suspension ones, and the distance between the towers is also affected, with the corresponding increase in operating costs.

3.3 Operational restrictions

The need to respect restrictions as regards minimum released flows in reservoirs to protect aquatic life, enable adequate dilution of effluents (sanitation), water abstraction, and minimum navigation levels are good examples of operational restrictions. As regards thermal plants, emission restrictions adjusted depending on air quality may severely affect the dispatch of some plants, with direct consequences on their costs.

3.4 Taxation

The impact of taxation on the costs and prices of electricity generation is quite clear and almost in line with the average rate in each country. Although some countries have public policies offering tax exemptions on inputs, equipment and plant construction, the great majority impose taxes on electrical supply. There may be partial tax exemptions for certain types of consumer classes, as those associated with incentive policies (for example, irrigation) or social support (low-income populations). Therefore, the taxation factor has an impact on tariffs, though its intensity may vary in different countries.

3.5 Origin of inputs (local vs. imported) and exchange rate regime

The origin of the inputs may be relevant to set generation costs. Imported inputs always result in higher costs, either due to international freight or to the country´s exchange rate regime, particularly if it involves a managed currency system.

3.6 Opportunity cost of capital

Higher opportunity costs of capital (interest during construction) increase the burden of costs incurred prior to revenue generation (Modigliani, Miller,1958) and reduce the weight of future costs, for example, fuel costs. Actually, the comparison between hydroelectric and thermal plants indicates that high opportunity costs of capital increase the interest rate component of hydroelectric plants and reduce the weight of operating costs to be covered in the future, which are relevant for thermal plants due to their fuel consumption. In the case of emerging countries, with remaining inflationary instability, basic interest rates have shown significant fluctuations. In Brazil, in a 15-year-period, rates have varied between 26% and 8% per year. As power plants are always long-term projects, debt servicing at such high interest rates may jeopardize the profitability of the project.

3.7 Availability of financing at differential rates

An important factor to explain the difference in generation costs among different countries are the government policies, implemented through public banks that offer financing at special rates.

3.8 Subsidies/sectorial incentives

Government policies that include subsidies and sectorial incentives exert a direct impact on the cost of the different generation options. The effect is most significant on the relative competitiveness between projects, should the subsidies or incentives be directed to one or more source types (Almeida Prado Jr, Silva, 2013). In Brazil it may be worth mentioning the fiscal incentives offered by some states for wind power generation; the discounts in transmission rates applied only to small size renewable sources; the reduction of import taxes or taxation on industrial products; amongst other mechanisms.

3.9 Fuel policy

Another factor affecting the relative competitiveness between energy sources, which may distort the comparison between generation costs in different countries, is related to the existence, or lack of it, of a fuel policy that encourages thermal generation from local inputs. An example of this is Bolivia, where the price of natural gas for thermal generation does not match the international price that could be obtained from exporting this product, thus forcing the expansion of thermal plants to the detriment of hydroelectric ones.

3.10 Size of the market and industrial facilities

The size of the market and the level of competition between suppliers is another factor that may explain some significant drops in energy prices. An example would be the drop in the price of wind power sold in the Brazilian consumer market. Market consolidation has attracted potential suppliers after the financial crisis affecting Europe during the first decade of this century. The existence of a sizeable industrial park to ensure competition between manufacturers, together with the technological status of production equipment, imply higher or lower efficiency in production/manufacturing, which has an impact on costs. On the other hand, the lack of an industrial park for equipment may drive the electric sector to import equipment and technology, thus affecting costs and leading to foreign exchange risks.

3.11Technological evolution vs. project automation level

It is widely acknowledged that the automation level of generation projects affects mainly the operating costs of power plants. A relevant example would be the small and medium-sized hydropower plants, where generation may run completely unattended and monitored from a control center. Automation also leads to the adoption of predictive and preventive maintenance systems, which reduce significantly the outage rates and, consequently, the generation costs. Automated equipment undergoes planned maintenance before failures occur, with considerable reduction in downtime.

