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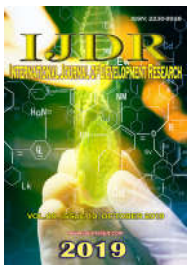

RESEARCH ARTICLE OPEN ACCESS

# GROWTH OF THE PARTICIPATION OF WIND ENERGY IN THE ENERGY-BRAZILIAN ENERGY MATRIX: AN ANALYSIS FROM THE REGULATORY FRAMEWORK

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**ABSTRACT**

This work presents as its central goal to analyze whether the electricity auctions that occurred between 2009 and 2014 favored the growth of wind energy participation in the Brazilian energy matrix. It aims to evaluate how the new theoretical frameworks of regulation in the electric industry collaborate to increase the search for alternative sources, specifically regarding wind power. It uses Demsetz's analysis (1968) to discuss the mechanism of operation of public services utility in order to understand the wind power auctions that happened in the analyzed period. In addition, this paper contains a brief presentation of the current configuration of the Brazilian electrical sector, including the recent regulation model and the most relevant changes in the composition of the national energy matrix. The results show that regulation through auctions has contributed to the diversification of the energy matrix, increasing the share of renewable generation sources such as wind power. However, it is also necessary to adjust some particularities of the auctions for more successful results regarding increasing the diversification of the energy matrix—focusing on renewable energy—and reducing dependence on hydroelectric power.



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## INTRODUCTION

This article aims to analyze how the development of the regulatory framework in recent years is affecting the national energy sector, especially regarding alternative sources of energy, in particular wind energy sources. To do so, we will analyze the auctions of electric energy carried out between 2009 and 2014, seeking to identify how much energy in the wind modality was contracted in relation to the energy matrix and characterizing how the concern with renewable sources by the sector has been growing, as well as the problems faced in making this expansion even more effective. For the development of the work, a review of the literature related to economic regulation (of the markets) will be done, as well as an explanation about the regulatory practice, exposing what led to its emergence, what it consists of and what criticisms led to the questioning of their need in some sectors of the economy. Greater emphasis will be placed on regulatory issues related to auctions, as part of this process takes place through the concession of this sector of public utility, through the mechanism of regulatory issues, to the private sector of the economy. The discussion will be based mainly on the propositions found in the so-called Demsetz critique (1968), in which the author questions the practice of regulation and exposes his point of view about the operation of the auctions that transfer the operation of concessionary activities to the private sector. The following is an overview of the current situation of the Brazilian energy matrix, with emphasis on the wind energy modality, explaining how the degree of concern with renewable energy sources has increased not only in Brazil, but in several other countries, mainly as a consequence of the environmental impacts caused by the predominant sources of most of the world's energy generation. It is worth remembering that in the Brazilian case the hydroelectric source, which makes up about 60% of the matrix, is considered clean, but also has strong environmental and social impacts when it is implemented, as well as exposing the country to supply crises due to long periods of drought and insufficient investments to cover the full sector demand. The operation of the Brazilian Electrical System will also be the subject of an analysis in the present work, emphasizing the main modifications of the energy production chain that have

occurred in recent years, aimed at the unbundling of the sector, and how this configuration is associated to the functions of the main sector, mainly of the National Electric Energy Agency (ANEEL). Finally, wind power auctions will be analyzed, including how these are contributing to the increase of the share of this source in the national energy matrix. Such an assessment will be made in light of the prospect that energy auctions arise to balance supply and demand for energyand to contribute to a greater share of new energy sources in the national matrix. Therefore, electric power auctions are considered as a parameter to show how the interests of the investors in the market in question are conditioned, and how they are contributing to the increase in the supply of energy from that source.

## MATERIALS AND METHODS

This section presents a microeconomic introduction to imperfect competition models, conceptualizing market failures and explaining how they contributed to the emergence of regulatory practices, with emphasis on "monopoly power," which can be applied to some public utility services.

### The Regulation Theory

Economic regulation theory expresses governmental actions that have the objective of limiting the freedom of choice of the economic agents, especially of the companies that hold high levels of market power. Thus, when a regulating agent (an agency responsible for some sector of the economy, such as electricity, telecommunications, etc.) sets a tariff for a particular service, it is restricting the freedom that a company has to set the price for its activity. (PINTO JR, FIANI, 2013). As is known, regulatory practices go far beyond tariff intervention, they also act on quality issues, raising the level of competition in the industry, evaluating mergers, acquisitions or other forms of combined acts, etc. The Brazilian electricity sector has a specific regulatory body, ANEEL, whose most detailed evaluation of its attributions will be made throughout the work, has, as its main attributions, regular generation (production), transmission, distribution and commercialization of electric energy; it is supervised, directly or through agreements with state agencies, concessions, permits and electric energy services; it implements the policies and directives of the federal government regarding the exploitation of electric energy and the use of hydraulic potentials; it establishes tariffs; it resolves differences at the administrative level between the actors and between those actors and consumers; and, it promotes the activities of granting concessions, permits and authorization of electric power projects and services, by delegation of the Federal Government.[1] In order to evaluate some of these attributions, we will briefly discuss below some theoretical and conceptual approaches on the functioning of markets and on regulation.

