PUBLIC POLICIES AS INNOVATION DRIVERS FOR THE WIND POWER SECTOR

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I. Introduction

Since the mid-nineteenth century the energy of the winds began to be used to produce electricity, but its use was still marginal. In the 1970s, due to the oil shock and the rising fossil fuel prices, there was an effort to diversify the world energy matrix. Several countries in the world, including Brazil, have set up programs for the technological development of the wind power source.

In the late 1990s, even with the stabilization of the oil prices, programs to encourage the development and use of wind energy intensified in several countries around the world. These programs aimed to overcome the technological and economic barriers that reflected the low competitiveness of this type of energy. Besides, the adoption of economic and regulatory incentives to stimulate the insertion of the wind power source in the energy matrix, the programs also supported its technological development.

Unlike the 1970s, when the search for energy alternatives was motivated by the rising oil prices, the support for ~~the~~ wind power in the 1990s was associated with concerns about environmental problems. As the 1990s were marked by an intensification of discussions on sustainability, the debate about the cumulative effects on the nature of global production and consumption patterns has become an important issue both within governments and at international conferences.

The intensification of the support for renewable energy sources from the mid-1990s represents the promotion of a new sustainable path. Since then, governments' strategies for achieving sustainability have been rooted in the possibility of dissociation between economic growth on the one hand, and material production and the use of conventional energy on the other hand. Sustainability should be achieved through a revolution in the materials efficiency, in resources and energy and in the technological development of renewable energy sources. Under these circumstances, incentives to the wind power become even more relevant.

In this context, the present article analyzes the main policies instruments that governments of different countries have used to support the wind industry. The hypothesis is that the insertion of the wind power source in the energy countries matrix is closely associated with the adoption of systemic and coordinated policies that promote their development and these policies are capable to influence the dynamics of the productive sector and the innovation processes.

It is used is the neo-schumpeterian approach of the national innovation system to support this analysis. This approach comprises the innovative process as interactive and systemic in which a broad set of institutions and policies affect the processes of production and accumulation of capabilities.

First, the paper discusses whether the increasing importance of technologies related to environmental sustainability can be an initial constitution of a green techno-economic paradigm. Then, a set of six countries representing the most significant policy cases in the wind industry are analyzed: Denmark, the United States, Germany, Spain, India and China. In addition, the historical analysis also puts in perspective the Brazilian case study in comparison to these other countries.

II. Technological Changes and the Current Ecological Crisis

The exploration of Nature by humans is not recent, but it has been especially in the last decades that the environmental degradation has increased in a vertiginous way. In this period, the production mode and mass consumption - which is highly intensive in the use of finite natural resources - has grown explosively and unprecedentedly, aggravating the pressure on non-renewable resources. The perverse effects of this process are evidenced by worsening global warming, increasing deforestation, rivers and seas contamination, large-scale extinction of the planet's biodiversity, among many other environmental problems.

For Serfati (2008), the current ecological crisis is explained by a convergence between, on the one hand, the cumulative effects of the patterns of production and consumption and, on the other hand, the dynamics of financial capital, whose valuation mode is outside the real production and consumption sphere, accentuating short-term pressures and irresponsibility with the future. Regarding this last aspect, it should be noted that bank deregulation, which took place in the 1970s and early 1980s, significantly expanded the power of finance and consolidated a new regime of accumulation. This finance-led capitalism regime has brought about a deepening of the environmental crisis, as financial deregulation has raised the rate of return on capital and pushed the productive chain to expand the use of natural capital. It is in this context that development proposals capable of allying economic growth and environmental preservation have been discussed.

In recent years, most of the proposals made by multilateral organizations that have been negotiated in official forums have been based on the so-called "green economy" approach. Conceptually, the proposal is based on the possibility of decoupling economic growth, on the one hand, and material production and the use of conventional energy, on the other. Such dissociation should be achieved through a qualitatively different growth model in which the scale effects of growth could be neutralized through structural and technological changes. It is emphasized the importance of allocating adequate value to natural capital inventories through market mechanisms, as well as stimulating innovation and technological progress as instruments capable of increasing efficiency and minimizing impacts on the use of non-renewable natural resources (SOARES, CASSIOLATO; 2015). The green economy, thus, points to technological change as a strong ally in the search for ways to generate sustainability for the current development model.

The work of Chris Freeman and Carlota Perez on technical-economic paradigms is an important starting point for addressing the role of technological change in the current ecological challenges. The next subsection presents this discussion.

II.1. Technical-economic paradigms

The dynamics of the capitalist economy are essentially based on differentiation and the search for the new. The qualitative transformations of this economic system rest primarily on the innovation processes and technical change. Thus, although constant in the market economy, innovation is not always continuous. Discontinuities are often stimulated by the exhaustion of possibilities along a certain technological trajectory.

Perez (2009) develops the notion of technological revolutions and analyzes the patterns observed in the evolution of technological changes, also addressing the interrelationships with the context that shape the rhythm and direction of innovation. According to the author, technological revolutions bring with them a lots of innovation opportunities and provide a new set of technologies, infrastructure and associated organizational principles that can significantly increase the efficiency and effectiveness of some industries and activities. However, the full dissemination of these opportunities in the economic system and the possibility of their full use depends, above all, on institutional arrangements that can be configured in different ways in space and time. Therefore, these changes occur differently in the diverse socioeconomic formations.

As new technologies spread and multiply their impact on the economy, it is consolidated in a new paradigm (technical-economic) that shapes the trajectories of individual technologies. Authors like Freeman and Louçã (2001) and Perez (2007) use the term techno-economic paradigm to describe technologies that spread throughout the economy and that influence the behavior of firms and different industrial sectors. In general, this process is associated with technological revolutions, which one or more technologies are able to modify the structure of the economy (PEIXOTO, 2013).

The influence of a new paradigm also extends beyond the production sphere, exerting influence on institutions and society, eventually modifying socio-institutional structures as well. It should be noted, however, that not always radical technological changes are accompanied by the conformation of an institutional configuration conducive to the diffusion of the new paradigm. The presence of tensions between incremental technological change along established paths and the diffusion capacity of radically new technologies is common. Consequently, the deep changes and opportunities that emerge from each technological revolution are not easily assimilated; thus, they demand the generation of mechanisms that induce changes, such as the formation of an adequate institutional framework and diverse sources of stimuli and financing (PEREZ, 1985).

Johnson (1992) corroborates this view, adding that institutional influence on technological change is not politically neutral and varies over time either by stimulating or retarding the effects of technological change. In the same direction, Perez (2007) points out that the space of the technological possibilities is much larger than the economically profitable and socially acceptable space. Economic agents innovate taking profit in mind, stimulating research efforts in certain directions based on their investment and financing decisions, which does not necessarily have to be with the most efficient based on the society standpoint.

So, the advent of radical technological changes is not always accompanied by the conformation of an institutional configuration that conduce the diffusion of a new paradigm. Often, government action becomes crucial to stimulate the necessary changes so that the gains derived from innovation and diffusion processes resulting from the new paradigm can fully occur in the desired direction. It is in this context that the political-institutional scenario emerges as a central element for analyzing the role of technological change in the current crisis, as well as for understanding the opportunities, constraints and potential scope of the emergence of a new "green" production paradigm.

II.2. Emergence elements of a new productive paradigm

According to Perez (2007), capitalism has experienced pendulum movements, with different technological systems evolving rapidly towards similar tasks. According to the author, the world is currently crossing a new breaking point, and the future would now be defined globally and in each country.

Based on this perspective, it is worth questioning what signals could characterize this point of change and what opportunities and challenges may arise from the scenario described by the author. Multiple expressions of this point of change seem to coexist and may lead to a different path of development. A low carbon technological trajectory, which could include other aspects related to the decline in the use of nonrenewable natural resources, could be envisaged (SOARES, CASSIOLATO; 2015).