3.12 Existing infrastructure

This factor affects primarily the comparison of generation costs between countries, since the construction of power plants is mainly affected by the level of infrastructure in the area where the projects are implemented, as for example, ports, railroads, highways, etc. A clear example of the impact on generation costs due to the lack of infrastructure may be observed in the construction of wind farms in the interior of the state of Bahia (Brazil). The wind performance in this region is excellent, but the existing roads are not adequate to transport the towers and other components of the windmills, which leads to higher costs as compared to regions with better infrastructure. The need to expand infrastructure also depends on the market characteristics. In more developed countries, where the basic needs of the population have been met and there is less demand to expand infrastructure, this effect may be complemented with public policies towards energy efficiency. The state of California is an excellent example of the latter. According to the EIA (2013), between 2001 and 2012, the richest state in the US had a drop in consumption from 396,9TWh in 2001 to 386TWh in 2012**.**

3.13Market load factor vs. capacity factor

The influence of the market load factor on production costs, depending on the capacity factor of the power plants, has already been mentioned in the discussion of run-of-river hydropower plants and the intermittent generation of wind power plants. It should be highlighted that system expansion does not occur only by seeking the power plant that best matches the market load curve, which would point to a single option of generation for such expansion. It is done by seeking the power plants that adapt themselves to the levels of load curve, indicated by the so-called base and peak periods.

3.14 Supply Assurance/Reliability Criteria

The criterion of energy supply assurance and that of electrical reliability fully condition the power generation options to be taken for system expansion and redundancy. Thus, comparing generation costs in countries with totally different demand levels as regards service quality may lead to markedly different values amongst countries.

3.15Energy policies

It should also be noted that energy policies may affect the costs of power generation and/or transmission. Costs can be reduced through incentives, as mentioned above, or be increased by restricting less costly generation options or shutting down power plants prematurely. This happened in Germany, where the government has decided to shut down nuclear power plants that could still remain operational for many years. It was done to meet the pressure on the part of environmentalists and to comply with a political decision taken after the nuclear accident in Fukushima, Japan.

3.16 Portion of production allocated to the domestic market and portion allocated for export.

Countries with well-defined surplus in their supply potential vis-a-vis their domestic needs, as Paraguay, Bolivia and Peru, have decided to implement projects on a much higher scale than would be compatible with their internal market. In this case, the country may develop its energy potential to reduce costs through an economy of scale, while it exports excess energy to neighboring countries at a price above that of its domestic market, thus subsidizing its own consumers.

3.17Proximity of the main sources to the system load centers

Countries with generation facilities located close to the system load centers, as well as those with small geographic dimensions, will benefit from this proximity with a reduction in transmission costs.

3.18 Load density of subsystems supplied by transmission and distribution networks

The load density supplied in the area covered by the energy transportation system, particularly as regards distribution, will certainly have a direct impact on the unit costs ($ / MWh transported) of the electrical network. Therefore, countries where the load is unstable will have significantly higher energy transportation costs.

3.19 Transmission and distribution modalities (aerial vs. underground)

Costs are very sensitive to the physical layout of the lines, in terms of the decision between placing the lines on towers for aerial transmission, or underground, on cable trays inside tunnels. In a comparative analysis between two countries with similar characteristics as regards average transportation distance and load density, the country bound by its environmental laws to implement more extensive underground transmission will certainly show significantly higher energy transportation costs. Countries with aerial transmission lines that are subject to strong wind gusts have much higher transmission costs, due to the wind load that must be used for the mechanical design of the transmission lines.

IV. Cost Attributes Of Projects And Examples Of Their Application To Diagnose Tariff Differences Between Countries.

Complementing the previous sections and considering the above-mentioned concepts, for each cost attribute, which in turn affects tariffs and electricity prices, this section presents examples of countries where these attributes are actually quite relevant. These influences become even more complex since, beyond the influence of the attribute itself, the impact is often strengthened by political options resulting from the economic scenario or other regional matters, as for example, the weather, the availability of natural resources or the existence of infrastructure.

4.1 Natural resources.

The availability of natural resources is clearly a relevant cost reduction component in electrical energy production. On the other hand, the lack of these resources not only exposes the country to higher production costs, but also increases the risks of volatility resulting from energy prices (besides the foreign exchange risks involving imported products), as well as other risks caused by geopolitical instability. An example would be the province of Quebec, where almost all the electricity is generated by hydroelectric power plants (over 99%), and Norway, where 93% of the production also originates from hydropower plants. The rising interest in wind power can also be analyzed in relation to natural resources. Boccard made an extensive study comparing the capacity factors of wind farms based on the availability of wind in several regions around the world (Boccard, 2014). Other examples would be the availability of natural gas in Russia[1] as well as in the state of Texas[2] in the US. The availability of natural resources may be so relevant in some cases as to affect the economy of a region or a country (Trevisan; Springs 2014). It may also have an impact on the international price balance, as in the case of shale gas, which some analysts believe has contributed to the recent drop in oil prices in the international market (Gold, 2014). The opposite effect may also occur, in which case, extremely low oil prices will affect the economic feasibility of other resources. Examples of the latter would be the recently announced reduction in the production of the shale gas fields in Bakken, North Dakota, and Eagle Ford, Texas (Di Savino, McAllister,2015), as well the potential damage to the exploitation feasibility of the pre-salt layer in Brazil (Bustamante, 2015). Analysts also believe that lower oil prices will reduce investments in wind and photovoltaic solar energy.