### Why Regulate?

Regulation can be defined as an essential practice in defense of competition, which tries to extract the maximum possible efficiency from the functioning of markets (MELLO, 2013).
Exploring briefly the history of regulation shows that this practice arose to prevent large companies from abusing market power. As small businesses have grown, with the goal of covering ever-larger spaces, there has been a search for economy by larger companies, which have acquired the smaller competitors, giving them greater control in this way and thus moving toward an oligopoly or monopoly situation. Since they were occupying positions of greater power, the companies charged high rates / tariffs from the consumers, aiming to maximize their profits, which generated a decrease in the social well-being. With large companies dominating markets, the government decides to set rates and create regulations to reduce abuse of power by large companies, both for smaller companies and for consumers. Moreover, without regulation in the more concentrated structures, there would be no incentive for competition itself, without stimulus for innovations (SALGADO and MOTTA, 2005). Regulation tries to cover both competition and monopoly situations at the same time. Regulation, in the economic sense, is used along with a measure to reduce the inefficiency generated by market failures, and it may consist of this al locative inefficiency (when the optimal quantities are not produced or consumed), technical / productive (when not produced at the lowest cost possible), or remain dynamic (when not enough resources are used to develop innovative practices) (PINHEIRO and SADDI, 2005).

The state is also led to regulate certain services for some strategic reasons. Among them is the pressure that specific groups place on the government in order to defend interests of the sector that will be regulated. In addition, there are the political goals sought by the government itself with respect to the exercise of power (PINHEIRO and SADDI, 2005). As this paper tries to evaluate the electric power sector, this should be understood within a specific perspective linked to public utility services of infrastructure. In this sense, Fagundes, Pondé, Possas (1998) consider that the regulation pattern of this activity should be classified as active regulation. Active regulation is the type of intervention that uses regulatory mechanisms and goals that tend to achieve greater economic efficiency in its broad sense, above all because of its importance and its impacts on society. The following will present some theoretical elements that are directly linked to the regulatory process of public utility activities of infrastructure, which will be applied to the electric power sector.

In 1968, Harold Demsetz had already questioned the need for regulation of companies providing public utility services by the government. For the author, the natural monopoly theory is not a reason for the price charged by the company to be the monopoly price. Demsetz (1968) considers the theory of natural monopoly to be very concise and not clear —since it cannot explain how production in an economy of scale may incur the monopoly price. He argues that regulation is used as a justification for avoiding a monopoly price, but actually serves to mask the discomfort generated by competition, which favors large companies. Deregulation is characterized by the reduction of supervision and the imposition of rules on companies, reducing state intervention in the functioning of the market that is, replacing state control with the competitive structure (KON, 2001). It is crucial to note that deregulation does not mean the absence of regulation, but that it is an antonym for creating barriers in the markets in order to maximize the benefits of the resources of the economy (PINTO JR.; FIANI, 2013). Because of regulation, some companies began to adhere to practices that tried to circumvent these rules established by the state, such as collusion, cartel and trustee, and corruption may even be a consequence of

[1] For more details see: http://www.aneel.gov.br/a-aneel.

these processes (BASSO and SILVA, 2000). An auction has its operation defined according to the number of bidding parties (bidder). The bidder must offer fair values, and what he earns is what puts the lowest fare with the highest bid, meaning that he can produce the same as the others but at a lower cost. It should be noted that in addition to offering the lowest tariff, the auction winner must commit to generating greater efficiency in the sector, improving the quality of the service provided and being able to satisfy the demand. If two or more equal tariffs are considered to be the lowest, the government will define some other criterion to decide which one will be chosen, or the parties that are not selected can cede their contracts to the one that has won. Sometimes it can happen that a bidder proposes a very low rate, but cannot assume it later. This is probably because the bidding company expects that after the bid is approved a readjustment will be made so it can bid at such low rates. There are also tariff-updating mechanisms, which can make adjustments according to some unforeseen circumstances or even at any given period. Another relevant aspect concerns the contracts that are assumed.

These contracts, as a rule, have a very long term, and it is not possible to predict everything that will happen in this period with the company and the market, so that most of them foresee some adjustments, such as inflation rate readjustment in force. For this auction to work, it is important to establish that there are no barriers to entry of participating companies, as this increases the credit of other bidding parties. It is also important to note the fact that the auction culminates in the reduction of the extraordinary profits, because the more bidders there are, the closer the situation comes to putting the price equal to the marginal cost, approaching a competitive situation (JÚNIOR and NETO, 2006. It also addresses the issue of collusion between companies, bringing some aspects such as the fact that although the number of collusive companies influence production, this will not necessarily be decisive for the cost of collusion. Some characteristics of collusion formation are explained, such as the fact that its members do not rely on prices of other activities or other companies. In addition, the author makes clear that the more interested a company is in participating in this eventual collusion, the lower their profits will be. This occurs until the time the profits earned by the members of the collusion equals the cost of participating in this collusion.

From there, if a company resolves to break the agreement, it will achieve larger profits for a short period. Collusion disintegrates once the firm's private cost of collusion becomes greater than the firm's cost in a competitive situation. Demsetz (1968) calls attention to some particularities of the auctions from the bidding franchise. This system shows that only a small number of companies providing public utility services can supply the quantity needed to meet a particular market segment. If there is a moment to determine the companies that will be able to perform the service in the most appropriate way, it is because competition has already existed between the rivals who were disputing to be selected to integrate this system. The companies that are responsible for this production are those that offer the best combinations (best package) between low costs and quality of service or product. Based on this, the author explains the need for duplication of infrastructures, since they are already granted through the auction.

Another situation would be when there is public ownership. Demsetz (1968) argues that public authorities do not have sufficient basis to determine the price to be charged, so the price reflects at least the opportunity cost of using scarce resources, so that over-utilization could occur that would not occur if an appropriate tariff were established. The author lists three difficulties encountered for the determination of this rate by the public power, they are: 1) there is a full understanding of the necessary requirements for the use of the resources in question in order to generate efficiency; 2) if there is interruption in the services this will not have such a high cost; and (3) putting a very high rate in order to eliminate the high utilization of services would be impractical. For the author only the last condition gives some scope for the existence of regulation, considering that the costs generated could still be higher than the return. In this case, there would also be competition between companies to try to offer the lowest price for the service in question. This decision would fall to the regulatory commission. However, the author makes it clear that even in the two cases described in which regulation has appeared this does not mean that it is desirable. The market replaces the regulatory commission.