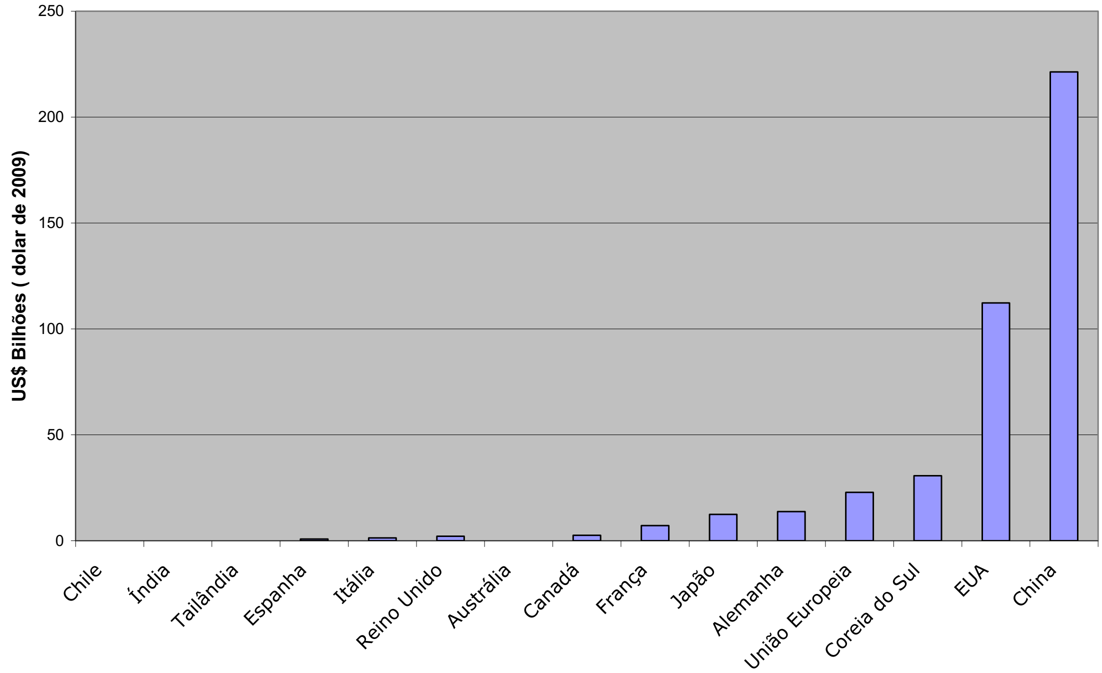
According to Maharajh (2015), some technological trends associated with this perspective would already be consolidating. These would come mainly from new sets of biomedicine, computing, power generation, storage and transmission, nanotechnology, quantum physics and synthetic biology.

Chesnais (2013) corroborates Maharajh's argument (2015) and suggests that the current environmental, social, economic and financial crises are manifestations of the exhaustion of the current techno-economic (TEP) paradigm. According to the author, there is a depletion of the productive paradigm based on the intensive exploitation of natural resources, especially the nonrenewable ones, and a possibility of the emergence of a more sustainable productive paradigm also centered in a low carbon economy and renewable energy resources.

It is also possible to perceive a tendency of some countries to invest in technological development in areas related to sustainability, especially after the global crisis of 2008. Robins *et al.* (2009) point out that the strategy of investing in technologies associated with sustainability was widely adopted by several countries as a form of economic recovery. According to the authors, the fiscal stimulus related to sustainability was about US $ 430 billion in 2008 and 2009.

As can be seen in figure 1, China appears as the leading country in investing in green technologies and in developing the necessary infrastructure for a sustainable paradigm, with a $ 221 billion fiscal stimulus package, mainly used in the search for sustainable energy and in the development of pollution control technologies, among others. The US comes in second with a fiscal stimulus package of $ 112 billion. Other countries and regions that stand out are South Korea, the European Union, Germany, Japan, France, Australia and Canada.

Figure1 - Green component of the anti-crisis package



Source: Own elaboration based on Robin *et. al*. (2009)

In terms of the participation of programs focused on environmental issues in the packages aimed at crisis recovering, Table 1 shows that, in the case of China, approximately 38% of the resources destined to recover from the crisis are directed to these programs. In the case of the United States, this participation is approximately 12%. South Korea's data draws attention to its magnitude: 80.5% of resources for the crisis recovery are allocated to environmental issues. In Germany and France, this share is significant, of 13.2% and 21.2%, respectively.

Table 1- Green dimension of economic stimulus plans

	US$ billions	Year	US$ billions	
Asia				
Australia	26,7	2009-12	2,5	9,30%
China	586,1	2009-10	221,3	37,80%
India	13,7	2009	0	0,00%
Japan	485,9	2009-12	12,4	2,60%
South Korea	38,1	2009-12	30,7	80,50%
Tailand	3,3	2009	0	0,0%,
Subtotal Asia	**1,153,8**		**286,9**	**23,10%**
Europe				

European Union	38,8	2009-10	22,8	58,70%
Germany	104,8	2009-10	13,8	13,20%
France	33,7	2009-10	7,1	21,20%
Italy	103,5	2009-10	1,3	1,30%
Spain	14,2	2009	0,8	5,80%
United Kingdom	30,4	2009-12	2,1	6,90%
Other EU	308,7	2009	6,2,	2,00%
Subtotal Europe	**325,5**		**54,2**	**16,70%**
Americas				
Canada	31,8	2009-13	2,6	8,30%
Chile	4	2009	0	0,00%
USA	927	2009-13	112	12,00%
Subtotal Americas	1,007,8		114,9	11,40%
Total	**2,796**		**436**	**15,60%**

Source: Robins *et al*. (2009)

Thus, several countries sought to respond to the crisis with economic and industrial policies aimed at shaping the new technical-productive paradigm and oriented towards a change of productive structure, mainly taking into account the limits in the use and exploitation of nonrenewable resources and the concern with sustainability and the appreciation of local specificities.

Among the environmental investments, those related to renewable energy have stood out. Robins et al. (2009) point out that, in general, renewable energy sources received the largest share of economic package resources. Among renewable sources, solar and wind power are leaders.

Anadón (2012) also shows in detail policies from different countries that are investing in the technological development of clean energy sources (particularly wind energy). According to the author, energy policy in the US, UK and China have as one of their priorities the development of clean technologies that allow the reduction of GHG emissions. Thus, it is possible to perceive that the global powers have bet heavily in the development of technologies related to sustainability and that this tendency may suggest the emergence of a new productive paradigm[1].

II.3. State performance and policy implications

State policies play a key role in the development of nations, especially in inducing the development of their production and innovation systems. In this context, the analytical framework of the National Innovation System (NIS) is also understood as a

[1]To discuss the emergene of a green Techno-economic paradigma, see Chenais (in press).

tool that can contribute to policymakers' decision-making in the constitution and elaboration of policies. Understanding how institutions influence technical change makes it possible for more effective policymakers to influence the direction of innovation toward socially desirable goals.

NIS's approach highlights the key role of the state as a policy maker. Cassiolato and Lastres (2014) argue that, in general, there are two central goals for the State as a policy maker to encourage innovation processes. First, the authors point that the state must ensure the basic conditions of a political and macroeconomic framework conducive to the formation of a benign regime capable of stimulating productive and innovative development[2]. Second, they highlight the state objectives of strengthening productive links, learning processes and creating and accumulating productive and innovative capacities.

