

Environmental Management

Analysis of the strategies for the commercialization of electric energy of generating agents in the short term environment

Análise das estratégias de comercialização de energia elétrica de agentes geradores no ambiente de curto prazo

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ABSTRACT

The development of the electric energy market has gained visibility due to the recent transformations in energy policies in Brazil and worldwide. For many years, investments were not made in the Brazilian electricity sector, causing a delay in the energy matrix. With this, the government implemented measures for structural and institutional reforms in the electricity sector with the objective of guaranteeing the expansion of the generating park, attracting private investment, and promoting market competition. The restructuring of the electricity sector led to the emergence of new ways to negotiate energy, new structures and entities, with the objective of increasing transparency, competitiveness and efficiency among market agents. In the new model of the Brazilian Electricity Sector (SEB), energy trading is carried out through two contracting environments, the Regulated Contracting Environment (ACR) and the Free Contracting Environment (ACL). This research analyzes the electric energy commercialization strategies through generation agents acting and competing in the short-term energy market, through the use of competitiveness graphs.

Keywords: Electricity Trading; Free energy Market; Trading strategies

RESUMO

O desenvolvimento do mercado de energia elétrica ganhou visibilidade em virtude das recentes transformações nas políticas energéticas no Brasil e no mundo. Durante muito anos, investimentos não foram realizados no setor elétrico brasileiro, ocasionando um atraso na matriz energética. Com isso, o governo implementou medidas para reformas estruturais e institucionais no setor elétrico com objetivo de garantir a expansão do parque gerador, atrair investimentos privados e promover à concorrência do mercado. A reestruturação do setor elétrico levou ao aparecimento de novas formas de negociar energia, novas estruturas e entidades, com o objetivo de aumentar a transparência, a competitividade e a eficiência entre os agentes de mercado. No novo modelo do Setor Elétrico Brasileiro (SEB), a comercialização de energia é efetivada através de dois ambientes de contratação, o Ambiente de Contratação Regulado (ACR) e o Ambiente de Contratação Livre (ACL). Esta pesquisa analisa as estratégias de comercialização de energia elétrica por meio de agentes de geração atuando e competindo no mercado de energia de curto prazo, por meio da utilização de gráficos de competitividade.

Palavras-chave: Comercialização de Energia Elétrica; Mercado livre de energia; Estratégias de comercialização

1 INTRODUCTION

The Brazilian Electric System (SEB) has a large number of power plants, thousands of kilometers of transmission lines and a large number of substations and control centers. The high complexity of managing all the equipment and the costs involved have encouraged the government, research groups, universities and companies to seek safe and efficient tools and techniques to operate and expand the national electrical system (NOGUEIRA and BERTUSSI, 2019).

In the 1990s, the government implemented measures for structural and institutional reforms in the electricity sector with the objective of guaranteeing the expansion of the generation park, and attracting private investments, since the government was showing signs of stagnation with the reduction in investments in the expansion of the system. These reforms were marked with the enactment of Law n° 8.631/93, which provided for the tariff structure for the public electric power service, extinguishing the guaranteed remuneration

regime, and creating supply contracts between generators and distributors, aiming to reduce their financial difficulties (BRASIL, 1993).

Other important milestones can be highlighted for this reform, such as in 1995 the enactment of Law nº 9.074 that stimulated the participation of private initiative in the electric power generation sector, creating the independent power producer (PIE), being autonomous to act in the market and free to make their own decisions, assuming the results from such decisions (BRASIL, 1995; HUNT and SHUTTLEWORTH, 1996). This law initiated the competition in the commercialization of electricity with the introduction of the Free and Special Consumer, and in 1996 with the implementation of the Restructuring Project of the Brazilian Electric System (RE-SEB), which enabled the deverticalization of the sector (NOGUEIRA and BERTUSSI, 2019).

