The challenging increase of renewable energy use. The law as a tool for the evolution of Brazilian wind power promotion policies

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Abstract
Energy policy is an important aspect of climate mitigation policies and can be analyzed under a holistic approach of public policies understood as a coordination of ends and means related to governmental acts for maintaining or changing the *status quo* in a specific matter. In the case of power generation, that change of *status quo* regards the promotion of alternative sources. The purpose of this article is the analysis of the Brazilian energy policies implemented from 2002 to 2020, for the development and increase of the wind power source, that grew from 0%, in the beginning of the decade of 2000, before specific governmental policies, to 9,5% in 2020, analyzing their context, features and instruments.

Keywords
Brazilian energy policy – wind power - climate policies – PROINFA – renewable energy auctions.

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Introduction

National climate policies directly address or impact emitter sectors policies since its emission reductions are a requirement for climate mitigation. Although other sectors may account for a greater part of emissions – as is the case of agriculture and deforestation and land use change in Brazil[4] – energy use accounts for a substantial percentage of global emissions. In this sense, energy policies, although based on typical objectives and instruments, are aligned, or should be aligned, with the objectives and the process of implementing climate policies. In this context, energy greener options have been considered and inserted in the Brazilian energy policies in the last decades (PEIDONG et al., 2009).

Brazil is a peculiar case, since its challenge is not to transition energy from fossil sources to renewable ones, because in this country water is the mainstream source of power generation. In fact, the country's development was based mainly on hydropower which accounted for up to 75% of its power matrix in the beginning of 2000s (BRAZILl, MME, 2003). However, the increase in demand as well as the exhaustion of the hydropower potential, the remaining potential sites located in very sensitive environmental areas in the Amazon region, are factors that impose strategies to avoid supplying that new demand by thermal power plants. Aligned to this purpose, Brazil's first Nationally Determined Contribution (NDC) proposed in the term of the Paris Agreement settled forth the goal to expand the use of renewable sources, besides hydropower, in the total power matrix.

Because of that, this paper considers wind power as an alternative source, according to Federal Statute 9,478/1997, article 2, IV, the National Energy Policy (NEP). It states that energy policies with national scope will pursue the goal of establishing directives for specific schemes of alternative sources such as natural gas, coal, nuclear, biofuel, solar, wind and others. The mentioned terminology is consistent with categorizations that distinguish traditional renewable energy, such as big hydropower plants and large-scale direct biomass burning plants – from new renewable energy that includes small hydropower, wind, solar, biomass, geothermal and ocean energy (PEIDONG et al., 2009).

Brazilian investment in alternative energy sources, however, is recent. In the beginning of 2000s, before specific governmental policies, generation by onshore wind energy grew from zero, to 9,5% in 2020 in electricity sector[5]. For time being, only land-based farms were developed in the country, so this percentage rate of wind source growth generally refers to this kind of plant.

We understand energy policy in a holistic approach that includes ends and means and is referred to by Schaffrin and others (2015) and PISCHKE and others (2019) as policy output, which follows acts and decisions of governmental branches. Such decisions relate to act or not to act in order to change or maintain the *status quo* of a specific matter. Energy policy's main goals are energy security and self-sufficiency (PISCHKE et al., 2019), but environmental and climate change issues pressure such policies towards climate change mitigation and environmental impact reduction purposes. The development of renewable and green power sources become goals that more than reconcile energy and environmental policies, can contribute to the core energy policy goals, as it improves diversification of sources.

The development of such sources and wind in particular are influenced by many factors, but governmental policies to specifically foster the increase of wind farms can be considered as a key factor

[4] According to data available on the website of the Ministry of Science, Technology and Innovations, Brazil. Available at: https://sirene.mctic.gov.br/portal/opencms/paineis/2018/08/24/Emissoes_em_dioxido_de_carbono_equivalente_por_setor.html. Accessed December 8, 2020.

[5] According to data available on the website of the Brazilian National Electric Energy Agency (ANEEL, in the Portuguese acronym). Available at https://app.powerbi.com/view?r=eyJrIjoiNjc4OGYyYjQtYWM2ZC00YjllLWJlYmEtYzdkNTQ1MTc1NjM2IiwidCI6IjQwZDZmOWI4LWVjYTctNDZhMijMzRH Accessed December 8, 2020.

for the development of the wind source and the increase in its competitiveness. Those policies are connected to regulatory reforms and restructuring of the electricity industry (Menz & Vachon, 2006).

