Wind energy production in Bahia state (Brazil): mapping and discussion of the supply chain

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Abstract. The qualitative research, involving literature review and documental analysis aimed to analyze Brazilian wind energy production, and its challenges for supply chain. Logistics changed by new government's regulations and companies operating on this field. Strategies as partnerships and supply chain risk management are identified as alternatives for coming years.

Keywords: wind energy production; supply chain; renewable energy; strategies.

INTRODUCTION

The energy sector has received increasing attention from public policy of Countries around the world. There are more requirements for energy production to attend both population and manufacturing development, at low costs. This scenario can be critical in emerging economies like Brazil.

The Brazilian government developed a set of strategies on the last years. First, stimulus for efficiency on energy use, that on manufacturer's side means technology and process innovation, whereas population confronts growing taxes especially on high demand seasons (a flag system was implemented on first quarter, 2015). The efforts have been on the way to diversify the energy matrix and reduce dependence on fossil sources, searching alternative and sustainable ones.

The results are increased investments for hydroelectric, wind, photovoltaics, as well as biofuels sources. Finally, the opening of the energy market, allowing private companies to participate on the energy supply chain on production and distribution stage. The opening of energy market started in 1997 with non-renewable energy (gas and petroleum) and renewable energy production, trying to establish adequate support to increase production.

Renewable energy has widespread benefits, as lower prices, reducing global carbon dioxide (CO_2), social development as new work force training, land restoration, reduction of air pollution, reduction of global warming, diversity on fuel supply, and also reduction of risk with nuclear

energy dependence (Johansson et al., 1992). On the other hand, there are still some disadvantages, as the biofuels that need the destination of land replacing food production, a much criticised point on emerging countries.

In Brazil, hydropower is the most important font of renewable energy, being for many years its representative font. Hydropower structures generate great amounts of electricity, necessaries to attend a region or also a whole country. But on the last years, these projects received some rejections. The money to support constructions and environmental cost, with flooded areas were some of the arguments. Also, climate change generated water crisis on vast regions and limited hydroelectric capacity, like in 2015, when affected Brazilian system. This scenario increased the need to search new fonts of energy.

New technologies developed on the last decades allowed diversification on sources for energy production, technological and financially. As representative quantities of energy on wind power, solar-thermal and photovoltaic farms able to connect to the central energy grid. Also new technologies for alternative fonts are being tested, as ocean waves, geothermal, biomass, biogas, etc.

Companies that are part of these projects face increasingly competitive challenges that require dynamic management, effective responses in shorter deadlines, without losing control of cost efficiency. That is because management of risk is a key point to mitigate their consequences.

The adoption of best practices in infrastructure, policies and methodologies that allow more efficient management of the limits of acceptable risk, capital, and price of the portfolio is defined as risk management (Crouhy et al., 2000). It is important to highlight that in fact, all aspects of a company are exposed to risks, which are often out of control. Thus, risk management helps in developing ongoing strategies designed to control, minimize or even eliminate the risk (Lee and Whang, 2005; Simchi-Levi et al., 2013). It is understood by risk management in the supply chain or supply chain risk management (SCRM), the identification of risks through the supply chain and coordination of its members, to reduce the vulnerability approach as a whole (Jüttner et al., 2003).

The categorization of various types of risks in the supply chain is considered a challenge due to their complexity (Choi and Krause, 2006; Pfohl et al., 2010). To Simchi-Levi et al. (2013), potential interruptions can happen within the supply chain (eg insufficient quality, unreliable suppliers, machine breakdowns, uncertainty in demand, etc.) or outside (eg flooding, terrorism, strikes, natural disasters, large variability in demand etc.). Another proposal for categorization is considering three types of risks (Waters, 2007): (i) on a focal company, (ii) outside the focal company, but within the supply chain, and (iii) outside the supply chain but affecting the focal company in its respective place of origin.

The aim of this paper is to explore the Brazilian wind energy production and its supply chain, especially focusing on the north-east region. The following questions conducted the study: What is the current status of Brazilian wind energy production, and its relation with the national energetic matrix? What are the characteristic of wind power supply chain in Brazil? What challenges are to be confronting in the next years, especially regarding risk management?

METHODOLOGY

The methodology was qualitative with literature review and documental analysis (Saunders et al., 2007). The literature review was developed in google academic database. This source was

chosen by allowing the access to various fonts, including congresses, journals, symposiums, etc. It involved publications on wind energy production in Brazil on the last five years.