Demsetz (1968) also explains the problem with windfalls (unexpected inheritances), an issue that concerns long-term contracts. As exemplified in the electricity market, the contracts signed by the companies that will be responsible for the projects made possible in the auctions have a duration of 20or30 years, a common feature of the public utility concession contracts. In such a long period, changes in the conditions of production may occur. Incidentally, if the contracts have a very short duration, this may incur higher costs. The central variable in this study is the uncertainty about what the future production conditions will be. In addition, innovations, transformations in the productive process and increase in the prices of the inputs are also variables that can change the costs, meaning that the reality does not follow what was established in the contracts. In this situation, prices must change in order to keep pace with changes in production costs. Again, in this situation, the regulatory commissions would get involved, as there is no possibility of revising the contract signed years earlier. However, Demsetz (1968) contradicts this need for regulation, arguing that when experts write the contract, it ends up being satisfactory to both parties. It also states that the contract may contain some clause that gives rise to renegotiation. It also says that a cost-plus system could be used, which would put a rate on unplanned earnings. In addition, there is a distinction between windfalls and forecast able rents, stating that while the first form deals with unexpected gains, the second deals with something that is already predicted. In this way, the initial bid will include those expected earnings. The questions posed by Demsetz's critique ask us to evaluate the regulatory process of the Brazilian energy sector and how it has acted to increase the participation of wind energy in the national matrix, as well as whether this practice has been efficient in its attempt. To do so, a brief evaluation of the Brazilian regulatory process will be made, with emphasis on the National Electric Energy Agency (ANEEL).

**Regulation in Brazil**

When it comes to utilities, many cases refer to monopolistic structures, such as gas supply, piped water, fixed telephony, transmission and distribution of electricity, etc. According to

ANEEL and ONS (National Electricity System Operator), two major changes deserve attention: the privatization of the companies—the cost is higher for the government when it needs to supervise a private company in relation to the control of a state enterprise, and the political objective is not always in accordance with the interests of a population (SHAPIRO and WILLING, 1996—and the institution of a new model within the electric power plant sector in Brazil, which aims to ensure that energy demand is met. All of these date back to the second half of the 1990s, and occurred in the midst of a new economic context being implemented, especially from the Real Plan. It was from the 1990s that Brazil and several other developing countries began an era of economic liberalization, privatization and reform. According to its formulators of the economic policies adopted in this sense, one of the objectives of these changes in the economic scenario was to make the companies more competitive and to seek better functioning from new investments. The scenario facing the world at that time drove these events, which was dissatisfaction with the economic consequences of the crisis in the 1970s (FIANI, 1998). Within a world scenario that sought greater economic openness, in a process initiated in the late 1980s in the Washington Consensus and led by countries like the United States and the United Kingdom, a concern arises with the process of deregulating the markets. As we know, the Washington Consensus was an agenda planned by economist John Williamson, which consisted of some measures aimed at macroeconomic stabilization (WILLIAMSON, 2004).

Among the proposals were the privatization of companies that were controlled by the government and the reduction of barriers to entry of potential incoming companies, as well as a new institutional regulatory framework, such as the adoption of new antitrust legislation. In Brazil, the 1994 Antitrust Law (Law 8,884 / 94) reflects the effects of this scenario. It is through this law that the CADE (Administrative Council of Economic Defense)—which makes up the SDBC (Brazilian System of Defense of Competition)—became a federal authority, becoming relatively independent of the state, with financial and administrative autonomy, despite its being appointed by the Executive. The CADE judges whether a company has committed an infringement of the economic order. In addition, the Concessions Law (Law No. 8987/95) came into force in Brazil, in 1995, in the context of the widespread privatization of public enterprises, which transferred oligopolies and state monopolies to the private sector. It determined how public services should be regulated in the country after the creation of several regulatory agencies.
These regulatory agencies, although some of them already existed in Brazil before this decade, come to symbolize more strongly the way in which the government would act on activities that were previously public sector and which had been privatized. In the energy sector, ANEEL was created in 1996, during the government of then-President Fernando Henrique Cardoso, with the function, among other things, of increasing the level of competition in the energy market, in addition to determining the tariffs / rates applied in the sector. It is worth mentioning that ANEEL acts on the four phases of the productive chain of the sector of the sector: generation, transmission, distribution and commercialization, whose details will be presented next.

**The Electrical Energy Sector in Brazil**

The electric power sector in Brazil currently has a productive chain divided into the generation, transmission, distribution and commercialization segments. The energy generated in the country comes from several sources, the main one being hydroelectric power. However, there is already concern about the search for renewable sources of energy generation. Regulation in the sector is done through regulatory agencies that are organized in the structure of the Brazilian Electric System. In this sense, in the energy sector the regulation also happens through the auctions of purchase and sale of energy.
The electric energy travels along a path from the place where it is generated to the place where the final consumer is located. In 1996 a project was started, which had as one of its objectives the unbundling of the Brazilian Electrical System (SEB), under the coordination of the Ministry of Mines and Energy, which was renamed RE-SEB Project (NUNES, 2009). The Concessions Law also represented a milestone in the verticalization of public utility services (CHIGANER et al., 2002), enabling segmentation in generation, transmission, distribution and commercialization. From the last decades of the last century, countries began to seek greater efficiency in the production, transmission and trade of energy. The creation of regulatory mechanisms, the possibility that sectors that were originally monopolistic (SANTOS and GHIRARDI, 2003) and regulated by the state were considered to be competitive, as well as the unbundling of the segments of a given activity within a productive chain, helped the development this process. Hence the division between the management of these segments.