There is an extensive literature on policies related to the promotion of the wind energy sector; the inclusion of such a goal in the legislation, and its results in different developing countries.

Among the studies, many referred to China (HU; YUAN; HU, 2011; LIAO, 2016; PEIDONG et al., 2009; YUAN; ZUO, 2011; ZHAO et al., 2016). Hu and others (2011) highlighting the alignment of the energy policy with the environmental and climate policy in the country and showing that the goal to develop new renewable energy sources, reducing greenhouse gas emissions and improving the capacity to deal with climate change was included in the Chinese energy policy since the 1980s, although they emphasize the need for a coordinated political apparatus.

In addition to China, other developing countries were subject of relevant studies on this topic.

In a research paper published in the mid-2000s, Winkler (2005) examined policy options to promote renewable electricity in South Africa. Lewis and Wiser (2007) made a cross-country comparison of the policy support mechanisms that have been employed to promote wind technology manufacturing directly and indirectly, in 12 countries, considering, in its sample, countries of different levels of development. Another important cross-country comparison of the policy support mechanisms was made by Pischke and others (2019), through the exam of the historical development of federal and state or provincial renewable energy policies across five federal countries in the Americas: Argentina, Brazil, Canada, Mexico and the United States. In addition, another important comparative study was made by Saidur and others (2010) who discussed the existing successful energy policies in selected countries and compared them with policies in Malaysia. Besides, Schmid (2012) carried out an empirical study on the effect of the introduction of the Electricity Law of 2003 and the 2006 Tariff Policy in India, as well as the implementation of feed-in tariffs and minimum quotas of electricity from clean sources, on the development of grid-connected renewable energy in nine Indian states during the period 2001–2009.

In Brazil, attempts to restructure the electricity sector had many twists and turns. Reforms towards large scale privatization of state-owned firms failed to define adequate regulation and especially an instance to plan investments and energy security. The alterations on the model and the reestablishment of planning were part of the regulatory environment where alternative energy policies were developed.

In that context, this paper seeks to contribute to the existing literature that analyzes how policies in the energy sector can efficiently direct efforts towards a greener electrical matrix and so contribute to climate and environmental policies, analyzing specifically the case of Brazilian wind source implementation. It focuses on the insertion of the goal of development of the alternative energy sources in the legislation and on the instruments designed to implement it. From the literature review, we identified a thematic gap for the study of policies to promote the wind energy sector in Brazil, especially from the analysis of the legislation and instruments implemented in the last decades and their results, analyzed from the background of the Country's electric power development peculiarities. It´s purpose is the analysis of the Brazilian policies implemented from 2002 to 2020, for the development and increase of the wind power source, analyzing its context, features and legal instruments.

Based on the literature review on renewable energy policies and on the measures adopted to promote wind power development in Brazil, as well as Brazilian governmental data, the article is divided in four sessions. The first section shows data and discussion about the evolution of Brazilian power sector, highlighting wind power's participation in the electric energy mix in Brazil between the first two decades of the 21th century; the second section presents a theoretical framework on energy policies instruments; the third section, shows how the main policy instruments for the promotion of renewable energy sources and specifically wind sources were inserted into the legislation and implemented in Brazil from 2002 to 2020; finally in the fourth section, it discusses the results of those policies instruments implementation.

1. Evolution of the Brazilian power sector from the 1960s to the commitments made in the Paris Agreement

Since the beginning of its industrialization process, in the mid-20th century up to the early 2000s, Brazil incremented its power generation infrastructure, based on the development of the hydropower source, mainly in the military dictatorship period (1964-1985)[6], despite the huge environmental impacts deriving from the construction of the dams.

The first hydroelectric plant in the country started operating still in the 19th century, but the investment in the hydropower source of power generation turned even more strategic with the increase in the price of the oil barrel, in the 1970s. Between 1964 and 1985, the military dictatorship period, the total power generation capacity incremented by 609.4%. Hydropower sector recorded a 749.8% growth while the thermoelectricity increased by 274.4% (BRAZIL, IBGE, 1990).

Yet it should be kept in mind that, although hydropower is currently considered a clean source of energy for – in theory – emitting a small relative amount of GHG in the atmosphere, it accounts for serious environmental impacts in the area where the hydroelectric power plant is installed.