For Freeman (1987), national technological policies are essential, especially in developing countries, as the intensification of global competition as a consequence of the globalization process increases the importance of the concept of national induction policies. Erber (1992) converges with Freeman (1987) and affirms that in peripheral countries the importance of these public policies is exponentially increased, because the situations of backwardness in these countries are characterized by the absence of central links in the productive and institutional structure, which requires a structuring action of the State to induce - or even take direct responsibility through state-owned companies - the assembly of certain sectors in the productive matrix. It is necessary to create capacities in those activities essential for the existence of industrial production.

Cassiolato and Lastres (2001) also stress that in less developed countries these policies should also consider the need to limit or prevent undesirable social consequences, seeking, centrally and first of all, to promote the inclusive, cohesive and sustainable development. They point out that it is important that policies are continually adjusted and reformulated as technologies evolve, avoiding the retraction or destruction of the scarce productive and innovative potential of these nations.

[2]The authors' idea is influenced by Coutinho (2003) who defines benign macroeconomic regimes as "those that manage to combine low interest rates with relatively underappreciated exchange rates - that is, stimulants for domestic production and for exports. On the other hand, malignant macroeconomic regimes would be those that combine high interest rates with overvalued exchange rates, detrimental to domestic production and to the country's export competitiveness "(COUTINHO, 2002, p.194).

It is also crucial that exists an alignment between innovation and other policies. The systemic approach suggests that the companies' innovation strategies and results are influenced by other policies that directly or indirectly affect the innovation system. When properly organized, a national innovation system can be an important tool for progress. On the other hand, if poorly organized and connected, it can seriously inhibit the innovation process (FREEMAN, 1987).

In short, it is fundamental to recognize innovation as a result of a systemic process. In this context, in order to develop innovation policies, it is important to consider all the agents of this system, their interactions, specificities and contexts. Only a systemic approach has the capacity of mobilize the agents properly, stimulating the whole system to seek, in an integrated and coordinated way, the appropriate innovation to the local context. Thus, the next section presents examples from selected countries related to the development of wind power.

III. National Policies to Support Wind Energy: selected examples

In the 1970s and 1980s, the emphasis of these policies was to support scientific and technological development projects. Thus, countries such as Denmark and the USA have implemented research and development (R&D) programs for wind energy. In the late 1980s and throughout the 1990s, many governments implemented a mix of energy policies that secured a share of the electricity market for the wind power source and/or offered a tariff that remunerate energy generators at a price above the market (feed-in tariff)[3]. In gereral, these policies were extremely successful in stimulating enterperneus to invest in widn energy.

In the last decades, governments' actions have been expanding and including the support for the development of wind equipment. Numerous research centers, equipment testing stations, turbine standardization and certification programs have been supported by different national governments. In addition, many countries also used traditional industrial policy instruments such as: protection of domestic market, adoption of a minimum local content index for wind turbines and incentives to export equipment.

[3] Feed-in tariffs is a way to compensate producers for the high cost and high risk of producing and specific energy.

The purpose of this section is to briefly describe, from a historical approach, the main instruments that were used by governments in supporting the development of the wind industry. Some countries were selected in order to encompass the most significant policy cases in the wind industry: Denmark, United States, Germany, Spain, India and China.

Denmark and the United States were selected because they were pioneers. Denmark is not among the leaders in wind power capacity in absolute terms, but it has the largest national share of wind energy in the world: 20% of the country's electricity comes from the wind (IEA, 2012). The US concentrates the second largest installed wind power capacity (IEA, 2013).

Germany has become a reference for several countries that have adopted policies to support the wind industry, as it has developed a strong industrial base of wind equipment, introduced important technological innovations and concentrates the third largest installed wind power capacity in the world (IRENA 2012; IEA, 2013).

Spain is a latecomer, and it is interesting its policies implementation aimed at the production of wind turbines and the installation of parks. Currently, Spain is the fourth placed in installed capacity of this energy source (LEWIS, 2009, IRENA 2012 and IEA, 2013).

India and China are important players in the global wind industry and, unlike the other selected countries, are emerging countries. Both countries began to invest in wind power in the 1980s, but in a timid manner, and only in the 2000s they did become global leaders (IRENA, 2012; LEWIS, 2009). In these two countries, the impact of the international crisis on the wind power market and wind turbine production was positive, while in the first four countries it meant a downturn in this industry, (LEWIS, 2011; BOTTA, 2013). China is an extraordinary case in wind power, as the country has become a leader in installed capacity and its companies have become global leaders in an extremely short space of time.

IV.1. Denmark

The Danish State was one of the pioneers in supporting the development of wind turbines for the purpose of generating electricity. In 1973, at first oil crisis, Denmark's energy matrix was composed of 90% of oil (IRENA, 2012). So, in 1976, the Danish government decided to invest in renewable energy.

The Danish government started supporting R&D projects focused on reducing the vulnerability of the Danish energy matrix – as the Energy Research Program settled up in the 1970s. In 1976, Denmark installed the first commercial wind turbine connected to the public power grid in the world (COSTA et al., 2009). From the 1976 law that encouraged local energy production, farmers were the first to invest in the manufacture of wind turbines to generate their own energy. As these turbines had a high cost, their production developed within the model of local cooperatives (IRENA, 2012).

In 1981, Denmark launched its second energy plan, which laid the foundations for the rapid growth of the local renewable energy market, creating what could be considered a first version of a feed-in tariff (HEYMANN, 1998). A series of subsidies were given for the construction of wind farms until 1988, in addition to tax incentives for families that generate wind energy in their communities. As a result, a growing number of small wind turbine cooperatives begun to consolidate in the country (IRENA, 2012).

In 1985, the Ministry of Energy agreed some targets with the wind energy dealerships and it became an important support to the local wind industry. Wind energy was considered the nuclear substitute and became the most supported source of energy by the Danish government (IRENA, 2012). In 1990, Denmark established an energy plan, implementing a goal of reducing Danish CO_2 emissions by 20% between 1990 and 2005 and specific targets as 10% of the country's electricity should originate from wind turbines by 2005 (this objective was reached in 1997, COSTA et al., 2009).

A year later, a feed-in tariff system was introduced. The Danish system decoupled the purchase price of the wind power from the electricity tariff and the projects received taxes refunds from Danishcarbon (total) and energy (partial), resulting in a double payment for wind projects in the first five years of its operation. This mechanism was extremely efficient, as it guaranteed stable revenues for the producer, contributing to the expansion of the wind industry in Denmark.

In addition to market policies, the government has also adopted various industrial and technological policies. Support for R&D, for example, was, since the beginning, one of the pillars of the wind industry development in Denmark.

Denmark distinguished itself from the others pioneers countries (USA and Germany) by the stability of its R&D programs. The turbine quality standardization and certification programs were also essential for wind power innovation policies. Denmark was the first country to require equipment certification as early as 1979 and used its pioneering approach to create an implicit technological barrier to local market access.

Another measure taken by Denmark to protect the national industry was the financing availability with favorable interest rate for any wind projects that use national turbines.

Finally, it is important to highlight the importance of research centers for the development of Danish industry. Denmark has developed large wind energy research centers that operate at all stages of research: research, design, field testing and demonstration. Because they have an important infrastructure, they also attract turbine manufacturers, wind energy dealerships and even other research institutions. These centers also have a strong relationship with local universities and have become central players in the National Wind Energy System in Denmark, acting as a locus of interaction between wind industry actors (MEYER, 1995).

The Danish government was extremely efficient in mobilizing existing technological capabilities to develop a national wind energy industry. In 2010, Denmark had 180 companies in the industry, employing more than 20 thousand people internally and moving US$ 4.4 billion annually (COSTA et al., 2009).

IV.2.Germany

Like Denmark, discussions of sustainable electricity generation in Germany began after the 1973 and 1979 oil crises. During the 1970s, German government efforts focused on supporting basic and applied research.