With the energy crisis that occurred in 2001, the government through Decree nº 5.163 created the new institutional model of the Brazilian Electric Sector (BRASIL, 2004). The new model created the Energy Research Company (EPE), with the function of developing studies and research for planning the expansion of the system. It also created the Energy Sector Monitoring Committee (CMSE), with the function of evaluating the security of electricity supply, and the Electric Energy Trading Chamber (CCEE), responsible for buying and selling electricity through two trading environments, called the Regulated Contracting Environment (ACR) and the Free Contracting Environment ACL (TOLMASQUIM, 2015; NOGUEIRA and BERTUSSI, 2019).

The new model for the electricity sector made possible the liberation and deregulation of the electricity market. The market restructuring process was intended to provide favorable conditions to stimulate competition and market efficiency for the benefit of society as a whole. In this scenario, the modification of paradigms inserted by the opening of markets evidenced the deverticalization of a state-controlled industry, providing the division of the areas of generation, transmission, distribution and commercialization of energy, and the creation of incentives for private agents to participate in the sector (HUNT and SHUTTLEWORTH, 1996; DA SILVA, 2001; RUDNICK and ZOLEZZI, 2001; HUNT, 2002; NERY, 2012; SIDDIQUI and GABRIEL, 2013).

A competitive electricity market needs to establish a model with clear, stable rules and appropriate and effective regulation that provides a balanced relationship between all agents involved.

A market model is understood to mean methods and resources that enable negotiations to be done properly. More specifically, a market model consists of the means to organize the buying and selling of energy, through laws and regulations that define the rights and underpin the contracts, the market, and the regulatory standards (MCMILLAN, 2004).

A market model must be consistent with public policy in order to contribute to regulatory stability, which brings certainty to consumers, the energy market, and investors (KURI and LI, 2004). Therefore, it is important to observe the market and its behavior periodically, in order to provide continuous improvements so that it operates efficiently. An efficient model, based on a regulatory mechanism, helps to resolve the issues faced by electricity markets (STOFT, 2002). In this perspective, the electricity market is encouraged to develop and improve its market models to provide efficiency and economic growth through competition and sustainability, with guaranteed energy supply, with quality, reliability and fair cost to consumers (ZUCARATO, 2012).

This research analyzes the electric energy commercialization strategies in the period from 2012 to 2020 through generation agents acting and competing in the short-term energy market, through the use of competitiveness graphs.

2 ELECTRICITY MARKET

Several countries have changed the economics of their electricity markets from monopolies to oligopolies in an attempt to increase competition. The restructured electricity markets have enabled the deverticalization of the sector, creating competitiveness in the different activities of the value chain, providing several benefits for the sector. Some of these benefits were, the liberation and deregulation of the electricity sector in the late nineteenth century, marking the beginning of the introduction of competitiveness in some segments of

the electricity sector, such as in the generation and commercialization of energy with the introduction of the Free and Special Consumer (RAMOS-REAL et al., 2009).

This restructuring introduced risks and uncertainties in a sector that was traditionally state-owned (HUANG, 2008; STREET et al., 2009). In the literature a number of contributions have been observed with respect to energy trading strategies in competitive environments. Some of these works focus on the Brazilian electricity market, which has specific trading rules. For example, (STREET et al., 2009) developed an optimization model to explore the optimal generation mix of biomass and small hydro plants. The proposed model composes an optimal portfolio of these two alternative generation sources, seeking to determine the best trading strategy to maximize the revenue of an energy trading company.

Teive et al. (2010) propose a mathematical model to support decision making to help the energy-trading agent to identify risk situations and opportunities to maximize the performance of its portfolio of energy contracts. The model takes into account energy reserve capacity constraints, using linear programming, as well as risk analysis using the VaR (Value at Risk) and CVaR (Conditional Value at Risk) methodologies.

De Amarante et al. (2018) developed a multi-stage optimal programming model addressing the supply strategy of a thermal generator considering price uncertainty.

Decker (2014) presented a decision support methodology for the trading of electricity from small hydropower plants. He used for this, a multi-stage stochastic optimization model with two levels. The first level is "strategic" and represents all annual trading decisions, while the second level is "operative" and the strategy of the first level is evaluated monthly according to market rules and opportunities.

