 DOI: 10.4215/RM2016.1501.0009

GEOLOGICAL RISK EVALUATION IN THE EOLIC ENERGY PLANNING ON RIO GRANDE DO NORTE, BRAZIL

avaliação de riscos geológicos no planejamento energético eólico no Rio Grande do Norte, Brasil

Marcelo Motta de Freitas *

Resumo

Embora o discurso de sustentabilidade sobre o processo de geração eólica de energia seja bem difundido, existem riscos envolvidos em todas as fases do projeto, que vão desde a sua instalação ao processo de geração de energia. Assim, para além da imagem energia de limpa e renovável, os campos de exploração podem ser analisados em sua relação com o espaço geográfico no qual se inserem. Embora o presente artigo se concentre sobre a descrição dos riscos relativos ao meio físico dos campos de geração de energia eólica de Macambira I e II, Baixa do Feijão e Aventura, todos localizados no estado do Rio Grande do Norte, Brasil, ele também aponta como estes riscos podem incidir sobre as relações sociais. Particularmente, o estudo da situação geológica dos campos de geração apresenta condições de risco associadas à presença de cavidades. Estas cavernas e grutas são formadas pela ocorrência de calcários da formação Jandaíra, que desenvolvem redes subterrâneas de túneis em áreas de relevo plano. Além do aspecto geotécnico que coloca em risco as torres eólicas, as preocupações recaem sobre a hidrogeologia regional e sobre o patrimônio espeleológico. Ainda associado à geologia, a condição sísmica regional oferece risco a instalação das torres e o acervo fossilífero das formações sedimentares complementam as limitantes ambientais para os empreendimentos.

Palavras-chave: Riscos geológicos; Planejamento energético; Energia eólica.

Abstract

Wind power generation has a reputation for being environmentally friendly. However, beyond its clean and renewable aspects, the exploration fields can also be assessed in its relationship with the geographical space, as the risks involved in this activity can be identified in all project phases, going from its implementation to the final moment where the actual energy generation takes place. This article provides a description of the risks related to the physical environment of the wind power generation fields of Macambira I and II, Baixa do Feijão and Aventura, all located in the state of Rio Grande do Norte, Brazil. Although the research focuses on the physical context of the generation fields, it also indicates that social relationships are affected by it. Particularly, the geology mapping demonstrates that there are risks related to the presence of caves. This morphology can be seen on the Jandaíra Formation limestone, which is marked by a subterranean tunnel network that occurs in plain terrains. Beyond the geotechnical aspect, which exposes the wind power towers to some risk, there are environmental concerns regarding the regional hidrogeology and the speleological patrimony, as well as the fossil layers that are present on the sedimentary formations. Furthermore, the regional seismic context can also offer risks to the installation of wind power generation towers.

Key words: Geological risks; Energy planning; Wind energy.

Résumé

Les entreprises qui produisent de l'énergie éolienne ont la réputation d'être environnementalement responsables. Cependant, au-delà de ses aspects renouvelables et propres, les champs d'exploration peuvent également être évaluées concernant sa relation avec l'espace géographique ou ils s´inscrivent. Les risques inhérents à cette activité peuvent être identifiés sur toutes les phases du projet, allant de sa mise en œuvre jusqu'au dernier moment où l' énergie est geré. Cet article fournit une description des risques liés à l'environnement physique des champs de génération d'énergie éolienne de Macambira I et II, Baixa do Feijão et Aventura, tous situés a l'État de Rio Grande do Norte, au Brésil. Bien que la recherche se concentre sur le contexte physique des champs de production, il est possible de remarquer que les relations sociales sont aussi affectées. En particulier, la cartographie géologique démontre qu'il existe des risques liés à la présence de grottes. Cette morphologie peut être observée sur la formation de calcaire Jandaíra, qui est marquée par un réseau de tunnels souterrains qui se produit sur des plaines. Au-delà de l'aspect géotechnique, qui demontre que les tours d'énergie éolienne sont exposées à un certain risque, il y a des préoccupations environnementales concernant l'hydrogeologie régionale et le patrimoine spéléologique, ainsi que les couches fossiles qui sont présents sur les formations sédimentaires. En outre, le contexte sismique régional peut également offrir des risques à l'installation de tours de production d'énergie éolienne.