The German citizens also formed the first cooperatives of wind turbine producers. The involvement of a large number of small investors has contributed to a broad public support for wind power projects. After the Chernobyl accident in 1986, Germany resumed its wind power R&D programs more significantly (JACOBSSON, LAUBER 2006). In 1989, the German government initiated a specific program for wind energy that involved mainly the guarantee of payment of a tariff for the electricity produced by the wind.

Based on this experience, in 1991 the Electricity Feed-In Act (EFL) regulated the purchase and electricity price generated by hydropower, wind, solar, gas and biomass and proposed a feed-in tariff for generators of these sources (IRENA, 2012).

The subsidies were also important for reducing the risk for the development of projects related to these sources. The 250 MW Wind Program (1989-1996) provided subsidies for investment in wind farms and financing with very low interest rates and long amortization periods (JACOBSSON, LAUBERB 2006). It is worth remembering that the development of an industrial park associated with wind equipment has always been considered as a priority for the German government. For example, the subsidies for the construction of wind parks were directed to projects that used national turbines and the granting of preferential financing, with interest rates far below those practiced in the market.

As in Denmark, German research centers played a central role in the learning process of the wind industry as they have become the interaction locus of the main players in the industry.Germany also invested heavily in the search for outside markets for its wind equipment and launched two incentive programs for the export of wind equipment in the 1990s. The programs provided subsidized financial resources for the purchase of German equipment. Through this programs, turbines were installed in countries of Africa, Eastern Europe and mainly in China (MIZUNO, 2007).

In 2011, in response to the nuclear disaster in Fukushima, Germany decided to eliminate nuclear energy by 2022, expanding its investments in energy efficiency and increasing the use of renewable energy sources (BMU, 2011b).

The German experience can be considered as extremely successful: since 1991, the year of implementation of the Feed-In act of electricity, until 2007 Germany has maintained the world leadership in installed capacity (DUTRA, 2007). In 2007, there were more than 19,000 wind turbines in operation, allowing the production of 7% of the total energy used in the country. By 2030, the goal for this percentage is 30%. In 2007, the three main German manufacturers - Enercon, Siemens and Repower - dominated approximately 20% of the world market of aerogenerators. Siemens was the ninth largest wind turbine company and is a leader in the offshore wind turbines sector. The German State has united a strong environmental concern and the country's energy needs to a project to strengthen the German industrial park.

IV.3. United States

Together with Denmark and Germany, the US have also been a pioneer at the wind energy market as a result of significant investments in energy programs and support to equipment manufacturers.

In response to the 1973 oil crisis, the US government began to implement federal programs to support basic and applied research and demonstration projects related to renewable sources. Five years later, the federal government introduced market incentives, such as tax credits and implemented an electricity market for autonomous electricity producers through the Public Utility Regulatory Policies Act (PURPA).

State and local governments have played an important role in the development of the renewable energy sector. The US states adopted a range of tax incentives and financing programs for wind investments (BIRDA et al., 2005). The state of California, for example, in the early 1980s introduced an investment subsides on wind power which, combined with PURPA and federal tax credit, helped in the development of the country's first utility wind farm.

The strongest interest in wind power would only surface in the United States with the Gulf War in 1989. In 1990 the Advanced Wind Turbine (AWT) program was implemented and expanded through the Energy Policy Act of 1992 (EPAct)[4]. The program involved applied research, which was carried out by the national and turbine laboratories together with the industry, as well as field tests also carried out in cooperation for the solution of technical problems (MIGLIORE, CALVERT 1999). A ten-year tax credit has been stipulated for renewable energy producers and private and public companies.

In the 90's, the federal government structured specialized centers in wind energy[5]. In 1994, it built the largest wind park research center, the National Wind Technology Center (NWTC), which has coordinated various research programs. As in Denmark, North American centers also manage demonstration projects for wind parks and host field testing stations. These activities involve varied actors from the industry and investment in training for certification.

The year of 1999 was characterized by a maturity of the wind market. According to Birda *et al.* (2005), the expansion of this period occurred due to the continuity of state and federal policies and the reduction of costs due to advances in technology and economies of scale. This phase is characterized by a movement of decentralization of market creation policies for renewable sources. The most important instrument of federal legislation during this period, however, was the Energy Policy Act of 2005 (EPACT05), which can be understood as a continuation of the Energy Policy Act of 2002. Among a variety of other provisions, it extended the coverage of tax credits for production and

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[4] The EPAct law promoted the deregulation of the electric sector in the United States, leading to the opening of transmission networks to independent energy producers and forcing competition among electricity suppliers. In this context, PURPA has lost its relevance. Within the scope of the EPAct, support for wind energy has been expanded.

[5]There were already some research centers, such as the NationalRenewable Energy Laboratory (NREL), which had already done some wind research. In addition, there were occasional projects at universities. However, wind power activities gained another dimension in the 1990s.

stipulated short-term consumption targets for renewable sources in general (EPACT, 2002, 2005, BIRDA et al., 2005)

It is necessary to highlight the articulation between the US Department of Energy (DoE) and the wind industry as a crucial factor for the US to achieve leadership in the productive development of wind equipment. Most of the technological achievements reached by the sector were attended by DoE. DoE's wind energy program has provided strong support to equipment export, allowing the industry to achieve successive growth records.

The United States became the country with the largest increase in wind power capacity in the world in 2007 and became the leader in terms of total installed capacity in the following year. In addition, the US has developed a strong wind equipment industry. According to Costa *et al.* (2009), the US wind power strategy can be classified as an aggressive government policy of incentives that allowed the US to become an industrial power in this segment.

However, the economic 2008 crisis has caused a downturn in the US wind industry, which has cut installations, dismissed employees, delayed projects and other impacts. The US government has tried to minimize the effects of the crisis with some measures, such as the 'Recovery Act' and 'Reinvestment Act', which included various provisions to support wind energy. Another measure was the Employment Creation Act of 2010, which established that projects under construction, including wind power, would become eligible for the US Treasury grant program (TAYLOR and TURNER, 2012).

IV.4. Spain

Spain has quickly become one of the countries with the largest installed capacity and production of wind equipment in the world. Unlike the first three cases presented, the policy to stimulate the importation of foreign technology was the main mechanism in the creation of a domestic wind industry in Spain (DINICA, 2008).

Spain had its first contacts with wind power in the 1980s, when occasional R&D subsidy programs for the development of wind turbines were adopted. But it was in the following decade that Spain expanded its installed wind capacity and its local wind industry (SALGADO, 2011).

Renewable energy projects have benefited from federal subsidies. In 1994, Royal Decree 2.366 was the first attempt to introduce specific tariffs for renewable energy. In 1997, the Electric Energy Law was introduced, which established new rules for renewable energy and the process of liberalization of the electric energy sector in the country, seeking to make price guarantee more flexible, combining a market mechanism with a second price system.

In addition to the mechanisms of market creation, several measures such as R&D programs and the development of certification centers were implemented. Testing activities, adaptation and development of technology began to be carried out in Spain by the Research Center for Energy, Environment and Technology (CIEMAT) in the early 1990s.

The production of the first wind turbines in Spain was based on a process of technology transfer from the pioneer countries, adopting the following mechanisms: (i) creation of joint ventures with companies already consolidated in the equipment production, (ii) creation of a standardization and certification system, (iii) development of large R&D centers with of basic and applied research, and (iv) direct state investments in technology development (LEWIS, WISER 2007).

In 1994, a joint venture between Spain's Gamesa and the Danish world leader Vestas was signed, which allowed Danish companies to gain access to the growing European market and enabled Spain to access the most advanced technological processes. According to Lewis and Wiser (2007), the success of Gamesa and other manufacturers is also related to the set of policies implemented by the Spanish State.