Hesamzadeh and Biggar (2012) proposed a methodology to analyze extreme-Nash equilibria in a wholesale market.

Menniti et al. (2008) argue that the theory of non-cooperative games and the concept of Nash equilibrium, cannot be easily applied when a multiplayer game should be considered to simulate the operation of the electricity market. However, the authors suggest using evolutionary game theory with Nash equilibrium to simulate the electricity market in the presence of more than two generation agents.

For Weber and Overbye (2002) Nash equilibrium can be a solution for bidding strategies in electricity markets. However, it is difficult to solve the market equilibrium problem because the characteristics of an electricity system, such as transmission constraints, make the market clearing mechanism difficult and make payoff functions non-differentiable. That is, the Nash equilibrium strategy may not exist, leaving only the mixed Nash equilibrium strategy.

As for Yang et al. (2011) the analysis of Nash equilibrium in electricity markets with imperfect competition is subject to two major challenges, the treatment of games with multiple players and the determination of the existence of multiple market equilibria. To solve these obstacles, the authors propose a solution method based on the payoff matrix approach and polynomial equations to calculate all market equilibria.

Belyaev (2010) states that the opening of the electricity market provided by the regulatory frameworks imposed by the government has caused an increase in energy transactions and related financial instruments to occur, corroborating the further development of the market.

The restructuring of the electricity system provided a secure, transparent, dynamic and reliable environment for the commercialization of energy. Energy may now be contracted according to ACR or ACL rules. Table 1 shows the main changes that occurred with the restructuring of the market.

Table 1 - Development of the electricity market in Brazil

SEB until 1995	Free market from 1995 - 2003	New SEB model as of 2004
Participation of State Companies	Opening of the market and the beginning of privatization of companies	Participation of State and Private Companies
Monopoly	Competition in the generation and commercialization of energy	Competition in the generation and commercialization of energy

Captive Consumers	Free and Captive Consumer	Free and Captive Consumer
Verticalized Sector	The beginning of the sector's deverticalization with the division of the generation, transmission, distribution and commercialization sectors	Deverticalization of the sector, activities divided into generation, transmission, distribution, commercialization, import and export
Public Financing	Public and private funding	Public and private funding
Tariffs are regulated	Regulated tariffs in distribution and transmission, but freely negotiated in generation and commercialization	ACL - freely negotiated price for generation and commercialization and ACR - the price for distribution and transmission of energy is negotiated in auctions and bids for the lowest price
Total market contracting without penalty	Contracting for distributors and free market 85% by 2003 and 95% by 2004	Total contracting of the energy produced in the market plus the reserve energy
Settlement of differences (surpluses and deficits) divided between buyers	Settlement of differences (surpluses and deficits) carried out at MAE	Settlement of differences (surpluses and deficits) in the Short-Term Market made at the CCEE
Planning prepared by the Electric Systems Planning Coordinating Group (GCPS)	Planning prepared by Eletrobras and the Ministry of Mines and Energy (MME)	Planning elaborated by the Energy Research Company (EPE)

Source: Adapted from (CCEE, 2019).

Most research has been done for hydroelectric and thermal power systems, where generators generally use bid-based pricing strategies for each hour of the day.

3 METHODOLOGY

This article analyzes the electric energy commercialization strategies in the period from 2012 to 2020 through active generation agents and competing in the short-term energy market, through the use of competitiveness graphs.

For this purpose, a time series of the PLD of the electricity market was manipulated available on the website of the Electric Energy Trading Chamber (CCEE) (CCEE, 2020a). The data refer to January 2012 to September 2020, totaling 210 observations for each submarket analyzed (Southeast / Midwest, South, Northeast and North).

For this, the igraph library was used together with the R programming language, in order to build a graph based on the mapping generated between selling companies and buying companies. Each stretch is added to the graph as a vertex, and edges are included from the list of connections between the participating companies. Using the methods offered by igraph itself, some of the inherent properties of the network as a directed graph were calculated.