There are differences between the microeconomic models that lie behind each of the segments. In this case, the generation and marketing parts are encouraged to become more and more competitive, one of the objectives of the electric sector reform. The transmission and distribution parts are considered natural monopolies, given the complex infrastructure required for such activities, which makes it economically unfeasible to have many companies in the same industry. So they are also more regulated. Within the proposed reform of the electricity sector in the late 1990s was the search for free access to transmission and distribution networks (GOLDENBERG and PRADO, 2003). It is the segment of the generation that is responsible for the production of electric energy. There are several generation ventures, but most of them are currently concentrated in thermoelectric power plants. Until 2012 it was a field that was considered competitive, but since then the prices came to be controlled by ANEEL. In particular, the segment receives funding from BNDES (National Bank for Economic and Social Development) when it comes to renewable energy projects, such as solar, biomass and wind.

This branch has the function of transporting the energy generated by the plants. Brazil innovated with the creation of transmission as an independent field; prior to the change, the transmission tasks were carried out by the distribution companies. The number of transmission projects is much smaller than that of generating ventures. However, if a transmission line suffers some sort of unforeseen issue, an entire city, or even a state can run out of power for as long as it takes to resume normal line operation. This branch has rigid regulation, since the necessary structure for its operation is very complex (SERRATO, 2006) and, therefore, it is impossible for many small companies to exist in the sector. To integrate the transmission part, the company must win a transmission auction and join the concession agreement with the government.

The costs of the electricity sector are divided between energy generation, transportation (transmission and distribution) and sector charges which are taxes that affect costs (ANEEL, 2017). With the development of the country, there is an expansion of the transmission systems, which results in an increasing increase of expenses with this segment of the sector. In addition, since most of the energy generated in the country is hydroelectric, this implies that the power generation points are outside the large consumer centers, which requires a more elaborate transmission system. The energy distribution system has the role of injecting the transmitted energy into the consumer units (companies, residences, factories, etc.). The distribution companies also have their prices controlled by ANEEL, and they adhere to concession contracts. The largest portion of the energy distribution business is run by the private sector. It is an extremely diversified system, since it needs to reach consumers directly. The regulation also has a strong influence on the distribution area, since in addition to being a public service, ANEEL itself establishes rules to be complied with.

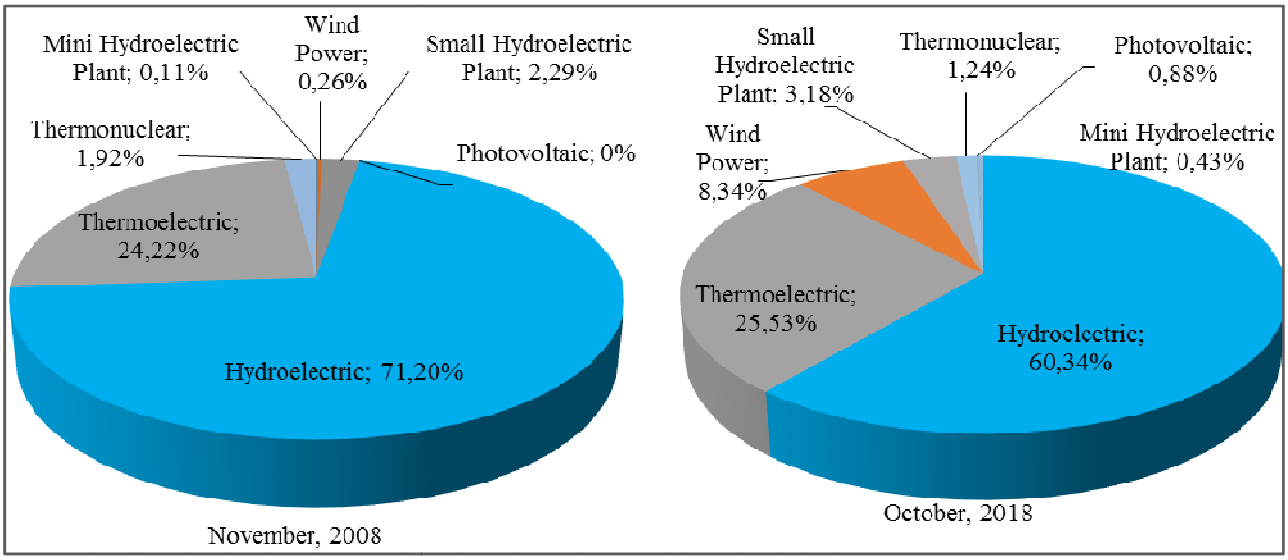
Being a recent creation, it has as its main body the Chamber of Commercialization of Electric Energy (CCEE), which was created in 2004 replacing the Wholesale Electricity Market (MAE). It is through this that the activities of buying and selling energy are carried out. It is the CCEE that runs the electric power purchase and sale auctions in Brazil, previously controlled by ANEEL.

**The Brazilian Energy Matrix**

The Brazilian energy matrix is considered one of the cleanest in the world because it has a large part of its energy being generated by hydroelectric power plants such as Itaipu in Paraná and Belo Monte, São Luiz do Tapajós and Tucuruí in Pará. Reason for the high dependence of this source, which has already resulted in energy rationing because of lack of water. In the middle of 2001, the country suffered from the possibility of a blackout, which was aggravated by the lack of rainfall during the same period and caused the population to undergo rationing. In 2015 the country also suffered from the dry season, which forced the population of cities such as São Paulo to reduce energy consumption.