Motss clés: Risques géologiques; Amenagement de l'énergie; Énergie éolienne.

(*) Lecturer, Doctor of the Pontifícia Universidade Católica do Rio de Janeiro - Rua Marquês de São Vicente, 225, sala 413F, CEP: 22453-900, Rio de Janeiro (RJ), Brasil. Tel: (+55 21) 3527 1666 - marcelomotta@puc-rio.br

ISSN 1984-2201

INTRODUCTION

The Brazilian energy policy has advanced in various directions over the past 50 years. Since the so-called "Brazilian miracle", attributed to the impulse given to the construction of infrastructure in the country, we have historically witnessed spatial transformations in the Brazilian territory on behalf of the accelerated industrialization process. The development discourse has justified the installation of several hydropower plants in the main Brazilian river basins and has strinkingly marked our energy park. More than 60% of the electricity generated in Brazil comes from hydropower, a heritage associated with the country's abundance of water resources and the potential of national rivers for energy generation. But recently other sources have been introduced in the Brazilian energy landscape, mainly due to the cheapening of production caused by technological advances. Specifically, wind entered the Brazilian scene at the end of last century, and today it reaches 2.71% of the Brazilian energy sources, counting 177 plants installed (ANEEL, 2014).

Although a discourse about the sustainability of wind power generation is very widespread, there are risks that range from its installation to the generation process. In this sense, environmental licensing and studies of economic and environmental viability of the projects highlight several factors, from the impacts to migratory birds to social responses to the leasing of land for the installation of wind farms.

The changes brought about by the advance of wind farms influence the construction of the geographical space. The social relations that weave the geographical space are affected, and they present risks for the entrepreneur and for the rulers who make incentive policies for this type of energy production. However, although they are less obvious, there are also risks that the environment can present to these actors and agents of the construction of wind farms, more specifically risks from the geological and geomorphological conditions. This article deals with wind projects planned in the central and northern portions of the Rio Grande do Norte state and focuses on the risks involved in enterprising without prior knowledge of the environmental conditions of the site.

This study seeks to demonstrate that beyond the reputation of sustainability linked to wind power there is a geographical context, which must be observed in order to ensure that the activities involved in the wind farm are actually sustainable. In this sense, we recommend the study of location alternatives. Risks can often be avoided with simple changes that are inexpensive to the entrepreneur, thus avoiding downtime in the licensing process, damages to the image and significant financial losses. In addition, it is suggested that the physical environment risks be faced from a complex perspective, since they easily affect social risks. For example, the collapse of a cave can cause the death of a worker, which in turn can generate protests from the neighboring community to which the worker belonged.

The projects provide some fields for the installation of towers, spread over three installation sites in the municipalities of Touros, Jandaíra and João Câmara, in the northern part of the center of the Rio Grande do Norte state. The fields have been named, respectively, Aventura, Macambira and Baixa do Feijão, each located in a specific geological and geomorphological condition. For this reason, the fields fit as excellent study objects, due to their particular conditions, which provide different risks for the enterprises.

The methodological procedures included the collection of secondary data, making use of existing geological mapping conducted by the Geological Survey of Brazil and the Brazilian Institute of Geography and Statistics, as well as the use of primary data collected in field work conducted in each of the areas of the studied projects. A total of two field campaigns were carried out, during which data related to outcrops were collected, as well as samples, landscape descriptions and photographs. We have also carried out a review of the literature on the geological and geomorphological characteristics of the region. Furthermore, we have prepared a table of georeferenced points or field stations (database drawn up with the support of GPS device). The risks/threats were divided as follows:

Low – Low potential damage, easily mitigable.

Medium – Moderate potential damage, but with the possibility of mitigation.

High – Relevant potential damage, but still with the possibility of mitigation.

Fatal – Can cause life risk and should be avoided.

The data collected were processed by the ArcGIS software for the production of the mappings, and the analysis of the latter were divided by field of study and are presented below.