Over the years, there was still a significant variation regarding the role of the Government in the sector. Until the 1990s, government corporations were responsible for the whole power chain, from generation to retail companies. In the late 20th century, there was a process of deverticalization and privatization of the power sector. This measure did not attain the results desired and was one of the major causes for the "big blackout crisis" experienced in 2001 (MERCEDES *et al*, 2015; TOLMASQUIM, 2015; SILVA, 2011), one of its major causes being the dismantling of the main governmental areas of planning and power system operation, the lack of institutional coordination among the sectoral bodies, and restricted investment by the government corporations (TOLMASQUIM, 2015). Besides, the projected privatization was not achieved, as it reached only 70% of the power distribution capacity and 30% of the generation. Yet the reduction in governmental participation hit the planning capacity, which, added to the regulatory uncertainties, prevented private stakeholders from making new investments in the sector (GOLDEMBERG; LUCON, 2007). The 2001 crisis opened the doors to power source diversification opportunities started in 2002.

In quantitative terms, regarding the participation of each source in power production, in the 2002 data, the lack of participation of new renewable energies, such as wind, biomass and solar, is highlighted. However, in that year, the first program to foster alternative renewable sources was implemented, the Program to Foster Alternative Sources (PROINFA, in the acronym in Portuguese), which boosted their growth. The Federal Statute 10,438/2002 allowed the government to pursue the goal of increasing the electric generation from wind, biomass and small hydro power plants.

[6] This period started with a military coup in 1964 and ended when the term of the then first civil president started in 1985.

Box 1: Comparison of the Brazilian power mix in 1985 and 2002.

	Participation of the source in 1985 (%)	Participation of the source in 2002 (%)
Hydric	84.4	74.7
Thermal	15.6	12.0
Nuclear	-	3.6
Importation	-	9.6
Total	**100%**	**100%**

Source: box elaborated by the authors based on data from the Brazilian MME (2003) and Brazilian IBGE (1990).

In 2003, a sequence of presidential terms occupied by the *Partido dos Trabalhadores* (Labor Party) started, lasting until 2016. The result of this change was the relevant alteration in the directions of the power sector policy, valorizing the governmental role and planning.

The new model adopted was established by the enactment of Federal Statute 10,848 in 2004, which ruled about the contract models for electric power and defined the auctions system, an important instrument for the increase of the wind source.

Also, the planning tool was resumed by the Government, especially by the establishment of the Energy Research Company (EPE, in the acronym in Portuguese), accounting for conceiving the long-term planning, as well as decennial plans, supporting the Ministry of Mining and Energy (Cataia, 2014). Following the definitions of those plans, power auctions were implemented by the National Electric Power Agency (ANEEL, in the acronym in Portuguese).

According to ANEEL, 43 power auctions were held in Brazil between 2005 and 2019. The Division per power source traded occurred as displayed in the box as follows:

Box 2: Total power traded in auctions between 2005 and 2019, separated by source.

Source	Units	MW traded	% MW
Hydraulic	189	27,549.36	34.5%
Fossil TPP	71	20,769.57	26%
Wind	761	19,654.21	24.5%
Renewable TPP	139	7,578.11	9.5%
Solar	149	4,207.14	5%
Industrial wastewater TTP	1	490	0.5%
Total	**1,310**	**80,248.35**	**100%**

Source: box elaborated by the authors based on the data available in the ANEEL electronic site.

In this survey, which considers the potential already contracted as a whole, whose plants were still not operative, and the units already in production, we observe that most of the auctions in that period traded power from hydraulic and fossil sources, followed by the alternative wind, biofuel and solar sources.

The data from the regulatory agency also points out that, in 2009, the first specific wind power auction was held. In the same year, the Law of the National Policy on Climate Change (PNMC, in the Portuguese acronym), Federal Statute 12,187/2009, was enacted.

Although the PNMC does not set forth binding obligations to the government, nor to the private sector, it requires the establishment of "*mitigation and adaptations sectoral plans aimed at the consolidation of a low carbon consumption economy in power generation and distribution",* among other economic sectors. In the implementation of that rule, the sectoral plans already established for the power sector incorporated the climate mitigation and adaptation aspects. That legal arrangement allowed an alignment between the climate and power policies. The second´s goals, however, relate to power security and source diversification, that can be improved by the development of the wind source but also relied on fossil sources in the years of this study, challenging the alignment of the energy and climate goals.