Moreover, even the water source generates social and environmental impacts, such as those arising from the construction of a hydroelectric power plant, including flooding of a large area, causing many people to leave their homes, as well as the modification of fauna and local flora. The graph below shows the percentage of the main energy modalities within the national energy matrix, considering the plants in operation, showing the evolution from the end of 2008 until 2018. The search for new energy sources also came as a result of concern about the environmental impacts caused by the energy sources that stand out in the world market, which are non-renewable energies, such as petroleum and coal, that generate pollution, contributing to the destruction of the ozone layer and being one of the main causes of global warming (PINTO JR, 2016). In addition, it is necessary to consider that other energy sources have great potential or generation in the country, as is the case for photovoltaic sources and particularly of wind; some studies indicate about 60,000 MW potential for this source (ANEEL, 2002).

From an economic point of view, rising oil prices in times of crisis, as in the case of conflicts in the countries of the Middle East, are also a reason for the search for new sources of energy generation. Therefore, programs to encourage the use of renewable energies, such as PROINFA (Incentive Program for Alternative Sources of Electricity) in Brazil, created in 2002, aim to increase the participation of wind energy in the national energy matrix. To own projects of small hydroelectric power plants and thermoelectric power plants that use as fuel biomass, thus contributing to diversify the composition of the national energy matrix. Initially, the program established the generation of 3,300 MW of power, equally divided among the three sources mentioned above. PROINFA is financed by BNDES for about 70% of the project (SALINO, 2011), but also receives support from other institutions, such as the Bank of Northeast of Brazil (SIMAS, 2012). However, the policies that encourage the use of renewable energy have still been only minimally explored, so it is not visible to the population how much benefit would be generated by replacing the sources that are the majority in the current energy matrix—oil products—from renewable sources. Reducing pollution and making better use of the abundant natural resources in the



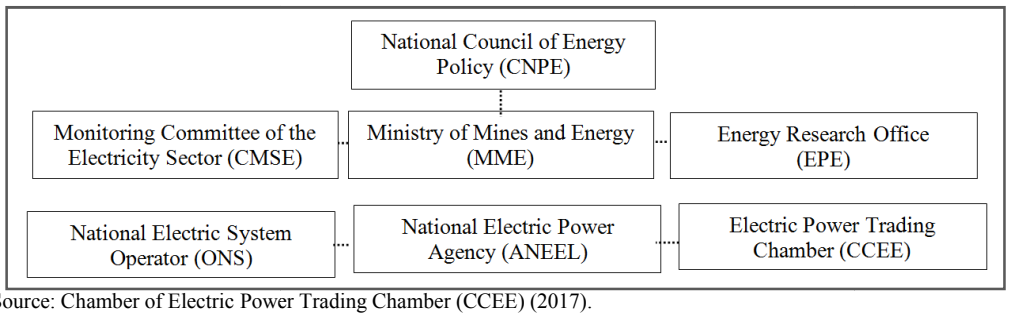

Source: Authorship, using data from the Generation Information Bank (BIG) of the National Electric Energy Agency (ANEEL) (2018).

**Figure 2. Evolution of the composition of the Brazilian energy matrix, projects in operation – 2008 and 2018**

Country are clear consequences, but it is necessary to create this idea of sustainability, of sustainable development, in the Brazilian mentality.

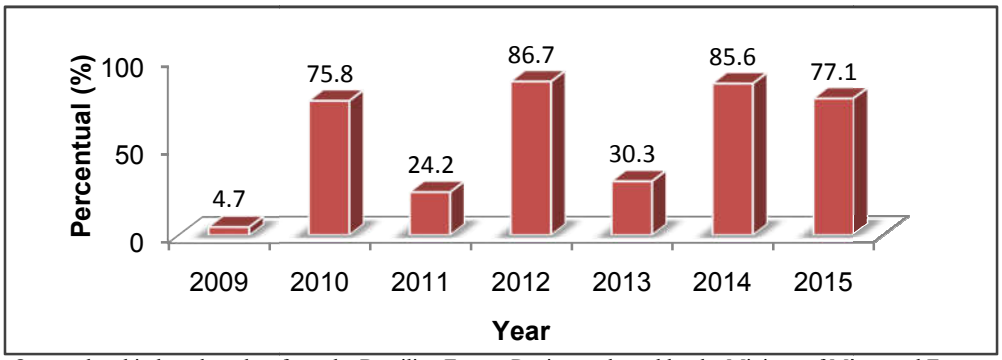
## The Brazilian Electrical System

The Brazilian Electricity System is composed of the National Council of Energy Policy (CNPE), which communicates directly with the Presidency of the Republic, and its main functions are to coordinate energy programs and specific policies for each region of the country and to evaluate the energy matrixes more pertinent to each locality. Under the CNPE is the Ministry of Mines and Energy (MME), which is in charge of planning energy policies and implementing them. Under the care of the MME are the Electric Sector Monitoring Committee (CMSE), which oversees the operation of the electric power production chain, and the Energy Research Company (EPE), which is responsible for carrying out the studies and research required by the sector, as well as providing information on important events such as power purchase and sale auctions. In addition to ANEEL, which is linked to the MME, one can cite the National Operator of the Electric System, which was created two years later, under the coordination of ANEEL, with the purpose of supervising the operations within the field of generation and transmission of energy. Also, in 1998, the Wholesale Electricity Market (MAE), which was responsible for commercial energy transactions, was replaced by the Electric Energy Trading Chamber (CCEE) in 2004. In the following diagram, it is possible to better visualize how the organs of the sector are organized.