The Spaniards also invested in the development of their own turbine standardization system and in quality test programs. These programs were essential in the technology transfer process between the pioneer countries and Spain. In addition to stimulating the improvement of production processes and forcing user-producer interaction, such instruments were essential in the process of adapting technology (DINICA, 2008).

As of 2000, there has been an in increased resource allocation for wind energy projects, involving research institutions and turbine companies and components and engineering companies (BOLON et al., 2007). The Spanish strategy since 2000 has been guided by a goal of expanding the country's technological autonomy. In this context, in addition to expanding the R&D amounts, new centers were created.

It is possible, therefore, to perceive a change in the Spain's strategy. Until the late 1990s, it invested in attracting Original Equipment Manufacturers (OEMs)[6], joint

[6] OEMs are the Original Equipment Manufacturers, i.e, firms that design and produce the wind turbine.

ventures, and technology adaptation efforts. Starting in 2000, there is an effort to acquire technological autonomy and attract component manufacturers in detriment of complete manufacturers.

The development of the wind industry has become a national success story and installed wind capacity has grown from 7 MW in 1990 to over 377 MW in 1997. The Spanish experience seems to effectively combine foreign direct investment attraction and national industry development. In addition to local content requirements, stable feed-in tariffs and attraction of leading OEMs, investments in large R&D centers that have coordinated basic and applied research in the field of wind power, development of quality testing centers and a system of technical standardization specific to the country were essential for Spain to become one of the main producers of wind equipment.

IV.5. India

The Indian case has similarities with the Spanish one, since it also adopted traditional mechanisms of technological transference. Although India has adopted a range of policy mixes to develop the domestic wind power production industry, it is possible to state that the creation of joint ventures and the technology licensing processes between Indian companies and the mains turbine manufacturers of the pioneer countries were the main mechanisms of the country's access to imported technology (LEWIS, 2009; MIZUNO, 2007).

The quest for energy self-sufficiency was one of the main drivers for the development of renewable energy sources in India. Efforts in that country also began after the two oil crises of the 1970s, with the creation of the Committee on Alternative Energy Sources, responsible for implementing programs for the development of new and renewable energies and systematic R&D for wind power.

In 1982, the first wind turbine connected to the grid was created and some fiscal incentives to support wind energy were introduced between 1985 and 1990 with the 7th Five-Year Plan and the Indian Agency for Renewable Energy Development (IREDA) to provide concessional lending to energy efficiency and renewable energy.

Until the early 1990s there wasn't a long-term strategy for national technological development in wind equipment in India. As a consequence of the process of economic liberalization in the same decade, foreign direct investment (FDI) was encouraged in

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This firms invest in innovation and may produce most parts of the turbine or they can outsource some parts of wind turbines (PLATZER, 2011).

several segments of the economy, including the wind industry (IEA, 2012). Thus, the start of the construction of a local productive base in equipment for wind power generation in India coincided with this opening of the country to FDI. External investments, whether or not conditional on the formation of joint ventures between foreign turbine manufacturers with domestic companies or local content compliance requirements, was an essential factor for the initial formation of the wind turbine production structure in India (KRISTINSSON, RAO 2007).

Government support has become significant since the second half of the 1990s, when the development of technologies adapted to local specificities was adopted (RAJSEKHAR et al., 1999; MIZUNO, 2007). In addition, in 1997, the Ministry of Non-Conventional Energy Sources was created, which coordinated the promotion of wind energy research, participating with 50% of project costs. The projects became more interactive, emphasizing the exchange between industry, research institutions and final technology users.

Thus, the expansion of wind farms has gained impetus in India since the 2000s, when the government set the quota system for wind power and subsequently approved a national content law. In 2009, the government implemented a subsidy per kWh of electricity generated, with duration of 10 years, (IEA, 2012).

So all of these factors made India the fifth largest wind energy market in the world and boosted Suzlon, the largest Indian wind power company, to become the sixth largest in the world in this segment in 2011.

IV.6. China

Until the mid-1990s Chinese efforts focused on building small demonstration wind parks using Chinese or foreign government funding (LEMA et al., 2011) and the wind power industry was developing at a slow rate.

It was only in 1997, through programs that encouraged the technology import - transfer or licensing - that the wind industry had the first impulses. At this year, the government launched the Riding Wind Program, which formalized the strategy of building a domestic turbine industry through the introduction, incorporation and absorption of foreign technology. In addition, the Chinese government began to negotiate joint ventures composed by Chinese and foreign companies, offering access to the local market (LEMA et al., 2011).

With the Tenth Five-Year Plan (2001-2005), the Chinese government has introduced a wide reform of the Chinese electricity market. It was decided that the wind energy sector would be guided by a concession policy, in which the main objectives were to expand the installed capacity rate and the national production capacity of wind equipment and reduce the costs of wind power generation. As conditions to be eligible for the bidding process, wind turbines needed to have at least 70% of national content (WANG et al., 2010).

However, until 2006, despite the Chinese advances in relation to renewable sources, these were still marginal. Only this year that the Renewable Energy Act stipulated that renewable sources development was a national priority and it was established that public companies should prioritize renewable energy in relation to other sources and allocate resources for wind energy R&D projects and for wind equipment manufacturing projects (PENGFEI, 2005).

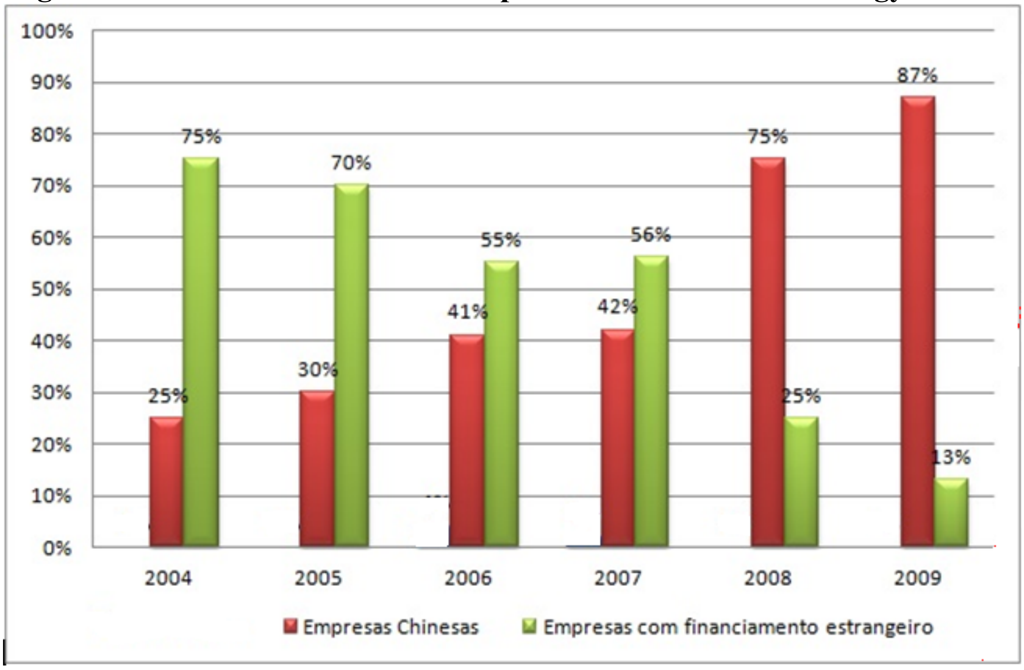
The following year, the government launched the Medium- and Long-Term Plan for Renewable Energies, which had national targets and a fiscal incentive package to favor domestic turbine manufacturers. Local content rules were maintained and strongly stimulated the development of a national production system for wind equipment (MARTINOT, JUNFENG 2010).