A directed graph is a network in which each edge has a direction from one vertex to another, that is, each edge has the shape of an arrow (Newman, 2010), as can be seen in Figure 8. Mathematically, a directed graph D , consists of a collection of vertices V and a collection of arcs A , which we can represent by $D = (V,A)$ and each arc with specific adjacent vertices: tail and head (VAN STEEN, 2010).

The network are directed graphs represented by companies that buy and sell energy, the size of the vertex tells about the quantity bought and sold of energy in amounts of MWh.

4 RESULTS AND DISCUSSION

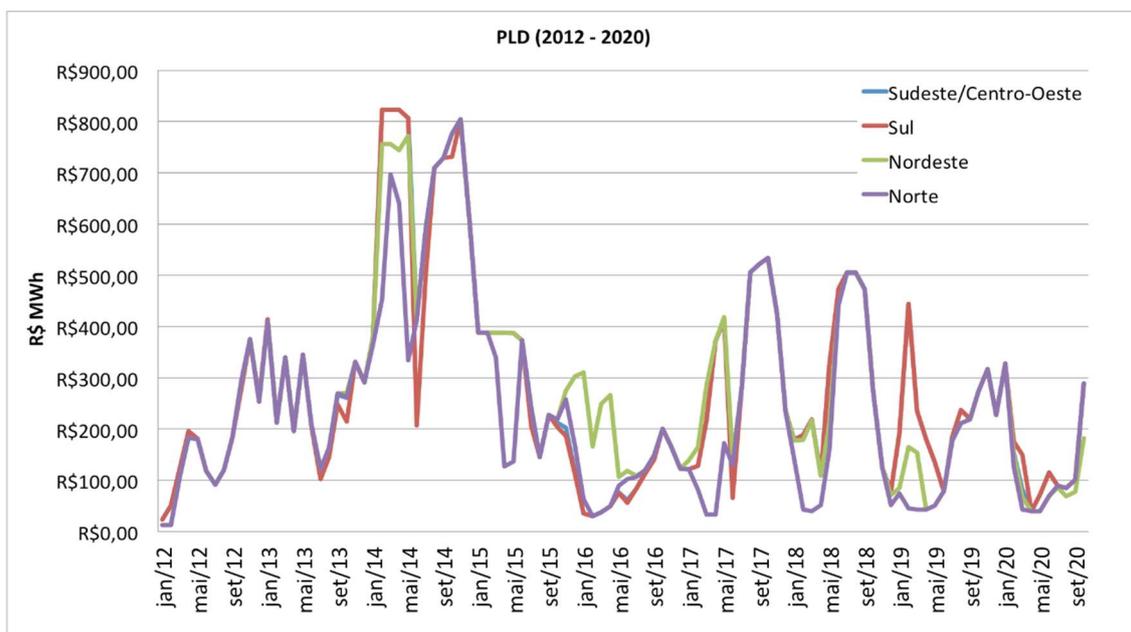
The commercialization of energy in the Brazilian Electric System (SEB) occurs between the agents participating in the Electrical Energy Commercialization Chamber (CCEE) by means of purchase and sale contracts. The CCEE accounts for the differences between the energy that was contracted and what was generated and consumed, this difference (the

surplus) is valued through the price of settlement of differences (PLD) in the short-term market.

The commercialization of short-term energy in the free environment occurs with free negotiation among the agents involved. The purchase and sale of energy, the delivery period and the volume are freely negotiated between the agents and concluded through contracts registered with the CCEE.

The SEB's main source of generation is hydroelectric power plants. In times of little rain, these plants cannot be activated and thermal plants have to be put into operation. Because of this, the minimum price of energy observed in Figure 1 corresponds to the operational cost of a hydroelectric plant (UHE), while the maximum price corresponds to the operational cost of a thermoelectric plant (UTE) which are more expensive.