Some countries are in great need for imported resources due to their lack of natural ones. Japan is one of the most significant examples in this regard. The country imports 96% of the energy necessary to meet its demand. Only the volume of liquefied natural gas the country imports from Qatar and Australia amounts to US$ 13 billion per year. (Bresciani, Inia, Lambert, 2014). Finally, the importance of natural resources for the countries where they are abundant must also be highlighted. These countries do not diversify enough their energy sources, and they may fall victim to the so-called 'curse of natural resources'. This may be due to the shortage of resources resulting from a single or prevailing alternative, or to the extreme economic dependency on this resource to fund other areas of the economy.

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[1] Total supply of natural gas in Russia, in 2011, was approximately 713.011 MM m3/year (Quantum, 2013).

[2] 23 % of all natural gas reserves in the US are in the state of Texas (http://stateimpact.npr.org/texas/tag/natural-gas-production-in-texas).

4.2 Hydroelectric power

Amongst the natural resources used to produce electricity, hydroelectric power is one of the most relevant. Few countries count on significant and dominant hydropower sources. Of the countries analyzed, Norway, Brazil, Colombia and Canada run over 60% of their generation facilities on hydroelectric power. From this perspective, countries where hydroelectric sources are dominant tend to have low production costs of electricity.

Yet, hydroelectric power plants have high building costs, and they are complex works that may cause serious environmental and social problems as a result of the inundated areas. These alternatives have also faced increasing opposition. All of this has contributed to a trend in rising costs, even though the initial premise stating that hydropower is an inexpensive option continues to be valid.

Countries like the US have a large number of hydropower plants, but in percentage terms this alternative accounts for a small portion of the country´s overall energy matrix. The example of multiple usage of the water resources in the US is presented by Kosnik (2012), given the high number of agencies and departments involved in four spheres of government[3]. In this study Kosnik (2012) lists 19 entities regulating the management of basins, involving entities as diverse as the Department of Indian Affairs and the Department of Energy. Thus the resources destined for hydroelectric generation compete with fishing, agriculture, irrigation, tourism, historical and environmental preservation, river transport, fish farming and fresh water supply, amongst other uses. This entire environmental, political and regulatory environment contributes to an upward trend in the costs of hydroelectric power.

4.3 Thermoelectricity

The great majority of countries generate most of their electricity from thermal power plants using fossil fuels as the primary sources. Examples of the countries where over 60% of the generation infrastructure is based on thermal plants would be the following: Finland, Chile, Argentina, South Africa, Mexico, South Korea, the United Kingdom, Italy, India, Japan and the US (ex. in the states of in Illinois, Texas, New York and California). Although their cost of capital is lower than that of hydropower plants, thermal plants generating electricity from fossil fuels have higher operating costs. As mentioned above, the countries that are highly dependent on imports - as Italy that imports almost all the natural gas required - show a strategic weakness due to their dependence on factors outside their control, as international market prices and geopolitical issues.

Another relevant factor in cost formation is related to the availability of infrastructure to transport the fuels. In the state of Texas, with gas pipelines extending over more than 45 thousand miles, there is easy access to the vast natural gas reserves in the region, which contributes to lower production costs.

Wide availability of fuel transportation facilities has an impact extending beyond regional costs. There is also a relevant flow of natural gas between continents, both onboard ships and through pipelines (Quantum, 2013). It seems clear, therefore, that the means of transportation play a major role on final prices. Burning fossil fuels is usually associated with high emission rates. There may be an impact on prices depending on the higher or lower demand levels to obtain environmental licenses and the need to install pollution control equipment, as gas scrubbers and filters. In countries where legislation is rather lax, less expensive fuels, as coal, are more easily available. An example of a country that still emphasizes this solution would be South Africa. The opposite would be the countries that are also heavy users of coal for energy generation but are trying to migrate to other alternatives for environmental reasons. The United Kingdom and Germany intend to lower their dependency on highly polluting fuels, while China is making an attempt to reduce its dependency on coal by putting an emphasis on renewable sources. Other weaknesses besides the transportation of fuels can also be identified, especially in the coal industry, with extremely labor-intensive operations. Historically, this industry has been strongly rooted in its labor unions. In the United Kingdom, some analysts credit part of the reforms of the 1990´s to Margaret Thatcher´s political decision to weaken labor unions in the coal sector (Surrey, 1996).