In 2009, a premium rate was introduced for generation of wind energy for a period of 20 years. The Chinese government then went on to promote the fabrication and development of national technology more aggressively. The state began to act directly, forming large state-owned enterprises such as Sinovel, Goldwind, Dongfang, and investing in attracting foreign companies to the creation of national subsidiaries. As already mentioned, the access of the OEM subsidiaries to the domestic market was conditional on the creation of joint ventures with Chinese companies. The major international wind turbine manufacturing companies such as Gamesa, General Electric, Nordex, Suzlon and Vestas have been established in China. Due to the attractive domestic market, the country was able to link FDI to the evolution of the local turbine industry (LEWIS, 2011).

In addition to contributing to the construction of a local base for the manufacture of wind turbines, foreign capital was essential in the process of training local companies. Major world manufacturers of turbines operating in the Chinese market invested in capacity building in local companies.

Thus, as early as the mid-2000s, the Chinese wind turbine manufacturing industry has taken off rapidly and, since then, has grown exponentially. From 2007 to 2008, the number of domestic turbine manufacturers in China rose from 40 to 70. At the year 2011, Chinese wind turbine manufacturers Sinovel, Goldwind, United Power and Dongfang Electric entered to the list of the ten world largest wind turbine manufactures. Figure 2 shows the rapid technological endogenization process of Chinese enterprises. In 2012, China announced the first wind turbine developed exclusively with national technology.

Figure2 - Evolution of Chinese Companies in the National Energy Market



Source: GWEC, 2010

Thus, it is possible to say that the Chinese experience was extremely successful. In less than a decade, the country underwent a strong endogenization process of the technical process and became an important producer of wind equipment, in addition to achieving leadership in the installed capacity of wind power (LEMA et al., 2013)

In order to understand the extraordinary growth of Chinese companies, it is necessary to analyze both structural and conjunctural factors. In relation to the former, the success of the Chinese leadership's reach is the result of a systemic policy, which used a wide range of instruments to support the wind industry in the country. In its strategy, it is possible to identify some traditional mechanisms widely used by other countries, such as premium rates, wind energy purchase guarantees, availability of financing, tax incentives of all kinds and subsidies for both entrepreneurs and the equipment.

However, the Chinese government has created state-owned equipment manufacturing enterprises, purchased foreign high-tech companies, required to form joint ventures, established a nationalization index to participate in bidding processes for wind farms, among others actions (BOTTA, 2013). In addition, the huge Chinese market also served as an anchor for the development of this industry.

The Chinese government also made efficient use of policy instruments. Tariff policy is an example. Import tariffs were high when the objective was to protect the domestic industry and reduced when the intention was to stimulate imports to support the local development of the production chain (ZAO et al., 2012). Another example was the import taxation increase of complete average size equipment when the national industry produced this kind of equipment.

China's tax policy took into account the national technology stage. It had the ability to protect local industry from foreign competition in technologies that were dominated by leading countries and, on the other side, it maintained the processes of technology transfer in the segments that wasn't dominated by national companies. Thus industrial policies stimulated the formation of joint ventures as the main technology transfer channel. With the consolidation of Chinese companies in the production processes, these policies started to encourage Chinese training in the design of wind turbines.

But it must be understood that the policies adopted for the wind power go beyond a sectorial view. The development of the wind industry in China is linked to a broader development strategy adopted by the Chinese State. Since the 1970s, China has focused on the development of science and technology as a pillar of the country's development; In the 1990s, the Chinese State set itself the goal of achieving leadership in key environmental technologies and, in the 2000s, started to focus on the development of specific innovations for Chinese society, called indigenous innovation.

The Chinese experience reveals a structural reform supported by a wide range of instruments in which different contexts, cognitive systems and articulation forms, cooperation and interactive learning between agents have been incorporated into the policies.

In addition to the structural factors mentioned above, cyclical factors also favored the expansion of the Chinese wind industry. The international 2008 crisis has brought about a reconfiguration of the international wind sector, with more perverse effects on the US and Europe, changing the dynamic axis of productive growth of the global economy. The investment dynamism, production and consumption, began to originate in emerging countries. This redirection had repercussions on strategic areas such as wind energy. The crisis has weakened traditional wind energy markets and favored the expansion of emerging ones, with China being the country that has expanded most the wind sector since then. So, in 2010, China concentrated almost half of the world's investments in additional wind power capacity and exceeded the US in total installed capacity, achieving global leadership in both installed capacity and wind turbine manufacturing.

In short, the conquest of Chinese leadership in the wind industry was driven by conjunctural factors associated with the international crisis, but is the result of a structural reform of the Chinese State based on the introduction of a set of systemic and articulated policies.

IV. The Brazilian Wind Energy Policies

The first Brazilian investments in wind energy also occurred in response to the energy crisis of the 1970s. At the end of that decade, the military government initiated a series of initiatives aimed at developing scientific and technological capabilities in alternative energy sources. By the end of the 1990s, programs to encourage the development and use of wind energy have intensified. Unlike the 1970s, where the search for energy alternatives was motivated by the rise in the price of oil, support for the wind power of the 1990s was associated with concerns about environmental problems, since the 1990s was marked by an intensification of discussions on sustainability.

But it was only in the early 2000s that wind power became a concern for the Brazilian government, as the country was again in a situation of energy vulnerability. Strong energy rationing became necessary and an effort was made to diversify the sources of energy generation.

The next sections analyses some Brazilian policies to develop the wind energy in the country.

IV.1. Industrial Policy and Incentive Programs

In 2001, the first plan was launched to insert the wind power source into the energy matrix - the Emergency Wind Energy Program (PROEÓLICA). However, the Program failed for a number of reasons, such as the low reference value adopted that did not cover the costs, short deadlines and lack of regulation that clearly established the goals and benefits of the Program (Wachsmann and Tolmasquim, 2003). The implementation of the wind parks did not meet the deadlines foreseen in the Program and the targets were not reached.

With the change of government in 2003, the Incentive Program for Alternative Sources of Electricity (PROINFA) was launched in the following year with the objective of increasing the participation of renewable energy technologies, and wind power was among them. This would be done through some kinds of instruments: feed-in tariff; contracting quotas; long-term energy sales contracts with Eletrobrás and favorable financing conditions by the Brazilian Development Bank (BNDES). The implementation of PROINFA, therefore, established a market reserve for wind energy and reduced the risks of the associated investments.

The strategy to develop domestic capacity to produce wind turbines and their components was based on the attraction of foreign direct investment (FDI). For this, the main instrument in the strategy of attracting the subsidiaries of transnational companies was the institution of the index of nationalization (in which a portion of the components that would make up the wind park should be provided by Brazilian companies), initially linked to PROINFA and later to BNDES financing lines.

Although PROINFA appears to be well-drafted, as it has encompassed a number of traditional mechanisms that the leading countries have already adopted, such as setting a target for wind energy expansion, a price guarantee system and a preferential investment line, it is possible perceive a disconnection of the program with the Brazilian context, which resulted in obstacles to its execution. Some of the projects had financial difficulties and were sold to other firms[7], mainly large transnational companies[8]. Therefore, unlike Denmark and Germany, where local actors were protagonists in the initial development of the wind power source, Brazil opted to develop the wind sector through large international companies and with little participation of local players.

It is worth noting that feed-in tariff was one of the first policies implemented in Brazil for wind energy support and was not accompanied by a set of industrial policy instruments. Differentially from the leading countries, in which the feed-in tariff was

[7] As difficultied to comply with the guarantees required by BNDES.

[8] More than half of the contracted projects had their property changed. At the end of several ownership changes, large companies of the energy sector became the final owners of the projects.

instituted only after approximately a decade of development in R&D or the other latecomers where such policies were accompanied by numerous mechanisms to support technology transfer.