RISKS RELATED TO THE PHYSICAL ENVIRONMENT OF MACAMBIRA I AND II

GEOLOGICAL CONTEXT

The wind farms of Macambira I and II are located in sedimentary soils associated with depositional cycles in the interior of the Rio Grande do Norte state. The state's geology is quite complex, made up of very old orogenic belts associated with thermo-tectonic cycles that formed the geological substrate of Brazil. The state's crystalline basement has rocks ranging from the Archean to the Phanerozoic; the oldest date from 3.4 billion years and more recent granites are 450 million years old. After the thermo-tectocnic cycles, the process of the opening of the ocean installed by the Atlantic imposed intrusions of basic rocks and several cycles of sedimentary deposition, associated with marine invasions over the continental shelf. These sedimentary sequences start at the Cretaceous and continue throughout the Mesozoic and the Cenozoic, extending until the present day.

The Macambira wind farm is located on one of these sedimentary sequences, in the interior of the state, in Serra de Santana (municipalities of Santana do Matos, Lagoa Nova and Bodó), and is configured in a plateau relief, with a flat top and abrupt scarps in its limit with the crystalline basement, which is composed of Proterozoic granites.

Therefore, the Santana's ridge consists of a sedimentary basin formed by sandstones from the Serra do Martins formation, on the facies II, described in the Explanatory Text of Geological Mapping and Mineral Resources of the State of Rio Grande do Norte (ANGELIM et al., 2007), which has conglomeratic sandstones with quartz pebbles, ranging from subrounded to rounded, supported by a very thick sandy matrix to granules, both brown (Portalegre and Martins) and cream (Serra de Santana), where they are most kaolinic and occurre in the form of tabular packages. We can also observe conglomeratic sandstones formed by silty clay clasts, commonly red, rounded to ellipsoidal, scattered in sandy clay matrix, which is brownish red, and, locally, has white clasts, with creamy white matrix, kaolinitic, with a lenticular geometry (ANGELIM et al., 2007) (Figure 1).

Figure 1 - Aspect of the conglomeratic sandstone on the top of Serra de Santana

This formation of sedimentary rocks is covered by unconsolidated sediments and lateritic layers that sometimes outcrop in the surface, distributing a weathered material of ferruginous color. The unconsolidated sediments come from an eluvial cover which is a result of the decomposition of the sandstone itself, and its erosive reworking defines a concentration of alluvial deposits towards the drainage shafts. Such sediments are sandy and their colors are, respectively, cream and whitish (Figure 2).

Figure 2 (a, b, c) – Colors of the unconsolidated sediments: eluvial (a) and aluvial (b) and lateritic layers (c) which overlay the sandstones of Serra de Santana.

GEOTECHNICS

The presence of these sandstones and sedimentary covers does not offer risks to the construction of towers for wind generators in what involves the geotechnical aspects, especially because of the low steepness of the slopes, a topography which is locally known as “chan” and is represented by extensive flat areas on the top of the plateau. This condition also extends to the construction of access and the fixing of substations, due to the absence of geotechnical and erosion risks, obviously provided that the construction norms of the legislation and of the environmental control plan on the impact studies are respected.

It is noteworthy that the north and south ends of the sites of Macambira I and II abut to the limit of the plateau or “chan”, reaching the beginning of the slopes that descend towards the crystalline basement, which is topographically more recessed.

In these portions, the angles of the slopes increase abruptly, creating rocky cliffs, combined with steep slopes, where there are thalwegs generated by ephemeral local drainages, locally known as “grotões” (Figure 3).