Source: Chamber of Electric Power Trading Chamber (CCEE) (2017).

**Figure 3. Brazilian Electrical System**




Source: Own authorship based on data from the Brazilian Energy Reviews released by the Ministry of Mines and Energy, released from 2010 to 2016 (2017).

**Figure 4. Expansion of domestic wind energy supply in Brazil – 2009 to 2015 (percentage growth rate)**

In order to guarantee energy supply, a new model for the commercialization of electric energy was created during the first Lula Government, described in Laws 10,847 and 10,848 of 2004 (PINTO JR, 2016). With the central objective of balancing the supply and demand for energy, the practice of energy auctions became the main means of controlling the demand and supply of energy in the country. From the auctions, it is possible to identify which energy modalities are attracting greater interest from companies and investors, as well as contribute to the development of new energy modalities and lead new investors to enter that market. The operation of the auctions, based on the number of companies willing to participate in them, is what regulates the energy market. In this case, the role of the government is to regulate the operation of these auctions, which occur in the Regulated Contracting Environment (ACR) (PINTO JR, 2016). As the work focuses on increasing wind power production, greater emphasis will now be placed on this source, whose use of wind energy brings positive externalities, such as a reduction in environmental and / or social impacts (ALDABÓ, 2002). There is also an increase in the number of jobs (SIMAS and PACCA, 2013) and an increase in the degree of investment in technology, which has also resulted in a drop in external marginal cost, which is the additional cost resulting from the externality that is not determined by the company, but externally to it. Following is the growth in percentage terms of the domestic supply of wind energy in Brazil from 2009 to 2015.

## Wind Energy in Brazil

This paper analyzes the auctions of electric energy in which wind energy was contracted in the period from 2009 to 2014, considering the power generation projects, using data provided by the Energy Research Company, the Electric Energy Trading Chamber and the National Agency of Electric Power (Generation Information Bank). A comparison is made between the total power contracted in the auction (in MW) and the wind power (in MW) to reach a percentage of how much wind energy was contracted by auction analyzed. Also explained is the average price at which wind energy was

contracted at the auction. Next, an analysis of the data is made showing how auctions have contributed to increasing the percentage of not only wind energy, but also other renewable sources in the national energy matrix. This analysis takes into account data such as the estimated investment amount for that auction, the duration of the contracts and the uncertainty factor due to the long period between the auction and the end of the contract. Data on the distribution of generation ventures made possible by the analyzed auctions are explained, indicating the states of the country in which the wind energy projects will be implemented, in addition to relating the total number of projects of each auction with the number of projects made feasible for the source the same auction.

Finally, an analysis is made of the particularities of the analyzed auctions, analyzing the effectiveness of the regulation in increasing the participation of wind power in the national energy matrix. The following describes the types of auctions analyzed:[2]

- Existing Energy Auction: may be type A-1, in which the contracted energy has a delivery term of one year after the contract closes. Given the short period the ventures are already in operation and therefore have a lower cost. It can also be an Alternative Sources Auction, which is characterized by promoting a greater participation of renewable sources in the national energy matrix—such as wind power, biomass, photovoltaics and small hydroelectric power plants. There is also the modality of an adjustment auction, which is used to complement the energy that is lacking to serve the distribution segment, with short-term contracts. There is no case of an adjustment auction among those that will be analyzed.
- New Energy Auction: may be type A-3, in which the contracted energy has a delivery term of three years after the contract closes. It aims to increase the load of distributors. It can also be A-5 type. In this case, the contracted energy has a term of five years to be delivered, after the closing of the contract.
- Reserve Energy Auction: this type of auction aims at giving greater security to the supply of energy (both new and existing energy), that is, it is characterized by providing more energy than necessary.

## RESULTS

### Wind Energy Auctions in Brazil (2009/2014)

The 2009 Reserve Energy Auction was the first auction held exclusively for the contracting of wind energy. Altogether, 71 energy projects were possible with the energy achieved in this auction. The companies responsible for these ventures, which took place in the Northeast and South, signed contracts valid for 20 years; at the end of this period, it is estimated that R $ 19.59 billion will have been moved (EPE, 2009). In the 2010 Alternative Source Auctions, companies that negotiated wind power also signed 20-year contracts. Almost 80% of the projects auctioned were from wind farms, the remainder being divided into 12 projects for thermoelectric plants and seven projects for small hydroelectric plants. It is estimated that, together, the projects received R $ 9.7 billion in investment (EPE, 2010). Analyzing the Energy Auction A-3 of 2011, it should be noted that, once again, the highest percentage of projects for the slightly more than 2,700 MW contracted for energy are focused on wind energy, with 86.3% of the total of 51 projects. Another relevant event is that more than two-thirds of the contracted total was classified as renewable energy, dividing wind, water and biomass. Yet, the second largest contracted energy value, related to natural gas, with 1029.1 MW—which represents a percentage of approximately 37.5% of the total contracted shows that it was possible to compete between wind and natural gas (EPE, 2011a). At the 2011 Reserve Energy Auction, the wind power source accounted for more than 70% of total contracted energy and more than 80% of total projects, illustrating the predominance of biomass. More than R $ 3 billion in investment was estimated for the construction of the plants. The 2011 A-5 Energy Auction, again focused on renewable energy, contracted a total of 1211.5 MW in 42 projects, and more than R $ 4 billion were invested for the generation of energy for the year 2016. All demand was met with the total achieved in this auction (EPE, 2011b). At A-5 Energy Auction 2012, the focus was again on clean energy generation sources, with projects for hydro and wind power, with contracts of 30 and 20 years, respectively. Again, the competitiveness of wind energy prices was impressive. The 2013 Reserve Energy Auction had a total of 66-wind power generation projects, resulting in 1505.2 MW contracted. The estimated value of investments in the construction of wind farms was approximately R $ 5.5 billion. Results such as from this auction illustrate the growth potential of this energy source in the Brazilian matrix (EPE, 2012).