It can be stated that until 2009 the local content rule did not have sufficient strength to make Brazil attractive to receive FDI from OEMs. By the end of the 2000s, the international wind market was extremely heated and Brazil did not clearly set its goals for wind power.

In addition, since the abandonment of national content in PROINFA until the first auction of wind energy in 2009, there was practically no industrial policy on wind energy in Brazil. In 2009, industrial policy was taken up in a timid manner through preferential financing lines for wind parks that have won the auction, with a minimum national content as a requirement for these credit lines.

It was only as a consequence of the new world scenario marked by a crisis in the advanced economies and the main transnational companies with idle capacity in the countries of origin that Brazil became a promising option in the wind sector. The international environment was a slowdown in traditional markets and a shortage of credit, while the internal environment was a prospect of growth in the domestic market, a favorable exchange rate for imports, supply contracts that guarantee revenue for a period of 20 years and availability of subsidized financing lines. Therefore, the Brazilian wind energy market was driven by a window of opportunity.

In 2010, Brazil was chosen as the ninth best country in the world to receive wind energy investments and in 2011 achieved the cheapest price wind energy in the world (SIMAS, 2012; MME, 2013). The holding of an exclusive auction for wind power in 2009 allowed the country to take advantage of the opportunities of the conjuncture. As a result, the period from 2009 to 2013 was characterized by a strong expansion in the Brazilian wind market, which started to contract growing volumes of wind energy at low prices. Bot this expansion is more associated with conjunctural factors than the results of the policies implemented for its development. Until 2009, the policies adopted were even inadequate to the Brazilian context. It was only after that year that the new international context allowed the policy to begin to function.

It should be emphasized that in terms of the national strategy for the development of the wind power source, priority was given to a quickly constitution of the market, and this prevailed over the objectives of generating employment and consolidating a productive structure. There was, therefore, a subordination of industrial policy to the needs of the energy sector. It can be affirmed that Brazil's commitment to the attraction of FDI as a way to develop a wind industrial structure was not successful in relation to technological transfer processes and the strengthening of innovation capacity in the country.

Aware of this limitation, in 2012 the BNDES changed the local content rules associated with the financing of wind parks, with a progressive increase in the number of national components in the equipment. So, the country was able to build a local turbine industry. The change in BNDES rules had a significant impact on OEM production and innovation strategies, which has been making an effort to develop a network of national suppliers of higher technology components. Thus, only in 2012 there was a greater alignment of financing and industrialization policies with the processes of technology transfer and capacity building for innovation.

IV.2. Auction Model

In 2004, the Brazilian government launched the new regulatory framework for the electricity sector, with energy auctions being the main mechanism for energy sources. The model introduced a new logic different from PROINFA. While the auction was intended to stimulate competition among entrepreneurs through price in order to achieve a cost minimization, the premium rate, the main instrument of PROINFA, was intended to guarantee a remuneration above the generation cost to the entrepreneurs. It is possible to affirm, therefore, that there was an incompatibility between PROINFA and the new energy model, which led to the end of PROINFA in 2007.

Until 2009, no auction was held for the wind power source. Even with the creation of s specific auction for alternative energy sources (LFA) in 2007, in which these sources were free from competition with conventional ones, no wind power project was contracted[9]. This result suggests that opting for the auction mechanism to promote the wind power source was not an option consistent with the Brazilian context of wind energy. At that time, wind energy was still incipient in the country and only a portion of PROINFA's projects had come into force. The wind industry had not yet established itself locally and there was no possibility that wind projects could achieve a cost reduction due to the scale effect or the establishment of a network of local suppliers.

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[9] At that time, the price of wind energy was above R$ 200.00/MWh, making competition with other participating sources impracticable.

In addition, large global energy groups were not interested in the first LFA, mainly due to the strong growth in the global wind energy market at that time (China and US), as well as enjoying premium tariff policies in latecomer countries. Thus, the contrast between the high growth of the world market, the small national market and the lack of stability in the policies to support wind energy in Brazil made the large energy groups have as their preferred targets the leading countries. It is possible to affirm, therefore, that the use of the auction as an instrument to insert the wind source in the energy matrix in 2007 was an incoherent option with the context in Brazil and in the world.

It was only in 2009, when the government held an exclusive auction for the wind power source that the first wind projects were contracted. The auction was extremely successful, in which 71 projects were contracted.

In that same year, the nationalization index returned to the scenario of the wind power source, but this time linked to BNDES and Norwest Bank (BNB) financing. These preferential financing lines were important competitive factors for wind parks. Since these projects are capital intensive, access to low interest financing is central to the competitiveness of a venture.

IV.3. Science, Technology and Innovation Policies

Other policies have also encouraged the development of the wind energy source in Brazil, such as the Economic Subsidy Program ; the Electric Energy Sector Fund and the National Energy Agency R&D Program.

The objective of the "Economic Subsidy for National Innovation" program was to support the development, by Brazilian companies, of innovative products, processes and services, aiming at the development of strategic areas (FINEP, 2010). Despite starting in 2006, just in 2009, the announcement included the wind power as a priority. That is, only when it started to compete in the auctions and had already achieved a certain competitiveness, this source was considered a priority in the program.

It can be said that the economic subsidy, a pillar of technological policy, did not have the role of preceding the development of the wind market, as in most of the countries that developed this industry successfully. The withdrawal of wind energy in the 2010 announcement was a disconnection with the national scenario, since the 2009 auctions pointed to a perspective of continuous expansion of this source in the Brazilian energy matrix. It is also worth mentioning the subsidy given to small wind turbine projects, since the moment was marked by the prospect of development of the large wind industry in the country after the success of this energy in the auctions, which raises questions about the connection of the innovation policy instruments with the ones related to themarket constitution and regulation and with the industrial policy itself. Finally, most of the resources were destined to the southern and southeastern states, leaving the region with the greatest wind potential of the country - the Northeast - little contemplated. In 2012, one of the biggest difficulties in the industry was the shortage of suppliers located in the Northeast, a bottleneck that could have been minimized with the use of the subsidy Program for this region.

It is also worthy to note the Science and Technology Sectorial Funds created in 1999 to promote innovation in strategic areas through partnerships between companies and scientific and technological institutions. Brazilian Science and Technology Agency or the National Council for Scientific and Technological Development (CNPq) would grant nonreimbursable financing to the project and there was also the possibility of giving research grants through CNPq (KOELLER, 2009).

In 2001, an important fund called CT-Energy fund was created, in which projects related to wind energy could be applied. Until 2009, only the selection made in 2006 had the wind and solar photovoltaic sourcesas a priority. Of the 120 projects contracted, 15 were related to wind energy. However, the projects follow the same pattern of regional concentration as the Economic Subsidy program, located in the South and Southeast regions.

It can not be argued that sector funds did not promote interaction among local actors, but this interaction turned basically to the segment of small wind turbinesmanufacturersand research groups in the electricsector. Again, there is a mismatch between science and technology policy and other policies. In this case, it is evident that there was a lack of a systemic vision that would coordinate the market and technological policies and direct the instruments to the bottlenecks that the country faced.

Still in this context of science, technology and innovation policies, the Brazilian Energy Angeny (ANEEL) created in 2000 a Research and Development Program that concessionaires, licensees or authorized companies of distribution, transmission and energy generation should apply in the program a minimum percentage of their revenue annually.

However, since the beginning, many companies did not implement R&D projects and the resources were not fully utilized. Some reasons were: the ANEEL'scriteria were not always clear (NEVES, 2011); few companies, especially firms with more experience and vocation in R&D, submitted project proposals (Teixeira and Marques, 2008); the program was more focused on research than on development Polito, 2006); lack of projects articulation with the needs of the country and with industrial and technological policies (Silva et al., 2010).