From 2009 on, a significant decrease in fossil sources trade is observed, as well as an important increase in wind sources[7]. The hydric source share kept stable, as observed in the box as follows:

Box3: Total power traded in auctions between 2009 and 2019, separated by source.

Source	Units	MW traded	% MW
Hydraulic	175	19,375.27	34.2.%
Wind	761	19,654.21	34.7%
Fossil TTP	16	9,253.79	16.3%
Renewable TTP	88	4,206.37	7.4%
Solar	149	4,207.14	7.4%
Total	**1189**	**56,696.77**	**100%**

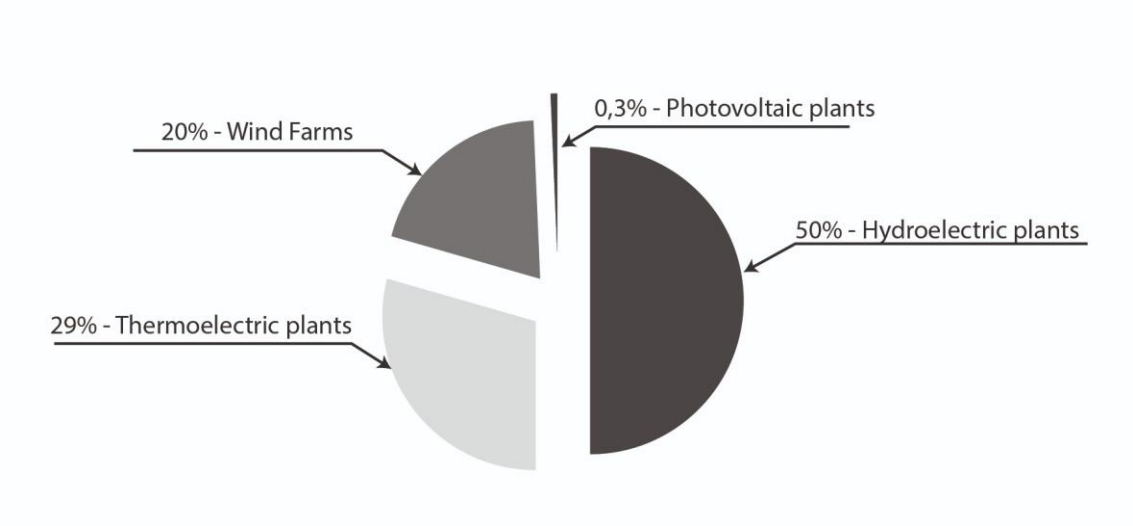
Source: box elaborated by the authors based on the data available in the ANEEL electronic site.

Another important aspect that must be considered, refers to the fact that from 2007 until 2019, the government implemented an infrastructure plan – the Growth Acceleration Program (PAC, in the Portuguese acronym), that directed public and private investment in the power sector promoting a significant increase in the power generation in Brazil.

From the compilation of the PAC balances between 2007 and 2017, we observe the inclusion of 43,071 MW in the Brazilian generation mix, 50% from hydric source, 29.42% from Thermopower Plants (12,673 MW), 20% from Wind Farms (8,830 MW) and 0.3% de Photovoltaic Plants (120 MW).

[7] These numbers refer to trade power auctions and do not correspond to the total of energy supply capacity.

Graph 1: Participation of the sources in the MW inserted in the Brazilian power production park within the PAC ambit (2007 – June/2017).



Source: graph elaborated by the authors based on the data available in the PAC balance sheets.

From the data analyzed, we observe that in the 2010s, there was an important growth in the power generation capacity in Brazil, largely boosted by PAC, increasing the participation of renewable but also of fossil sources, which indicates an alignment between increased investment in alternative energy and the enactment of national climate policy. The investment in wind power and thermoelectric plants was part of a federal government strategy to increase renewable energy capacity while ensuring security of supply, at the time still more dependent on hydric resources. Therefore, the thermoelectric plants, considering, also, the biomass, would play the role of backup power while the matrix was developed, in the long term, based on renewable sources (BRAZIL, 2020). In the future, thermal plants would be used occasionally, as intermittent renewable energies demanded complementary generation. The data on PAC's investment also shows a great deal of focus on hydroelectric dams. This political choice is also the target of criticism, especially from civil society, since large projects were built with enormous socio-environmental impacts on vulnerable traditional populations.