The source also included official publications (governments and organizations of wind energy production system) as the Global Wind Energy Council (GWEC) and the Brazilian Agency for Industrial Development (ABDI). Information from these sources were confronted and explored to highlight strategies to identify and manage disruption risks on the wind power supply chain on the next years. Data collection was developed between March and August, 2015.

LITERATURE REVIEW

A literature review on the last five years on Brazilian wind energy production highlighted various key factors. They were classified in: climate conditions, energy market, grids integrations, technology development and human resources.

Taking into account the page limitation of this paper, they will be listed only with short comments:

- Climate change. The potential of wind power in Brazil would not be endangered on the next years by climate conditions (Lucena et al., 2010a). On this sense, studies indicate that wind conditions must be the same, and particularly would be improved in the north-east region of the country (Lucena et al., 2010a and 2010b).
- Future market. Regulation polices are expected to consolidate wind energy market on the country (Pereira et al., 2012). This is received as positive signal for the different players involved on the energy market, to overcome barriers and attract new investments.
- Grids improvement: It is expected a combined expansion of wind generation with regard to conventional inflexible generation facilities, such as nuclear plants and hydropower (Borda, 2012). It is also showed that wind power generation complement hydroelectricity when rivers are on low levels in north-eastern Brazil (Jong et al., 2010). This is a key fact taking into account the last hydric crises on the country.
- Technology development. Development and acquisition of local technology is still incipient. It is still needed the production of wind turbine components as well as to increase collaboration between industries and universities in the country (Aquino-Juárez et al., 2014). Wind power projects are benefit from technology transfer between companies on different levels (Lema and Lema, 2013)
- Labour force and employment. Wind power is frequently matched with job's generation. Simas and Pacca (2014) demonstrated that the project's stage (design and construction) is the most important on new job's generation. The training of new labour force for specific skills is identified as very important. Other fields, as jobs with operation and maintenance relative to new installed capacity are less significant.

These finding support that wind energy production will maintain growing in Brazil on the coming years. Weather conditions and local consumer market are expected to show positive conditions.

Technical innovation is mentioned as critic for the next years. Grid's projects in Brazil needs to follow the development of new wind farms, been actually the biggest challenge for government to accelerate these projects on the country.

Regarding government's regulation, in 2002, Federal government implemented the Supports Program for Alternative Energy Fonts (PROINFA, in Portuguese) to impulse the participation of new fonts on the electric matrix, by the Law nº 10.438. The PROINFA was focused on (Brazil, 2002):

- Diversification of the electric matrix and reduction of hydrologic dependence;
- Rationalization of the energetic offer by stationery complementation between Eolic, biomass and hydrologic fonts.
- The possibility of choice face on the Clean Development System Program (MDL, in Portuguese), of the Inter-ministerial Commission of Global Climate Change created by Presidential decrete in July 7th, 1999.

During the next years, the PROINFA program received some modifications to help on the evolution of alternative's fonts of energy, reaching many of its objectives. Although is needed more actions for the future.

In 2014, government published new regulations. These are focused on environmental licensing of wind farms, offering greater flexibility in the process and clearer legal framework for developers (Resolution 462/2014 of the National Environment Council).

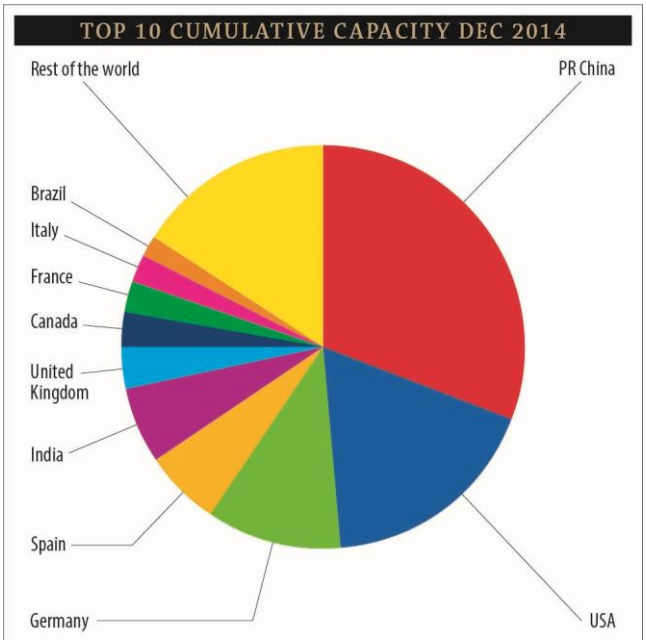
Also the regulations over the connection to the national distribution network (known as SIN, the national interconnection system) were modified, providing mandatory warranty for grid connection. An additional regulation is in discussing process; it is expected the introduction of tax incentives for local development of turbine parts and components.