Figure 1 - Historical series of the difference settlement price (January 2012 to September 2020)



Source: Prepared by the authors with data from (CCEE, 2020a)

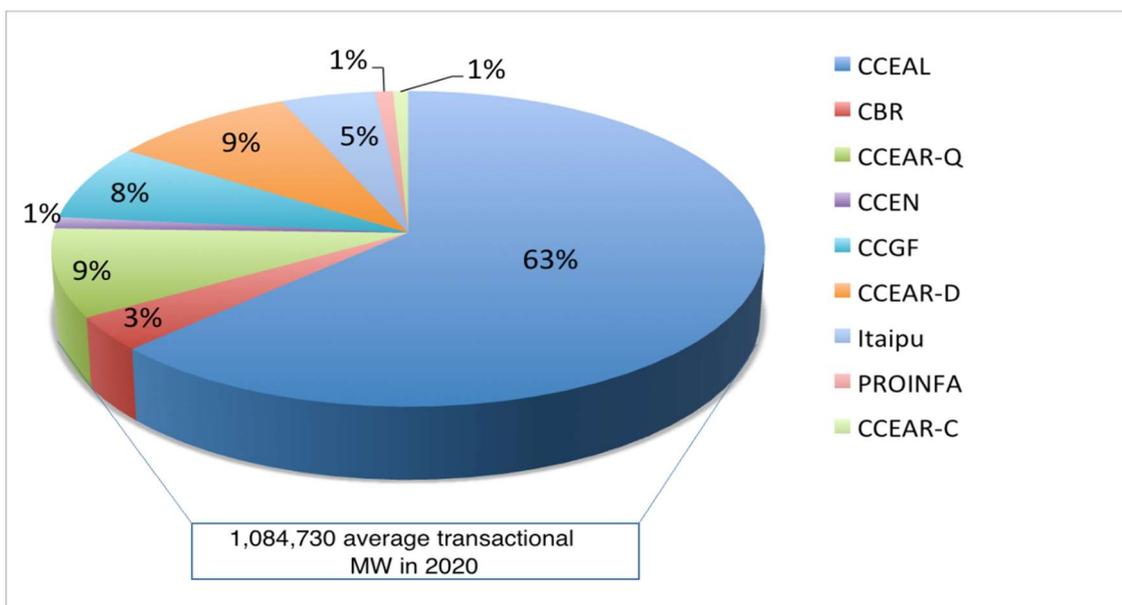
When analyzing the historical series of the PLD of the Southeast/Central-West, South, Northeast and North submarkets (Figure 1) between the period from January 2012 to September 2020, it is observed that the beginning of the decade was marked by a period of

low price behavior followed by an increase in the following years. It is noted that prices are inconstant, with records of high prices, such as in the period between February and May 2014, when prices reached the mark of 822.83 R\$/MWh and between August and November of the same year, when they reached prices between 709.53 to 804.54 R\$/MWh. In 2017, the PLD rose again, however, in this period it did not exceed the 533.82 R\$/MWh mark.

The volatility of the PLD for example, in the months of January 2013 with the average energy price at 413.95 R\$/MWh, in February 2014 with 822.83 R\$ and September with 728.95, and October 2017 with 533.82 R\$/MWh show that energy production was very expensive at that time, this event being motivated by reasons such as, lack of rain and increase in energy consumption. This increase in price, influences the future curve of prices charged to the final consumer in the following year.

In 2020 approximately 1,084,730 average MW of energy were transacted in the Brazilian market. Figure 2 shows the amount contracted in each type of contract.