The data above also shows that most of the power generation capacity inserted in the Brazilian power mix in recent decades is from renewable sources. Even though the hydric source keeps prevailing over the others, a relevant share of the investment was in the wind source, contributing to the increase in its participation in the Brazilian power mix.

Nevertheless, it can be pointed out that, although the investments have been concentrated on renewable power generation, also relevant was the development of the thermopower sector powered by fossil-origin sources, which require smaller financial investment and ensure the energy security of the system.

Finally, since 2015, Brazil has voluntarily committed to undertake climate change mitigation and adaptation efforts through its Nationally Determined Contribution (NDC) under the Paris Agreement. In this document, Brazil has set a goal of achieving an estimated 45% share of renewable energy in the energy mix by 2030. To this end, it provided for the expansion of the use of renewable sources other than hydropower in the total energy mix to a share of up to 33% by 2030, and the expansion of the domestic use of non-fossil energy sources, increasing the share of renewable energy, disregarding hydropower, in

the electricity supply to at least 23% by 2030, prioritizing the participation of wind, biomass and solar sources.

The assumption of a target for 2030 that considers an increase in the generation capacity of renewable energies, such as wind, solar and biomass, reinforces the interpretation that the investment in fossil generation was intended to ensure energy security for the country, that is rapidly expanding access to consumption, until new renewable sources could meet demand with less risk of insufficient supply.

We can conclude that climate and power supply policies tended to have a relative alignment, which means climate aspects were inserted in the supply policy that, nevertheless, is oriented to its core goals of energy security and diversification.

2. Climate and energy policies instruments

Instruments are in the core of policies as they connect goals and means toward the projected results and their legal design can contribute more or less to its effectiveness; especially with regards to the clarity and alignment to other rules and policies, that promotes legal certainty.

Discussion of instruments used in energy power policies often present classifications. Liao (2016) proposes the distinction among the environmental; the supply and the demand types of instruments, being the first considered indirect incentives while the second and the latter produces direct *pushes* and *pulls* in wind policies. The attention to environmental types of measures is noteworthy, as it sheds light on the potential of climate policies and its role in the fostering of alternative energy sources. It includes important instruments such as carbon taxes and cap-and-trade markets. Carbon taxes can be imposed on different emission sources, and usually includes the burning of fossil fuels. Cap-and-trade markets require business in some sectors to restrain its emissions to distributed or acquired emission allowances and so impose a price on carbon emissions. Those measures increase the costs of fossil sources of energy and indirectly foster alternative sources. However, due to the importance of other factors such as wind quality; the relative price of the energy sources and equipment, as well as consumer awareness (MENZ; VACHON, 2006) environmental policy measures alone may not be enough for developing and increasing the participation of renewable power sources, although they may be complementary (RADER; NORGAARD, 1996).

Other classifications focus specifically on energy policies instruments. Menz and Vachon (2006) propose three types: (i) financial incentives; (ii) mandatory rules and regulations; (iii) regulatory actions to facilitate entry of green-power producers. Notwithstanding the importance of climate policy instruments as part of a policy output, this article adopts this latter classification in order to analyze the Brazilian energy policies from 2002 to 2020.

Financial incentives aim at reducing costs either for the initial investments in alternative sources or to its operation as new technologies may be costly and uncompetitive compared to traditional sources. It includes tax incentives; credits and other kinds of subsidies such as preferential rate loans (Menz & Vachon, 2006). Also included in this category are the feed-in tariffs, which are fixed acquisition prices that assure alternative energy producers can sell energy which production costs may be higher than other sources (COUTURE et al., 2010), and the *feed-in premiums* (FIP), which consists in paying a premium above the market price of the power, so as to compensate for the higher cost of production. The successive use of those instruments in Germany is reported by SCHOMERUS (2016).

Mandatory rules and regulations usually require a share of power traded deriving from specific renewable sources as well as the disclosure of information regarding the source of power traded and its emissions. The most usual instrument is the *renewable portfolio standard* (RPS); sometimes referred to as *renewable purchase obligation* (RPO) or *quota system*. Its implementation requires that power suppliers purchase a percentage of their total sales from renewable sources (MENZ; VACHON, 2006;

RADER; NORGAARD, 1996). The requirement may consist in acquiring representative certificates of renewable power.