4.4 Nuclear energy

Although in the strict sense nuclear power plants are thermoelectric plants, a special terminology has been adopted due to the importance of this solution. In many countries nuclear energy was considered the most feasible solution, yet this alternative has lost relevance on account of the three large accidents, namely Three Mile Island, Chernobyl and Fukushima, as well as of the strong opposition on the part of society. Until 1965, the US had orders for 20 nuclear power plants, and in the following ten years this figure rose to 204. This led the Atomic Energy Commission (AEC) to predict that by the year 2000 there would be 1,000 nuclear plants in the US (Graetz, 2011). Yet, only 100 plants are presently using this technology. Most orders were cancelled because

[3] Municipal, state, federal and several regulatory agencies.

the costs of licensing and the fierce opposition on the part of civil society[4] had increased costs to a point that, by the 1980´s, no nuclear plant in the US was able to compete with coal-fired power plants. Graetz (2011) has estimated that costs rose during one decade at actual rates of 18% per year. Other authors have also shown evidence of the huge cost increases in nuclear plants, especially in the larger ones (Cantor, Hewlet, 1988). Thus, although there were high expectations of expanding nuclear energy in the US, the facts point to the aging of the present nuclear plants without any signs of replacement.

According to Scheiner and Froggatt (2014), 63 out of the 100 nuclear reactors analyzed had been running for over 30 years, and only one nuclear plant had been operating for less than 20 years. Despite these issues, some countries have opted for nuclear energy as their preferred source. The most relevant example would be France, where nuclear energy has the largest share of the country´s energy matrix (48.2%). Sweden and South Korea also have over 20% of their installed capacity based on nuclear sources (EIA, 2014).

One of the virtues of nuclear generation is its stability over time, which contributes to reducing production volatility and, consequently, price risks. Nuclear generation requires high investments, but the variable cost is lower than that of traditional thermal sources. In this regard, nuclear generation follows in the line of hydropower. There may increase opposition to hydropower plants, but the opposition faced by nuclear plants is much stronger and bitter, by far. After the accident in Fukushima, Japan implemented the most drastic alteration of the power matrix in a developed country by decommissioning 50 nuclear reactors. This reduced nuclear power generation, which stood at 29% in 2010, to a mere 1.6% of the country´s total energy consumption in 2013, that is, only 13,6 TWh (Schneider, Froggatt, 2014).

The French government intends to implement a partial reduction of nuclear generation by shrinking the share of nuclear in its total power generation from 75% to 50% by 2025, and replacing the reduced capacity with renewable energy (Eletronuclear, 2014). Other countries, like the United Kingdom, have shown a strategic interest in resuming the use of nuclear energy (O Globo, 2013). Despite the apparent contradictions in these political trends, it seems clear that opting for nuclear energy will increase electricity tariffs in the short and medium-term. As paradoxical as it may sound, the countries that took this option in the past and presently renounce to it may experience a rise in tariffs, due to the ‘sunk costs’ of shutting down plants not yet amortized (Rabl & Rabl, 2013). On the other hand, the countries that chose to continue running their nuclear plants tend to have higher costs, since rising environmental and safety requirements will also contribute to this end.

4.5 Wind and solar energy

International comparisons point to the great expansion of electrical energy generation from intermittent sources as wind and solar power plants. In Brazil the situation is similar to the rest of countries. In 2014, wind farms accounted for approximately 1.5% of all the power generated in Brazil, and they should represent 9.5% by 2022 (EPE, 2013). Solar power is still incipient in the country, and it should remain like this for the next five years. A report published by EPE (2013) indicated that, on a global scale, wind farms account for 1.7% of all the electricity produced, while solar sources5 represent only 0.2%. However, this trend may be reversed with the new incentives for distributed generation and the reduction in ICMS taxes for the energy sold in many Brazilian states. Though wind power is very attractive because of its low environmental impact, the proliferation of wind farms may potentially increase the operational complexity of the Brazilian interconnected electric system, and it may also add indirect costs (externalities) to the process.

In Brazil, this increase in complexity stems from the rising number of hydropower plants operating without storage capacity, the spatial mismatch between generation from different sources and, above all, the need to increase the number of thermal plants dispatching energy to the grid. In the international scenario, there are problems as the growing need of a spinning reserve to regulate frequency and voltage with immediate adjustments. Within the analysis of natural resources and their impacts on the cost of electrical energy generation – and consequently on final tariffs – it is also important to consider the portfolio of options that complement each other. Again, it should be highlighted that this complementarity may be analyzed within any combination of sources and/or energy resources available. Yet, for didactic purposes, the complementarity between wind and hydropower resources is an excellent example. In an important study entitled “Complementarity of hydro and wind power: Improving the risk profile of energy inflows”, Denault, Dupuis and Cardinal, (2009) concluded that the production of electrical energy from wind sources may reduce the volatility of this production when it is considered jointly with the hydropower plants. The authors suggest that diversification is a cost reduction factor to be taken into account in project planning.