Figure 2 - Contracts by type and amount in average MW



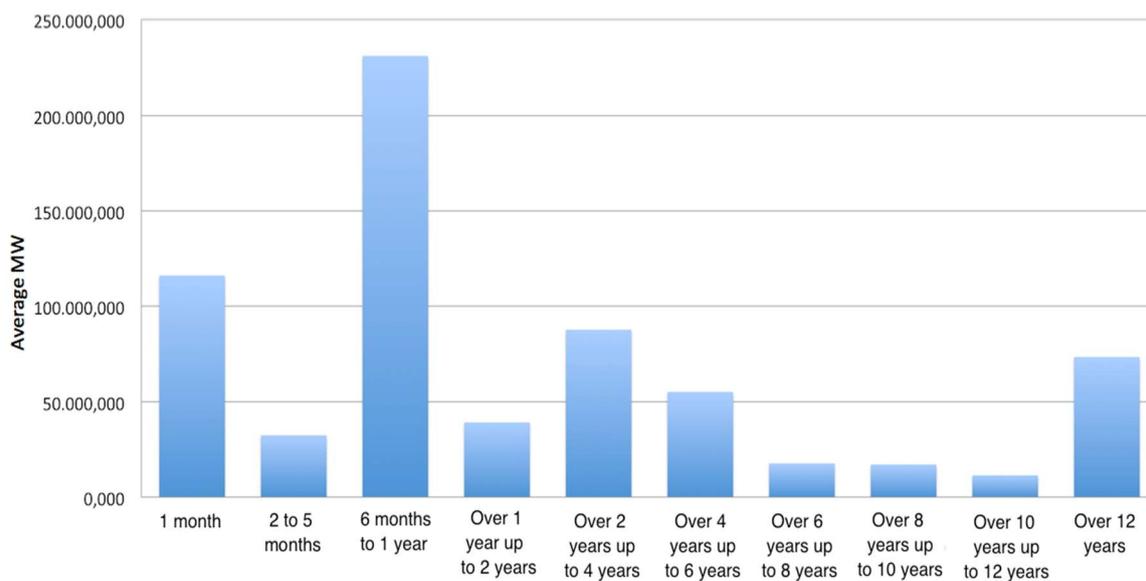
Source: Prepared by the authors with data from (CCEE, 2020b)

Note in Figure 2 that 63% of the contracted energy was negotiated through electricity commercialization contracts in the free environment (CCEAL), followed by quantity contracts (CCEAR-Q) and availability contracts (CCEAR-D).

In the quantity contracts modality (CCEAR-Q), the seller is responsible for the delivery of a certain quantity of contracted energy and assumes the risks in case unfavorable hydrological conditions affect the energy supply. On the other hand, in the availability contracts modality (CCEAR-D), the seller commits to make available a specific volume of energy capacity and the costs resulting from hydrological risks are assumed by the buying agents.

The purchase contracts considered in the CCEAL were executed by Independent Producers, Auto-producers, Generators, Retailers, Free and Special Consumers and Distributors, representing a seasonalized volume of 110,293.68 average MW. Figure 3 presents the contracted amount in average MW and the duration of the contracts. Note that the contracted amount is higher in the 6 month to 1-year period, followed by 1-month contracts.