A mechanism that has attracted attention for replacing the FITs schemes in the world as a preferential program for a greater insertion of renewable power is *tendering*, *bidding* or *renewable energy auction* (BENTO; BORELLO; GIANFRATE, 2020; HAUFE; EHRHART, 2018). In it, each supplier is invited to offer an amount of power that he/she is willing to accept for the lower price determined (BRAGA, 2016). This improves the allocation efficiency and the competitiveness among the sources and allows larger amounts of renewable power to be acquired for reduced prices in a shorter time (HAUFE; EHRHART, 2018). As will be explained in the next section, power auctions in Brazil included exclusive alternative source auctions and allowed a substantial increase in wind power participation.

The energy policies of the countries and states compose this range of instruments in a very diverse way and may be based on one of them or be characterized by a hybrid form (POULLIKKAS *et al*, 2012; IRENA-GWEC, 2012).

The characteristics of this composition in Brazil are the subject of the following section.

3. Climate and energy policy instruments for the promotion of wind power in Brazil

3.1. PROINFA: financial incentives and quota system

The first and fundamental wind power policy, PROINFA, was established by Federal Statute nr. 10,438/2002. The Program instituted a special rule for purchase contracts of alternative power. It was conceived to be implemented in two phases and relied mostly on the use of feed-in tariff and tariff reductions. It also defined a quota of renewables to be achieved.

The PROINFA phase 1 authorized the *Centrais Elétricas Brasileiras S.A. - Eletrobrás*, the state-owned power company, to celebrate contracts for the purchase of wind power at subsidized prices for 20 years. This subsidy policy worked on a basis of a feed-in tariff, with guaranteed contract and price, yet with the particularity of not involving private retail companies at this moment. Thus, it stimulated the so-called autonomous independent producers (those without corporate ties with companies acting in other activities of the energy power chain) to continuously generate power from the wind source.

The Program also established a renewable power insertion goal in the Brazilian power mix, aiming to reach the set of 3,300 MW in renewable power capacity at the first phase of the program, and 10% of the Brazilian annual consumption in renewable sources at the second phase. Of these 3,300 MW of capacity, 1,100 MW should come from the wind source. In PROINFA phase 2, the generators should annually emit Renewable Energy Certificates - RECs over the established renewable power quantity targets. The scheme intended a transition for a quota system (COSTA, 2006).

The PROINFA phase 1 began in 2004 with the signing of new contracts with independent wind generators and was predicted to end in December 2006, when the contracted wind farms were to start operating. That deadline was later postponed by 2008.

However, as a consequence of the regulatory changes of 2004, an auction scheme was instituted by law, which extinguished the possibility of celebrating new contracts by PROINFA, thus previously preventing the possibility of the second phase of the Program, which did not eventually occur (DUTRA, 2007). The contracts of phase 1 remain in force until their term.

In addition, PROINFA promoted a tariff reduction mechanism that significantly reduced costs for the wind generation. These tariffs, known as “Electric Transmission System Use Tariff" and “Electric Distribution System Use Tariff” - TUST and TUSD, are due for the use of power transmission and distribution structures. Such reduction was maintained even after the auction scheme was instituted and was still in force.

Later, the tariff reduction instrument was restrained by a new energy policy. Following a review on subsidies programs for competitive renewable sources, the TUST, TUSD rebate grants were limited for new wind farms and capacity expansion cases requested until March 2022 under the Federal Statute nr. 14,120/2021. Thus, the projects that applied for the mechanism or its extension should start operating within 48 months of the authorization. This phasing-out of the tariff reduction for the next wind projects means the end of an important state incentive, significative during the past stages of wind energy fostering policies, but also, a recognizement of the maturity and self financial sustainment for the wind power sector in Brazil.

Another feature of PROINFA was that its contracts allocated energy production risks to acquirers, discharging power generators to deliver a specific amount of energy, but to allocate a determined capacity production within the contract[8]. That contract rule was present in most of the contracts of wind power closed under the auctions system, after 2004.

Although only the first phase of the program was implemented, PROINFA is considered a well succeeded program, as it promoted the initial installation of a wind power capacity in the country, stimulated the national production in the wind power chain and built capacity in the sector.