[4] The two plants in San Luis Obispo, California, represent an excellent example of this opposition and the rising costs. They have a capacity of 1,100MW, and it took 18 years to finish them. Their initial cost of US$ 110 million became US$ 4 billion by the end of the project (Graetz, 2011).

[5] Conventional thermal sources (excluding nuclear) accounted for 66.5% on the same date.

4.6 Environmental legislation.

Until the early 1970´s, few cost impacts could be attributed to environmental concerns. Rachel Carson´s book 'Silent Spring' published in 1962, which became a best seller despite its technical nature, can be considered a landmark of the time when the environmental issue reached the general public. Relevant legislation was passed in the US during the Nixon administration, namely the National Environmental Policy Act (1969), the National Clean Air Act (1970) and the National Clean Water Act (1972). The Public Utility Regulatory Power Act (PURPA) was passed in 1979 under the Carter administration. This law exerted a significant impact on energy commercialization, although its main objectives were to boost small generation projects from renewable sources and increase the efficiency of small size co-generators. In 1997, the international agreement on climate change, also known as the Kyoto Protocol, had a strong impact on the issues related to energy and the environment. The impact of the climate issue and its relationship with energy is so significant that the United Kingdom changed the name of its Department of Energy, which is now called Department of Energy & Climate Change. On a global scale, it is presently acknowledged that 60% of the greenhouse gas (GHG) emissions result from the use of fossil fuels, and electrical generation accounts for 65% of the sector. This figure could be even higher if methane emissions from hydropower plant reservoirs were included. Recently, the European Union pledged to reduce GHG emissions by 40%, by 2030 (Valor Econômico, 2014). This commitment will certainly leverage the so-called renewable energy sources, which are also regarded as environmentally friendly. As was discussed in the previous section of the present study, this will undoubtedly lead to a rising trend in production costs and, consequently, electricity tariffs.

Besides the international agreements to reduce emissions from industrial production and use clean, renewable energy, the issues of environmental conservation and the assessment of social impacts have also become very relevant. Consequently, further environmental restrictions have been introduced, with the corresponding impact on the cost of new projects. In this context, countries with limited environmental demands tend to facilitate their licensing processes, often disregarding the use of filters and gas scrubbers and discarding social and environmental compensatory measures, especially for thermal plants. As regards overall investments, the time needed for licensing and the clashes in the judicialization set forth by the parties opposed to certain projects have proven to be very costly. This often leads to a delay in civil works and a rise in the committed capital expenditure. Part of the cost and the difficulties involved in obtaining the licenses, and consequently part of their associated costs, stem from the complexity of the regulations and the countless rules set by the different levels of government. In Brazil, a study made by the National Confederation of Industry (CNI *in Portuguese*) identified 30 thousand rules passed by the country´s federal and state governments involving environmental licensing. The average time to obtain these licenses is 28 months[6]. In countries as the United Kingdom, Germany, and even Brazil, costs have risen due to the limitations imposed on environmental impacts. In the US this factor is more prevalent in California and New York. In Brazil, the costs resulting from the pressure associated with the social impact and the judicialization of the environmental issue have been more relevant. In the North of the country, delays in the works of hydropower plants may have a significant impact on electricity tariffs in the next few years, depending on some regulatory decisions yet to be taken. The financial losses resulting from delays in the Santo Antônio, Jirau and Belo Monte plants amount to billions of reals, due to the energy not supplied according to the schedule set forth in the contracts (Bitencourt, 2015). Counterexamples of this would be South Africa or China, where lax restrictions have led to an expansion in energy supply disregarding environmental externalities, either on the cost of the project or on the electricity tariffs.

4.8 Operational restrictions

The costs resulting from operational restrictions may have different sources. In some poor Caribbean island countries, as Saint Lucia, Haiti, Barbados, Grenada, Antigua and Barbuda and Montserrat, the energy system is not even operational 24 hours a day (Kury, 2013) In those countries the more affluent classes, as well as the service and industrial sectors that are totally dependent on electrical energy, need auxiliary power generation systems. Although this may not be reflected in the tariffs, it does have an impact on costs. On the other hand, an experience in Thailand has allowed for a tariff reduction to be granted to consumers with flexible consumption, i.e. their supply may be interrupted (WEC, 2001). In many countries, the costs arising from operational restrictions are also due to insufficient training of the sector technicians or lack of infrastructure.