Figure 3 - Purchase contracts by duration and amount in CCEAL in average MW

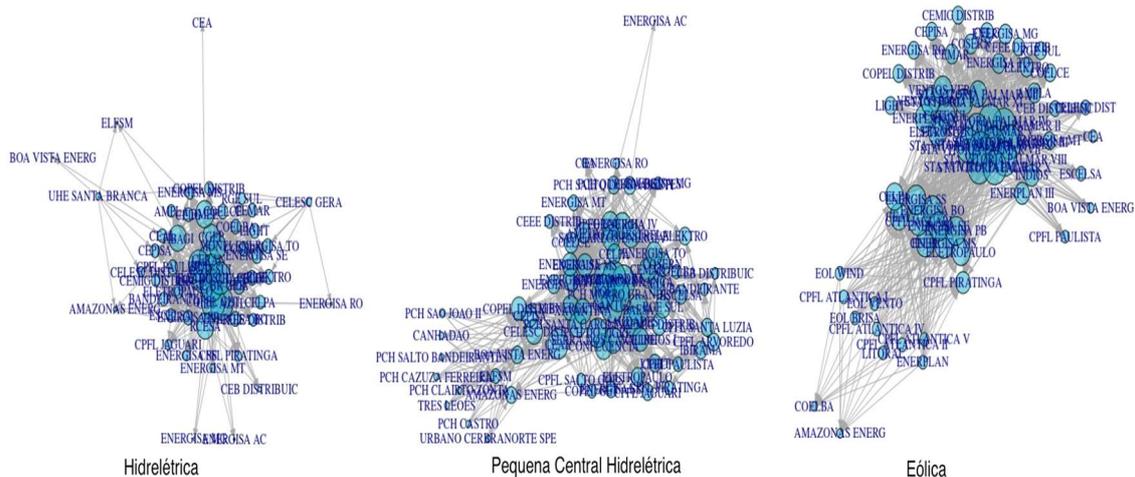


Source: Prepared by the authors with data from (Ccee, 2020b)

According to Nogueira and Bertussi (2019), the free energy market is an essential tool to promote competition, efficiency and technological innovation in the national market.

Based on the data set of contracts for the sale of electricity on the free market, the method of competitiveness graphs was applied. The results show that the most competitive energy sources in the South submarket are those generated by the Hydroelectric, Wind and Small Hydroelectric sources as shown in Figure 4.

Figure 4: Graphs of the most competitive energy sources in the South Submarket



Source: Prepared by the authors (2020)

The larger the circles in blue, the greater the number of contracts negotiated by the agents. The negotiation of the purchase and sale of wind power, involved 28 selling agents who negotiated 15,954,012.07 MWh in contracts. Of these 28 agents, the most competitive were in order, CPFL Atlanta V, CPFL Atlanta I, CPFL Atlanta II, CPFL Atlanta IV, CPFL Atlanta V and Eletrosul. The six largest selling agents, negotiated together 5,313,989.00 MWh in contracts in 2020.

The largest volumes negotiated come from the hydroelectric source with 89,663,498.76 MWh negotiated for the South submarket. Among the agents, the six most competitive were the energy producers Engie Brasil GER, Foz do Chapecó Energia S.A, Copel GET, CGT Eletrosul, Geração Céu Azul S.A and DME ENERGETICA S.A. - DMEE. Engie Brasil is

energy because it is very expensive. As 2020 is a year of drought almost all over the country, 30,606,192.11 MWh of energy ends were negotiated to meet the energy consumption of the country.

In 2021, the hourly PLD model comes into force, giving more detailed and faster information to the sector's agents. The quantities sold are valued at different prices and terms, and can generate significant disbursements (DE AMARANTE et al., 2018). However, according to (OLIVEIRA, 2020), the hourly price will impact the valuation of the agent's exposure in the market, and as in any other speculative market, being exposed to price variation, will bring risks and opportunities, leaving the agent to take the decision to continue speculating and be subject to hourly price volatility, or to seek security in your contracts.

CONCLUSION

In this research the strategies for the commercialization of electric energy were analyzed by generation agents acting and competing in the short-term energy market, through the use of competitiveness graphs. The agents involved in the commercialization (buying and selling) of energy in the southern submarket were analyzed. It was seen that the agents buy according to the need of their energy demand. The contracts involve in their majority, purchases by duration and amounts in a period for six months to one year. One-month contracts were also seen; these contracts generally seek to supply extra consumption.

Among the largest generating agents, the most competitive were those that sell energy from hydroelectric, thermoelectric, wind and small hydroelectric plants. The most competitive were Engie Brasil GER, Usina Termelétrica Pampa Sul - ENGIE Brasil (PAMPA SUL) and the CPFL group (Atlanta V).

ACLNOWLEDGMENTS

The authors would like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES) for funding this research project.

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HOW TO QUOTE THIS ARTICLE

Mendonça, A. K. S. et. al.. Analysis of the strategies for the commercialization of electric energy of generating agents in the short term environment. Santa Maria, v.25, e14, 2021. Available from: <https://doi.org/10.5902/2236117064441>. Accessed: Month Abbreviated. Day, year.