WIND ENERGY PRODUCTION

Wind power energy production has grown fast on the last years. Publication of annual statistics of the Global Wind Energy Council (GWEC, 2015) highlights some previsions to 2015-2019. For a positive and optimistic outlook, global production will reach an installed capacity of 60 GW.

As key player, China will maintain the status of major producer (representing more than 30% of energy share of the country). Latin America must concentrate the biggest accumulated growth, with Brazil and México maintaining major rates on investments and development of wind power structures.

Comparing global production, Brazil is on tenth position, ending 2014 with a cumulative capacity of almost 6 GW (GWEC, 2015), that represents about 1.6% of the country's energy share (Fig. 1). The grid connection pending was still a great issue of Brazilian fully commissioned projects in 2014 (GWEC, 2015). For the coming years, is waited to keep a rate of 2 GW on new capacity installed for wind power generation.



Country	MW	% SHARE
PR China	114,609	31.0
USA	65,879	17.8
Germany	39,165	10.6
Spain	22,987	6.2
India	22,465	6.1
United Kingdom	12,440	3.4
Canada	9,694	2.6
France	9,285	2.5
Italy	8,663	2.3
Brazil*	5,939	1.6
Rest of the world	58,473	15.8
Total TOP 10	**311,124**	**84.2**
World Total	**369,597**	**100**

** Projects fully commissioned, grid connection pending in some cases* *Source: GWEC*

Figure 1 – Top 10 countries on cumulative capacity installed (GWEC, 2015).

Number of companies was incremented over the years, and they are new ones interested to stablish its operation in the country. Farms locations are concentrated in two principal regions: Southeast (especially Rio Grande do Sul, followed by Santa Catarina and Parana States) and Northeast (especially Bahia, followed by Rio Grande do Norte and Ceará States).

Statistics about distribution on cumulative capacity between States showed (in MW): Bahia 931,4; Ceará 1.233,2; Paraíba 69,0; Pernambuco 104,7; Piauí 88,0; Paraná 2,5; Rio de Janeiro 28,1; Rio Grande do Norte 2.092,0; Rio Grande do Sul 1.118,8; Santa Catarina 236,4; and Sergipe 34,5. The north-east region is presenting major growth in project numbers. The main reason of this growth is wind characteristics, which are of good quality for energy generation, on velocity and almost without fluctuation during the year.

CHALLENGES FOR WIND POWER SUPPLY CHAIN

Compared to other fields, wind power supply chain can be noted frequently by high complexity needing a collaborative planning between its parts (Prostean et al., 2014). The value chain (Fig. 2)

includes: supply of materials, components and sub-components and installation of wind turbines, services, operation of wind farms (energy production) and distribution in the national electricity network. This makes necessary the split into sub problems to handle the various issues involved.

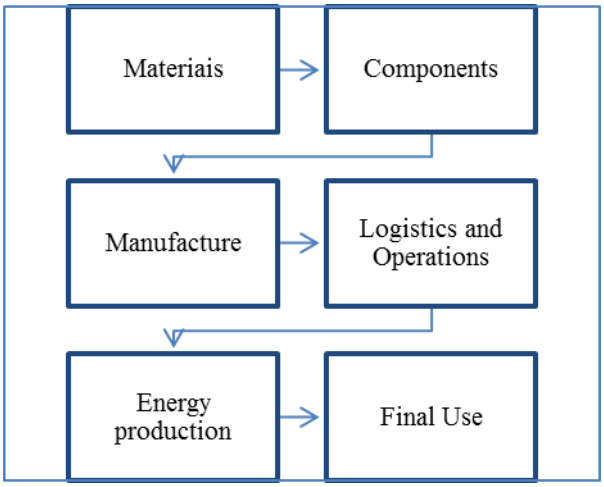


Figure 2 – Value chain of wind power system. Source: Adapted from the Brazilian Agency for Industrial Development (ABDI, 2015).