The A-3 Energy Auction of 2013 resulted in 39 projects focused on wind power and 867.6 MW contracted. There was also space for photovoltaic, biomass, small hydroelectric and thermoelectric projects. However, the result evidences the space conquered by wind energy. In the second Energy Auction A-5 of 2013, 97 wind energy projects were authorized, among the 119 that were also divided into small hydroelectric power stations, biomass and a hydroelectric plant. It was estimated that R $ 12.8 billion would be available for the feasibility of these projects, to be divided by all regions of the country, for energy generation in 2018 (EPE, 2013, ADECE, 2013). The A-3 Energy Auction of 2014 also highlights the predominance of wind projects; there are 21 wind farms out of a total of 22, and the other venture is related to the Santo Antônio hydroelectric plant in the state of Rondônia. According to ANEEL data, some R $ 2.15 billion were invested in wind power projects. At the Reserve Energy Auction of 2014, 50% of the projects were wind energy and the rest were solar energy. This auction had the novelty of being the first to negotiate solar energy separately, showing that photovoltaic sources have the potential to have the same development as the wind source already reaches. Together, the projects total a value of approximately R $ 7 billion in investment (EPE, 2014a, EPE, 2014b). The A-5 Energy Auction of 2014 was the auction with the second lowest percentage of contracted wind energy, among those analyzed, with a greater emphasis on thermoelectric power plants. Of the 51 projects, 36 were from wind power plants. It is estimated investments of R $ 3.46 billion were put into in wind projects (CCEE, 2014). By analyzing the data in Table 2, it is possible to notice that in the Northeast region stands out in the number of feasible projects of wind energy. States such as Bahia, Ceará and Rio Grande do Norte are highlighted, in addition to the very significant participation of Rio Grande do Sul.

[2]Definition made based on the classifications available on the CCEE website.

**Table 1. Auctions with contracting of wind energy**

| Auction | Date | Total installed power (MW) | Installed wind power (MW) | % of contracted wind power | Average price (wind power) (R$/MWh) |
|---|---|---|---|---|---|
| Reserve Energy Auction (Wind Power) -2009 | 12/14/2009 | 1805.7 | 1805.7 | 100.00 | 148.39 |
| Alternative Sources Auctions 2010 (A-3 and Reserve Energy) | 08/25 and 08/26/2010 | 2892.2 | 2047.8 | 70.80 | 130.86 |
| Energy Auction A-3 2011 | 08/17/2011 | 2744.6 | 1067.7 | 38.90 | 99.58 |
| Reserve Energy Auction 2011 | 08/18/2011 | 1218.1 | 861.1 | 70.69 | 99.54 |
| Energy Auction A-5 2011 | 12/20/2011 | 1211.5 | 976.5 | 80.60 | 105.12 |
| Energy Auction A-5 2012 | 12/14/2012 | 574.3 | 281.9 | 49.09 | 87.94 |
| Reserve Energy Auction2013 | 08/23/2013 | 1505.2 | 1505.2 | 100.00 | 110.51 |
| Energy Auction A-3 2013 | 11/18/2013 | 867.6 | 867.6 | 100.00 | 124.43 |
| 2ndEnergy Auction A-5 2013 | 12/16/2013 | 3507.3 | 2337.8 | 66.66 | 119.03 |
| Energy Auction A-3 2014 | 06/06/2014 | 968.6 | 551.0 | 56.89 | 129.97 |
| Reserve Energy Auction2014 | 10/31/2014 | 1658.7 | 769.1 | 46.37 | 142.00 |
| Energy Auction A-5 2014 | 11/28/2014 | 4979.8 | 926.0 | 18.60 | 136.00 |

**Source:** Author, with data from the Energy Research Office (EPE), the National Electric Power Agency (ANEEL) and the Electric Energy Trading Chamber (CCEE) (2017).

**Table 2. Energy destinations contracted in auctions**

| Auction | Number of projects | Wind power projects | Locality (state acronym) |
|---|---|---|---|
| Reserve Energy Auction (Wind Power) -2009 | 71 | 71 | BA, CE, RN, RS e SE |
| Alternative Sources Auctions 2010 (A-3 and Reserve Energy) | 89 | 70 | BA, CE, RN e RS |
| Energy Auction A-3 2011 | 51 | 44 | BA, CE, PE, PI, RN e RS |
| Reserve Energy Auction 2011 | 41 | 34 | BA, CE, RN e RS |
| Energy Auction A-5 2011 | 42 | 39 | BA, CE, MA, RN e RS |
| Energy Auction A-5 2012 | 12 | 10 | BA, MA e RS |
| Reserve Energy Auction 2013 | 66 | 66 | BA, CE, PE, PI, RN e RS |
| Energy Auction A-3 2013 | 39 | 39 | BA, CE, PE, PI e RS |
| 2ndEnergy Auction A-5 2013 | 119 | 97 | BA, CE, PE, PI, RN e RS |
| Energy Auction A-3 2014 | 22 | 21 | CE, PE, RN e RS |
| Reserve Energy Auction 2014 | 62 | 31 | BA, PE, PI e RN |
| Energy Auction A-5 2014 | 51 | 36 | BA, PB, PI e RN |

**Source:** Author, with data from the Energy Research Office (EPE), the National Electric Power Agency (ANEEL) and the Electric Energy Trading Chamber (CCEE) (2017).