According to the research, the energy transportation system in Colombia shows high unit costs due to the reduced load of the country´s networks covering a large territory. South Korea is in the opposite situation, with high density and low costs per unit of energy transmitted (Gesel, 2015). Physical restrictions also affect the interconnection of electrical systems. The Rocky Mountains in the US, for example, represent a physical barrier that hampers connections. When restrictions of this nature occur, dispatches are more frequent for electrical reasons rather than for energy reasons.

[6] Jornal Estado de SP 28 July, 2014, page. A3

4.9 Foreign exchange

Energy importing countries as Japan have a cost attribute resulting from the higher or lower value of their currency vis-à-vis the US dollar, which is widely used for most energy transactions, as for example, oil and natural gas. Jordan is also highly dependent on imported energy. Actually, 10% of the country´s GDP is earmarked for oil imports (WEC, 2001). This effect is more profound in developing countries.

4.10 Opportunity costs of capital.

Capital dependency is high in the electric sector. As tariffs need to remunerate the investment, the factors involved in the opportunity cost of capital - as the interest market- are extremely relevant to set these tariffs. This factor can be minimized n countries where the state plays a strong role in the sector, as for example in China. In others, where capital is scarce and there is competition due to the need for investments in infrastructure, the factor may be more relevant. An example of the latter would be the interest rates in Brazil, associated with the country´s risk rate and the interest rate of US government bonds. Yet, in many cases, countries with high real interest rates can minimize the above mentioned effect through incentive funding, as is the case of the BNDES bank in Brazil. In practical terms, it all comes down to 'competing' for the capital earmarked for infrastructure. The energy sector will certainly benefit in countries where low basic interest rates may be attractive for project funding, as for example, Japan or Germany.

4.11 Public policies.

Several public policies may affect electricity tariffs, particularly those geared to the poorest echelons of society. Thus, policies aimed to subsidizing the poor sectors of the population, as tariff policies for low-income people in Brazil or those geared to universalizing access to the grid, have an impact on tariffs for the rest of consumers. Especially the policies to universalize access to electricity have a significant effect, since 25% of the world´s population still has no electrical supply (Sovacool, 2012). As this deficit is eliminated, costs will certainly rise. The policies associated with subsidized tariffs may be implemented in a variety of ways: financial resources transferred from the public treasury to the power utilities; fiscal exemptions; or low tariffs that do not depict reality. In the latter case, this practice leads to a deterioration in the service and divestment. In several African countries, public policies are such that they do not allow electric utilities to recover costs, in practical terms. In a few years, this will result in a deteriorated system or significant and periodical readjustments when the sector becomes totally crippled. The following countries are examples of the latter: Nigeria, Malawi, Chad and Ethiopia (Tallapragada, 2009). The radical adjustments in electricity tariffs recently imposed in Brazil are a prime example of the above. There is also the case of Peru in 1993, where electricity tariffs rose five-fold, at one go, when subsidies were withdrawn (WEC, 2001).

4.12 Market size and level of competition between agents

Countries with limited economic relevance, as Chile, though their regulations favor competition, may not be as meaningful because the companies qualified to operate in the sector will not be very interested in these markets. The attribute of 'competition' must be credited to Prof. Littlechild, the first energy regulator in the United Kingdom, who affirms that competition is the best mechanism to defend consumers (Littlechild, 1983). In Brazil the bidding process has reduced the generation costs of the new energy sources, especially hydropower and wind power, to mention the most relevant options. Although recent research presents rather controversial results, a study in the United Kingdom (Porter, 2014) has shown that competition has brought about tariff reductions and benefitted consumers through processes allowing them to switch energy suppliers. The Brazilian Association of Energy Suppliers believes that competition between agents would lead to a significant reduction in tariffs (Ordonez, 2014).

4.13 Quality and modernity of the infrastructure

The infrastructure of the generation plants and the electrical energy transmission facilities reflects upon the energy production costs, and consequently, upon the tariffs. Modern facilities, however, do not necessarily imply lower costs. Tokyo, for example, has one of the lowest outage rates in the world, resulting from a system installed almost 100% underground, with the corresponding high infrastructure costs. A study by the Edson Institute has indicated that installing all networks underground would have a dramatic impact on tariffs to cover a cost of approximately US$ 1 million per mile, or ten times the usual cost. Other studies undertaken by utilities in Florida and North Carolina have shown tariffs would need to increase by a minimum of 80%, in some cases reaching 125%. A study in Virginia has shown the charge per consumer would amount to US$ 3,500 (Johnson, 2006). Modernization by means of underground networks may not be feasible even in rich countries. However, the need for new investments to refurbish and upgrade the facilities sets an upward trend on tariffs. In the US, 70% of the transmission lines and transformers are over 25 years old, and 60% of the circuits are over 30 years old. They were all designed and built before digital technology, which enables more automated operations (Johnson, 2006, Kassakian, Schmaleensee, 2011).