3.2. Power sector new model and the auction scheme

In 2004, the so-called new model brought important changes to the power sector, including the establishment of a tender system for the commercialization of electricity, that was divided into two separate systems: one for the regulated market and one for the free energy market. It needs to be added that, in Brazil, only consumers above 3,000 kW were free to acquire power in the free market by 2004 and distribution is a public utility service still regulated.

The new model tender system had the goal to diversify the power sources in the regulated market and for the viability of the alternative sources, established some exclusive alternative source auctions, being the first specific auction for wind power held in December 2009, when 1,805.7 MW of wind energy was acquired (BRAZIL, EPE, 2009). After this boost, as this source became more competitive, its participation in general auctions also increased and resulted in a remarkable growth in its participation in electricity trading contracts, as demonstrated in Box 3.

3.3. Other financial incentives for wind power

Some tax policies composed the policy output for the promotion of alternative sources and benefited the wind source. The Special Incentives Regime for the Development of Infrastructure (REIDI, in the acronym in Portuguese), created in 2007, allowed tax incentives in the purchase of equipment for installing wind farms, specifically, tax exemptions of 100% of the Social Integration and Civil Service Assets Formation Program - PIS/PASEP and the Contribution to Social Security- COFINS, taxes concerned with financing the qualification of human resources and social assistance. REIDI is inserted in the PAC, referred to in section 1.

State (sub-national) governments can also grant exemptions on the Consumption of Goods and Services Tax (ICMS), a kind of value-added tax, charged on the commercialization and transportation of some inputs and equipment concerned with wind generation. In the State of São Paulo, the most industrialized in the country, there is total exemption from the tax concerning the purchase of wind generator assembly parts.

As regards the wind power financing policy, it is promoted by varied means, by different fostering institutions, credits and funds. The Brazilian funding for wind power is granted by the Energy Development Account (CDE, in the acronym in Portuguese), a fund created by the PROINFA program, aiming to improve the market conditions for the power sector and to fund different public policies,

[8] According to Federal Decree 5,163 of 2004.

including power by incentivized sources. This fund is composed of different resources, deriving from the utilities contributions, from the fines levied by the regulatory agency and from the federal budget. In 2013, the CDE started to fund the tariff reduction on use and transmission of the wind source power (BRAZIL, ANEEL, 2020).

The Brazilian National Bank of Economic and Social Development (BNDES , in the acronym in Portuguese), a federal government financial institution, has lines of subsidized credit for renewable energy loans, especially through the FINAME, a program aimed to fund the manufacturing and acquisition of machinery and equipment at reduced annual interest rates, that had important role in the wind power sector (BRAZIL, BNDES, 2020).

In the Northeast Region, where important wind farms and a considerable share of the Brazilian capacity are located, wind power entrepreneurs can obtain financing resources with the Superintendence for the Development of the Northeast (SUDENE , in the acronym in Portuguese), a special independent public authority concerned with the regional development. SUDENE and the Bank of Northeast (BNB, in the acronym in Portuguese) are responsible for the asset management of the Northeast Development Fund (FDNE , in the acronym in Portuguese), that can be requested for installing new power generation units using wind source in the Northeast Region of the country.

These instruments, planned and implemented by means of institutional programs and actions, allowed for the results described in section 2 herein.

3.4. Remaining obstacles for the wind power development in Brazil from 2002 to 2020

Difficulties exist to the expansion of wind power generation, especially with regards to the economic situation of Brazil that results in venture financing scarcity and the lack of an adequate transmission structure (DIÓGENES *et al*, 2019; DIÓGENES *et al*, 2020).

The barriers of inadequate transmission structures, or “bottlenecks”, have to be acknowledged from the perspective of an integrated system operation. As a result of a deverticalization program for the power sector chain, the activities of generation, transmission and distribution of electricity must be performed by different companies. In this sense, transmission services are purchased by a public procurement process. Failure in articulated planning resulted that, in some cases, wind generators could not participate in renewable power auctions because of the overloaded capacity of transmission structures. In the same way, potential sites for wind production are still idle due to insufficient connection with the existing power grids.

Finally, considering the option for importing parts not available in the domestic market, the Brazilian currency suffers constant devaluation against the dollar, which undermines the financial clauses of contracts for the sale of energy and can raise the price to less competitive levels compared to other sources.