This has a great impact and serves to exemplify the importance of the presence of wind farms so that access to better quality of life is present, as this attracts investments to the place through attitudes of social responsibility of the business groups, such as entrepreneurship courses, dental treatment, archaeological museum construction, etc. (MME, 2016). In 2015, Brazil ranked first in relation to the capacity factor (38%), a factor that expresses the relation between effective generation and total capacity over the same period. This was due to the technological advance and the improvement of the facilities of the wind farms (MME, 2016). In addition, energy auctions have made it possible to price wind energy prices with prices from other energy sources. To get an idea, at the beginning of PROINFA in 2004, the average cost of the wind power source was R $ 342 / MWh. In 2009, after the completion of the LER 2009, the price was around R $ 150 / MWh and in 2012 with the A-5 auction, it was already below R $ 90 MWh. There was a slight increase in 2013/2014 and the price increase in 2015 can be attributed to the devaluation of the real against the dollar (MME, 2016). A relevant aspect shown by the data in the table, in general, is that in most auctions, the most significant percentage of contracted energy is related to the wind power source (MELO, 2013), evidencing the growing importance of this energy modality in the national matrix. It is important to highlight the contribution of facts such as this to the maintenance of the high percentage of renewable energy in the national energy matrix, considering that even if it were not the wind power source, most of the projects had been from renewable sources such as photovoltaic energy and hydropower. It is estimated that in 2024 the share of wind power will reach 24 GW (24,000 MW), corresponding to 11.6% of total installed power (MME, 2015). Currently, wind energy is considered the second most competitive source in the country (MELO, 2013), losing only to hydro.

In Table 1, it is possible to observe the results regarding the current condition of the wind source in the auctions of purchase and sale of energy. In general terms, there is a growth in the share of wind energy in the national matrix, as shown in Figure 2, which contributes to various aspects of the country's sustainable economic and social development. Although its contribution to the increase of renewable sources and consequent diversification of the national energy matrix is clear, there are some criticisms of how it is carried out. One is that many ventures start operating after the due date, which indicates that the auctions should be carried out in advance, and it is expected that a greater periodicity of the auctions will take place, so that more adequate planning can take place.

In addition, the Environmental Preliminary Licenses required by bidders for the projects are defined and disclosed very close to the date of the auction, preventing the price from being included in the bid amount, and defining some measures that cannot be applied in practice (ACENDE BRASIL, 2012). There are also cases where there are unexpected interventions on the part of those who wish to contest or who do not favor the occurrence of the auction. Another problem is the shortage of transmission lines for the flow of generated energy (ACENDE BRASIL, 2012). Regarding the new energy auctions, there is a criticism that the physical guarantee is not placed in monetary terms, which can cause the costs of the projects to be analyzed considering a price scenario incompatible with the value of the commercialized energy (CASTRO and BRANDÃO, 2010). It can be said that auctions have contributed to the composition of a more diversified energy matrix, providing better quality energy, with more space for cleaner sources of generation as can be seen not only in the case of the wind modality, but also in the photovoltaic sources, which also aroused interest of the companies that

participated in the auctions analyzed. In addition, the prices observed for the commercialization of these energy sources are more competitive, which can be considered as a crucial element for the viability of the cheapest generation of energy, due to the competition resulting from the interaction between the companies participating in the auction, in addition to bringing more efficiency to the sector and providing more energy to regions with more limited capacity.

## DISCUSSION

Countries have been seeking to diversify their energy matrix, opening space for the increasing search for renewable sources, such as biomass, photovoltaic and wind power. In the case of Brazil, although its matrix is already considered one of the cleanest in the world, the concern is justified by the demand for less dependence on hydroelectric sources, which still accounts for about 60% of the country's electricity generation. The increase in the share of wind energy in the Brazilian energy matrix has been evident in recent years. It can be said that auctions for the purchase and sale of energy show greater interest in the market with regard to renewable sources of generation. This practice has allowed for greater competition in the sector and a greater diversification of the matrix, so that this growth of wind energy participation in its composition is linked to the regulatory framework of the electric sector. The discussion is justified by the search for understanding on the issue of regulation through auctions, verifying the effectiveness and trying to soften the problems that are still considered obstacles to the maximization of the benefits of the practice. These issues involve reduced the participation of the state, which, at the same time, sought to prevent companies from acting in such a way as to abuse the monopoly power they have come to enjoy. It is worth noting that it is not only the market that is decisive for the search for new sources of energy, but also the infrastructure conditions of the country. Analyzing and proposing ideas to support the internal development of the regions where wind energy stands out is a crucial topic. In addition, attempting to correct and adjust any obstacles that still exist in the operation of auctions contributes significantly to the goal of achieving an energy matrix that is less dependent on specific sources, and which focuses as much as possible on renewable sources. One of the main elements that fit the view of Demsetz (1968) concerns the uncertainty that permeates the long-term contracts. The contracts made possible in the auctions have a duration of 20 or 30 years. Even in cases like these, the author does not consider the presence of regulation necessary, assuming that the contracts established must be satisfactory for both sides. As it was pointed out, if there was a greater periodicity for the auctions and a greater advance in relation to when the projects are put into operation, this could contribute to less uncertainty of the values incorporated in the contracts. The issue of environmental licenses being released in a period very close to the auction also makes it difficult for the value of the bid to realistically reflect what is necessary for the operation of the enterprise. Demsetz (1968) suggests a renegotiation clause for cases where values are not correctly incorporated into bid prices.

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