Obsolete systems lead to higher technical losses and, potentially, to higher commercial losses. India is a good example of this. In countries where commercial losses are high, as in Brazil, there have been discussions about introducing intelligent electrical networks to combat fraud and illegal connections. Covering the costs of this type of modernization will lead to higher tariffs.

4.14 The context of industrialization in Brazil

The industrialization level of Brazil may affect energy tariffs for different reasons. Countries with a large number of energy-intensive industries tend to have many incentives for the use of low cost energy – often through subsidies – to support their industrial facilities. Thus, for some consumers to pay lower tariffs, other sectors end up subsidizing the entire context. Lower prices to subsidize some sectors with high energy consumption may result from other factors, as is the case in South Africa or China, where little attention is paid to environmental requirements. On the other hand, places like Germany, California or the United Kingdom, with high demands for supply quality and assurance and strict environmental controls, may also have higher energy prices.

V. Conclusion

The diversity of electricity tariffs for the final consumer stems from two different sets of factors. On one hand, the availability of natural resources and the technical and economic characteristics of the systems in different countries lead to major variations in the costs to supply electrical energy. On the other hand, public policies in different countries may strongly interfere with the level of electricity tariffs for the final consumer. This may occur because the sector is burdened with the cost of government policies or high tax loads, or because the government uses its power to hold back the tariffs paid by the final consumer.

The present article has discussed many factors pointing to the complexity of the process that compares tariffs on an international level. The purpose is to assess whether prices and tariff policies in a specific country are outside the global reality, and whether the country´s industrial and commercial competitiveness may be jeopardized. Although it may seem that all these factors will turn the comparison even more complex, it must also be acknowledged that, on a more practical level, a country with extremely high electricity tariffs may have problems as regards its economy and the quality of life of its population.

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References

[1]. FIRJAN. Quanto custa a energia elétrica para a indústria no Brasil? Estudo FIRJAN, no. 8, 2011.
[2]. Fortunato, L.A.M. Introdução ao planejamento da expansão e operação de sistemas de produção elétrica (Editora Universitária, Niteroi, 1990).
[3]. Reis, L. B. Geração de energia elétrica (Ed. Manole, São Paulo, 2011.
[4]. Dixit, A., Pindyck, R. Investment under uncertainty (Prentice Hall, New Jersey, 1994).
[5]. Maués, J. A. Comparação de fontes primárias para geração de energia elétrica no Brasil baseada em conceito de risco. Tese Doutorado em Engenharia Mecânica, Pontifícia Universidade Católica do Rio de Janeiro, Rio de Janeiro, 2008.
[6]. Modigliani, F., Miller, M. H. The cost of capital, corporation finance and the theory of investment: a reply. The American Economic Review, Nashville: American Economic Association, v.48 (3), 1958.
[7]. Almeida Prado Jr., F.A., Silva, A.L.R. Estado da Arte de experiências internacionais na concepção de Tarifas "Feed In". Procedings of 23th Seminario Nacional de Produção e Transmissão de Energia Eletrica -SNPTEE, Brasília, 2013.
[8]. Department of Energy, Energy Information Administration EIA. Available in www.eia.doe.gov, 2012 access in 28 de maio de 2015.
[9]. Boccard, N. Capacity factor of wind power realized values vs. estimates, Energy Policy, vol. 37, 2009, 2679–2688.
[10]. Trevisan, C. e Springs, C. Boom do gás de xisto ajudou economia dos EUA a crescer, Jornal O Estado de São Paulo em 28 de abril de 2014.
[11]. Gold, R. Para entender o colapso global dos preços do petróleo, comece pelo Texas, Jornal Valor Econômico em 16 dezembro de 2014.
[12]. Di Savino, S., McAllister, E. Petróleo em baixa derruba produção nas áreas de xisto, Jornal Valor Econômico em 10 de março de 2015.
[13]. Bustamante, L. A. A queda do petróleo inviabiliza o pré - sal?, Jornal Valor Econômico em 14 janeiro de 2015.
[14]. Bresciani, G, Inia, D, Lambert, P. Capturing value in global gas: Prepare now for an uncertain future. McKinsey& Company, Report: 2014.
[15]. Prati, G., Zani, B. The Effect of the Fukushima Nuclear Accident on Risk Perception Antinuclear Behavioral Intentions, Attitude, Trust, Environmental Beliefs, and Values. Environment and Behavior, vol. 45 (6), 2012, 782–798.
[16]. Quantum. Estudo do mercado internacional de GN- Volume I- Asia. Relatório, Junho de 2013.
[17]. Reservas de gás nos EUA. Available in <http://stateimpact.npr.org/texas/tag/natural-gas-production-in-texas>, access in 15 fevereiro