Each stage on Fig. 2 involves:

- Materials. Manufacturing of parts and components. Wind towers includes: Steel, concrete, Aluminium, cast iron, glass fiver, resin, adhesives, magnets, Cuprum, etc. On these stage it is necessary the accomplishment of quality standards for the supply.
- Components. Most of the components are manufactured locally, as the tower, blades, hub, and generators. Technology development of wind towers allowed construction of major tower, reaching more than 100 meters high.
- Manufacture. Original equipment manufacturers and assemblers are responsible to assemble different components on the wind farms. On case of Brazil, this is characterized by long distances from parts and components manufacturers to the final project location.
- Logistics and Operations. The complex logistics of wind power projects involves project's developer, consultants on different fields as environmental ones, project manager, transport of parts and components (Fig. 3), assemble, and operation & maintenance. As on the previous stages, involves great amount of companies specialized on different service fields. As parts and components are biggest than in the past, transportation is a challenge, especially by the fact that Brazilian wind farms are onshore, been some country's routes don't properly prepared for transportation of big equipment.
- Energy production. Involves the proper enterprises of Eolic sector. Although wind farms are located on remote localizations, they need few amount of labour force to operate. Challenge for energy production is the connection of produced energy to the national grid, to ensure supply of energy to consumers.
- Final use. Involves private and public enterprises responsible by the distribution of energy on the country (including Cities, States and Federal government).

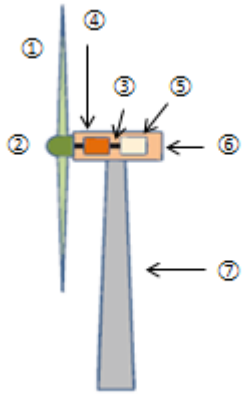


Figure 3 – Parts and components of traditional wind tower generators: 1) Blades, 2) Cube, 3) Axis, 4) Gearbox, 5) Generator, 6) Nacelle, and 7) Tower. Source: Adapted from the Brazilian Agency for Industrial Development (ABDI, 2015).

As identified the characteristics of the value chain for wind power generation, next can be pointed the key factors of risk on each stage (Table 1). Fonts can be internal or external to the supply chain. As example, on parts and components stage, prices of Steel and Cuprum have been fluctuated on las years affected highly by industrial requirements of countries like China. These fluctuations affect future contracts since they are signed with months before their assembly.

Table 1. Key factors of risk on supply chain for wind power projects

Key risk factors	**Affects**
Material prices, material quality, new standards	Materials
Technology development, Suppliers capacity	Components
Assemblers capacity and supply of components, assembly risks	Manufacture
Transportation of parts and components, wind fluctuation, tower's maintenance, climate conditions, labour force, environmental regulations	Logistics & Operations
Projects funding, electricity prices, grids and connections, fulfilment of contracted power, market regulation	Energy production
Grids connections, electricity prices	Final use

Challenge for Brazilian wind energy production is not only the structure of the electricity grid system. Logistics for production, transport and assembly of wind towers, parts suppliers that meets quality requirements are also some examples. There are players' characteristics as great number of companies, interaction between public-private companies, and big distances between farms and grid centres.

Regarding to the farms, they are completely onshore with horizontal type turbines. The government has expressed interest in developing research for offshore farms location, but it is not planned to hold investment for years to come. The predominance of onshore facilities is also due to the existence of good wind regimes in the country, especially the south and northeast regions.

CONCLUSIONS

Brazilian wind energy production has still some obstacles, not only the structure of the electricity grid system. Logistics for generator's manufacturers, transport and assembly of wind towers, and parts suppliers that meets the requirements are some examples. Number of companies was incremented over the years, and they are being received attentions of new ones interested to operate in the country.

Hydrologic font will continue as the most important font on the next years. This demonstrated to be negative for the country due to the water crisis of 2014 extended to 2015, and that generated an energetic crisis in 2015.

Farms locations are concentrated in two principal regions: Southeast (especially Rio Grande do Sul, followed by Santa Catarina and Parana States) and Northeast (especially Bahia, followed by Rio Grande do Norte and Ceara States). Wind energy production scenario indicates a sector in continuous growth, which should receive high investment with large number of companies. On the next years, smaller players will stand out as suppliers of parts or services. Thus, the sector will need continued improvements with strategies to enable efficient production at lower costs.

Future works will involve case studies with companies operating on this sector. The objective is to identify how companies are operating to avoid or mitigate risk factors. Furthermore, the development of strategies of supply chain risks management for wind energy sector on the next years.

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