4. Discussions and conclusions

Regarding GHG emissions, the Brazilian power mix is considered one of the cleanest sets of electrical sources when compared to other countries. For example, China, the United States, Russia and India rely deeply on fossil fuels or nuclear power to supply their electricity needs. Therefore, no transition from fossil fuels is necessary. The main challenge is to keep it clean through the increase of national generation from alternative sources. Wind energy had no participation in the mix at the beginning of the 2000s. After two decades, due to the implementation of significant energy policies, it increased its participation to 9% of the national generation, in a time when the power generation capacity in the Country grew significantly.

Currently, the Federal government has the legal attribution to plan and implement the energy and power policies, with reduced participation of states, that nonetheless contributed to it through initiatives such as tax exemptions. This legal framework allowed a good coordination of the policy at the federal level.

Brazilian energy policy output generated by legal statutes, governmental acts and decisions through the years 2002 to 2020 demonstrate the importance of governmental policies to foster wind energy and specially to allow the source an initial strength to further development and increased competitiveness. That aspect was highlighted in the literature related to the experiences of other Countries (MENZ; VACHON, 2006; PEIDONG et al., 2009). In addition, the evolutive analysis showed the acts and decisions of the government to change the *status quo* (SCHAFFRIN; SEWERIN; SEUBERT, 2015) of the wind sources in Brazil in those years.

With regards to the instruments to be preferred, Lewis & Wiser (2007), after a cross-country policy comparison, highlighted the importance of feed-in tariffs. This instrument was indeed important for the first of the alternative source development policies in the country that was the PROINFA. Its combination with a quota allowed the policy to overcome the downsizing of the feed-in tariffs, related to uncertainties about the achievement of the growth aims, as exposed by Winker (2005). Besides, the combination of both instruments with a bunch of financial incentives shows the importance of a mix.

After some years, with a level of capacity built in the wind sector and its increased participation in the electricity power matrix, the government was able to transit from the guaranteed long price contracts with feed-in tariffs implemented under PROINFA to the auctions system where price incentives were better combined with competition.

Another important initiative for fostering wind power infrastructure in Brazil was the approval of a specific policy for overcoming the problem of upfront costs for building the wind farms. Although the maintenance cost of the turbines may be considered relatively cheap, initial costs can be sensitively prohibitive for the start of most of the plants. With the purpose of attracting private investments to the sector, the REIDI program granted a substantial tax reduction of PIS/PASEP and COFINS for the acquisition of inputs (goods or services), such as machines, devices, instruments, equipment and building materials. The tax reduction in the REIDI program is above 9% of the total needed amount for starting. This is very significant considering all the factors that can threaten the financial feasibility of a wind farm. Also, it is a remarkable factor if we consider the challenge to maintain competitive market prices regarding the dispute with other sources, especially the conventional ones, structured for decades.

In spite of the implementation of all those instruments, the instability of the Brazilian economy and the value of its currency, financing scarcity and infrastructure bottlenecks were appointed as obstacles for the development of the policy.

Finally, the PAC was an important governmental program to increase generation capacity in Brazil. Although it was important to increase the proportion of alternative sources, it also incentivized the construction of thermoelectric and hydroelectric dams that caused significant environmental impacts.

It was also identified that, since the enactment of the national climate policy in 2009, which sets forth the goal of emission reductions for the power sector, there has been a significant increase in the participation of the wind source in the Brazilian mix. It is not possible to affirm that there is a true cause and consequence relationship between the growth of the wind source and the creation of the PNMC, but we can observe an alignment between those policies. However, such alignment is relative, as the core energy policy goals of energy security and diversification led to a parallel move to the increase of fossils that may undermine climate goals.

The commitments made by Brazil in its first NDC indicate the intention of the Brazilian government, at the time of the submission of this declaration, to prioritize the advancement of renewable energy, especially wind, solar and biomass, which indicates the intention to maintain thermoelectric plants as a backup to ensure energy supply in periods of intermittency. Climate change, however, may

require the acceleration of this policy, since periods of drought in Brazil have intensified, jeopardizing hydroelectric power generation. Therefore, it is possible that the use of fossil fuels will become more recurrent, to overcome this difficulty disregarded in the planning. Thus, to meet its emission reduction targets in the Paris Agreement, Brazil will have to further accelerate the supply of electricity from new renewable sources.

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