de 2015.
[18]. Kosnik, L. The anticommons and the environment. Journal of Environmental Management, vol. 101, 2012, 206 – 217.
[19]. Surrey, J. (editor). The British electricity experiment (Earth Scan, London1996).
[20]. Graetz, M. J. The end of energy (The MIT Press,New York, 2011).
[21]. Cantor, R. Hewlet, J. The economics of nuclear power. Resources and Energy Journal, vol. 10,1988, 315-335.
[22]. Scheneider, M. Froggatt, A. The world nuclear industry status report 2014. Heinrich Boll Stiftung- The Green Political Foundation, 2014.
[23]. Eletronuclear, Panorama da energia Nuclear no Mundo. Relatório Eletrobras 2014.
[24]. Rabl, A, Rabl, V. A. External costs of nuclear: greater or less than alternatives Energy Policy, vol. 57, 2013, 575-586.
[25]. Empresa de Pesquisa Energética - EPE, Anuário Estatístico de Energia Elétrica, 2013.
[26]. Ministério de Minas e Energia.- MME, Plano decenal de expansão de energia 2012- 2021, 2013.
[27]. Hirst, E., Hild, J. Integrating large amounts of wind energy with a small electric-power system. Working Paper Industry Restructuring, Washington, 2004.
[28]. Qadrdan, M., Chaudry, M., Wu, J., Jenkins, N., Ekanayake, J. Impact of a large penetration of wind generation on the GB gas network, Energy Policy, vol 38, 2010, 5684–5695.
[29]. Cutler, N. J., Boerema, N.D, MacGill, I. F., Outhred, H.R., High penetration wind generation impacts on spot prices in the Australian national electricity market. Energy Policy, vol 39, 2011, 5939 –5949.
[30]. Madrigal, M and Porter, K. Operating and Planning Electricity Grids with Variable Renewable Generation: Review of Emerging Lessons from Selected Operational Experiences and Desktop Studies. World Bank, Working Paper no.75731, 2013.
[31]. [Denault, M., Dupuis, D., Cardinal, S. C. Complementarity of hydro and wind power: Improving the risk profile of energy inflows. Energy Policy, vol. 37, 2009,5376–5384.
[32]. Valor Econômico. UE mantem corte de emissões, mas recua de meta para renováveis. Jornal Valor Economico em 25 de janeiro de 2014.
[33]. Bitencourt, R. Aneel propõe acordo a atraso de hidrelétricas. Jornal Valor Econômico em 11 de maio de 2015.
[34]. Kury, T. Notas de aula do curso de Regulação por Benchmarking. PURC Universidade da Florida, 2013.
[35]. World Energy Council, Pricing Energy in Developing Countries, WEC Report, 2001.
[36]. Sovacool, B. K; The political economy of energy poverty: A review of key challenges. Energy for Sustainable Development, vol.16, 2012, 272–282.
[37]. Tallapragada, P., et al. Monitoring Performance of electric utilities- indicators and benchmarking in Sub-Saharan Africa. World Bank, Report, 2009.
[38]. Littlechild S., Regulation of British Telecommunications' Profitability, Department of Industry Report London, 1983.
[39]. Gesel- Grupo de Estudos do Setor Elétrico UFRJ. Panorama e análise comparativa da tarifa de energia elétrica do Brasil com tarifas praticadas em países selecionados, considerando a influência do modelo institucional vigente. Relatórios do projeto de P&D, 2015.
[40]. Porter, D. Electricity Supply The British experiment, (Mereo Books, London, 2014)
[41]. Ordonez, R. O custo da falta de concorrência. Jornal O Globo em 12 de fevereiro de 2014.
[42]. Johnson, B. W. Out of Sight, Out of Mind? A study on the costs and benefits of undergrounding overhead power lines. Edison Electric Institute, report: 2006.
[43]. Kassakian, J., Schmaleensee, R. The future of electric grid. MIT Report, 2011.