Thus, in 2008, with the objective of increasing the agility of the program, was created the ANEEL Strategic R&D Project that defined thematic calls and criteria. Alternative energies have therefore been included as a priority theme.

However, it was only in 2013 that the first strategic public call for wind energy was instituted within the ANEEL Strategic R&D Program. Although it occurred late, the call was positive. As it was seen, in 2012 the BNDES changed the rules of national content linked to the financing of wind projects. Thus, it is understood that the institution of a strategic call a few months after the BNDES presented the new rule is an alignment between these policies. While the former required an increase in the local content of the production chain of wind equipment, the latter encouraged the ANEEL's R&D resources to be applied in the wind power chain.

IV.4. Conclusions About Brazilian Case

As it was seen, market structuring policies were adopted in an environment of energy uncertainties. In the context of the reform of the electricity sector, the specific needs of the wind power source were ignored and, only in the light of a new international situation, the market structuring policy started to work. In this way, it was possible to perceive the lack of connection of the market structuring policy with the stage of development of the technology and with the conditions of the national wind industry.

In relation to industrial policy, Brazil bet on attracting FDI. This option was first signaled with the establishment of minimum local content for the projects (PROINFA). This demand was eventually abandoned, as were industrial development goals, given the priority given to the rapid formation of a wind power market, which resulted in the abandonment of the employment generating objectives and consolidating a productive structure. There was no coevolution between the industrial policies and the market structuring policies, but an adjustment of the former in relation to the second one, being evident the subordination of industrial policy to those of market structuring.

From the abandonment of nationalization index in PROINFA to the first wind energy auction in 2009, there was practically no industrial policy for wind energy in Brazil. In 2009, a change in the international context ensured the success of these instruments and, from 2010, the main transnational companies began to open subsidiaries in Brazil. Thus, the country built a local turbine industry made up of subsidiaries of foreign companies, but did not associate instruments that promoted a technology transfer process.

In relation to science, technology and innovation (STI) policies, they were discontinuous, punctual and disjointed with the national context. The STI strategy in wind energy did not follow the productive strategy nor the objectives of the market structuring policy. The projects financed by these policies rarely coincided with the challenges of the wind industry, nor was there a direction of them to support the objectives established by the market structuring policies. Even though at the discourse level these policies were aimed at promoting innovation, they were limited to financing R&D projects without any apparent concern about how to use the possible positive results (which in turn had a high failure rate) to be used by the productive sector. The disconnection between policies was evident: while STI programs practically only financed small wind turbines, the energy policy objectives were not achieved because of wind bottlenecks in large wind turbines.

Therefore, the Brazilian experience pointed to a lack of coordination between the public policies aimed at the development of the wind power source. Market, industrial and scientific structuring policies seem to compete with each other and the objectives of one overlaps the goals of the others. That is, the synergies between policies were not fully utilized in the development of the wind power production structure in Brazil.

VI. Conclusion

Based on the analysis of the relations between crisis and innovation within the capitalist system and seeking to understand how technological revolutions arose to solve the main contradictions of capitalism, this article analyzed the importance of state policies for the development of the eolic power in different countries. The cases of Denmark, Germany, USA, Spain, India and China were discussed, as well as a deepening in the Brazilian case.

Thus, the article addressed the current crisis of capitalism, emphasizing the environmental dimension. Although most of the debate still revolves around the argument that the current crisis can be largely explained by problems associated with the financial sector, it is increasingly clear that it transcends nominal aspects of the economy, reaching substantively its realside. It is about a much broader crisis, with at least three important dimensions: economic, political and ecological.

The current accumulation regime is intensive in the use of nonrenewable resources and there is therefore the non-sustainability of the current technical-productive paradigm. Thus, the increasing importance of technologies related to environmental sustainability may be an indication of the constitution of a green techno-economic paradigm.

This possibility has already been affecting the strategies of large productive and financial corporations and states. Examples of state strategies that have placed environmental technologies as central among their recent public policies have been analyzed. As shown, the world economic powers are defining their technological frontiers based on the necessity of constitution and consolidation of new low carbon paradigms and technological trajectories and directed to the environmental sustainability.

Most of the wind power strategies discussed were initially development in response to the 1973 oil shock. Subsequently, this type of energy became an option for reducing the use of fossil fuels, responsible for the emission of greenhouse gases.

Nevertheless, some countries were leaders in the development of technologies, such as Germany and the USA, which had incentives to equipment export, allowing the technology transfer and economies of scale, reducing R&D costs and production costs. Other countries such as Spain, India, China and Brazil were importers of equipment and started their wind parks with technology transfers.

This dominant position in the development of technologies shows the movement of transnational companies, which seek to expand markets. In the post-crisis of 2008, when traditional wind power markets were negatively affected, emerging markets such as China and Brazil entered in the picture, following the valuing logic of global capitalism.

Although each country has its idiosyncrasies, international experiences show that both the development of installed wind energy capacity in the country and the industrial development associated with the wind sector have always been linked to a state project. The promotion of wind energy does not escape the rule of other great radical innovations that have been strongly developed anchored in government resources and research programs (MAZZUCATTO, 2011). The wind power source has an extremely dynamic technological trajectory, marked by recurrent innovations and a strong articulation with the scientific capacities.

And although international agencies insist that governments should only act on policies that focus on wind parks creation, international experience has shown that in countries where wind power has developed successfully, States have used a wide variety of policies that go beyond market instruments. Different policies, such as educational, tax, STI, fiscal, were used to support the development of the wind industry. States did not restrict their actions to a sectorial view.

On the other hand, in the Brazilian case, there is a lack of coordination between public policies aimed at the development of the wind power source. An example is the non-connection of the market structuring policy with the stage of development of the technology and with the conditions of the national wind industry. In addition, industrial policy was subordinated to the needs of the energy sector. The priority was given to a rapid constitution of a market with FDI attractiveness and this prevailed over the objectives of job creation and consolidation of a productive structure, leaving a gap in terms of technological transfer processes and capacity building in the country. Market, industrial and scientific structuring policies seem to compete with each other, and the objectives of one overlap the goals of the others.

The comparison of the Brazilian case with other countries reveals the importance of adopting a systemic vision that promotes an alignment between the different policies adopted. It is important that the policy instruments are connected with the socio-institutional context of the country. The stage of technology must be taken into account, as should the specificities of the countries. Therefore, the difference is that others countries developed systemic and coordinated policies than Brazil, that had an disarticulation between policies that limited the development of scientific capacities.

As Mazzucatto (2014) stated, in order to move towards more inclusive and sustainable growth, the state must play a crucial role and must lead the process. The forces driving technological change are cumulative, and thus only market forces are unable to reduce asymmetries (CIMOLLI & PORCILE, 2011). Thus, the insertion of the wind power source into the energy matrixes of the different countries is closely associated with the adoption of policies that foster their development, and these policies are capable to influence the dynamics of the productive structure and the processes of innovation.

It is undeniable that the partial substitution of fossil fuels for wind energy represents an advance from an ecological point of view. Reducing the consumption of fossil fuels and other resources that are harmful to the environment, replacing them with renewable and/or abundant resources is essential to maintaining the planet's ecological balance. Even so, the energy demand side should also be the target of public policies, since energy intensive consumption patterns need more energy sources, which, however renewable, always have some impact on the environment when the life cycle of the equipment are analyzed.

Therefore, as Sachs (2012) stated, it is clear that the challenges of sustainability go far beyond the management of natural resources. The construction of a sustainable development model needs to guarantee an innovative capacity and anautonomy in the scientific and technological research of the countries. Inclusive and sustainable growth will not happen on its own. Specific instruments need to be in place for this to happen.

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