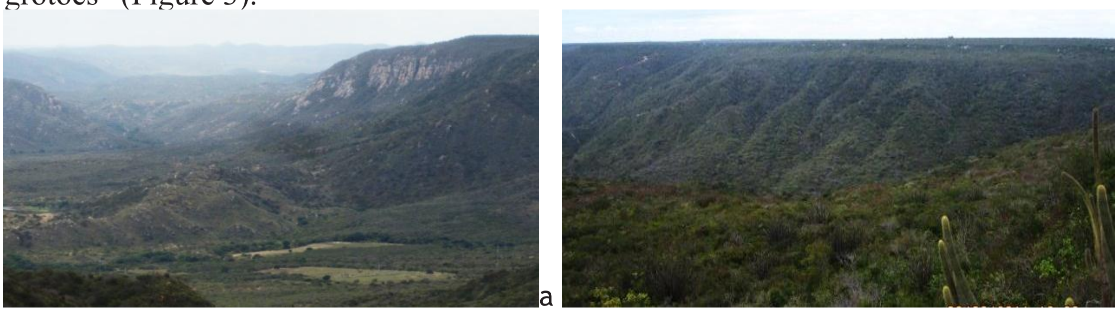

Figure 3 (a, b) – Aspects of the northern boundary of Serra de Santanta, in the contact of the sandstones with the more topographically recessed granitic basement, exposing typical plateau walls (a) and thalwegs deepened by the drainages that descend the steep slopes of the mountain range (b)

Because of their declivities and the occurrence of local springs ("grotões"), these plateau "edges" are protected by environmental law – CONAMA's 303/2002 Resolution – as APPs (Permanent Preservation Areas), as follows:

Whereas the Permanent Preservation Areas and other territorial areas specially protected, as instruments of relevant environmental interest, integrate the sustainable development, an objective of present and future generations, it is established:

> Article 1. It is an object of this Resolution the establishment of parameters, definitions and limits relating to Permanent Protection Areas.
>
> Article 2. For the purposes of this Resolution the following definitions are provided: (...)
>
> XI - Tray or plateau: Flat topography landscape, with an average declivity of less than 10%, approximately 6o and surface of more than 10 hectares, ending abruptly in a scarp, the plateau being caracterized by large surfaces in altitudes of over 600 meters.
>
> Article 3. It is a Permanent Preservation Area the area situated: (...)
>
> VIII - on the scarps and on the edges of the trays and plateaus, from the rupture line in a track measuring not less than one hundred meters in horizontal projection on the reverse direction of the scarp.

As stated, only the ends of the farms border these walls, and there are no wind turbines projected for these areas. Nevertheless, after the assessment of the site, it can be stated that the risk of inviabilty is high, since the law inhibits the occupation of these areas.

CONAMA's 369/06 Resolution, on the other hand, establishes an exception to this law in cases of social interest or public utility, where the power generation activity fits. However, the use of these areas is not advised for the preservation of the condition of local water sources, since these drainages are of great ecological importance for the region, which is marked by a low annual rainfall rate and the ephemerality of its rivers. Likewise, risks may be configured by the increasing possibility of cavities related to the concentration of water directed to the edge of the mountain range; and, despite low rainfall, mass movements and the falling of blocks as an erosive process are common in these areas, even when the ground cover is conserved.

HYDROGEOLOGY

The sedimentary formations, particularly sandstones, are potentially good aquifers, with high storage capacity of groundwater. In the case of the Serra de Santana formations, infiltration of rainwater occurs at the top and on the slopes of the plateaus, which, given the porosity of the geological substrate, recharge the regional aquifers. This subsurface and groundwater flow exfiltrates at the foot of the slopes, generating the local drainages – the majority of which, in this case, are intermittent, due to the water scarcity of the region and high infiltration of soils and rocks – or emerging in the form of ponds, as is the case of Lagoa Nova, after which the local urban headquarters were named.

SPELEOLOGY

There is a presence of cavities, caverns or caves or voids (hollow) in the underground of the area where the foundation of the wind turbines will be constructed, which can generate construction problems, such as the consumption of great volumes of concrete to fill them out, or even, in a more serious situation, the collapse of cavity ceilings, which can lead to the fall of the wind turbines.

The lithologies present in the study area can be summarized as detrital sedimentary rocks of greater and lesser thickness which, according to the methodology for the analysis of the speleological potential followed by the National Center for Research and Cave Conservation (CECAV, 2011), are considered of low potential for the lateritic covers (10% to 29%) and of medium potential for the sandstones (30% to 59%).

The speleological heritage is a relevant environmental attribute and is protected by law, but in the region there are not any occurrences of cavities known or recorded by CECAV or even by the local population (informally interviewed during the field work). It is believed that the local sedimentary formations do not present cavities as a morphological process. However, it is noteworthy that, to certify the risk of construction and fixation of wind towers, geophysical studies with GPRs (Ground Penetraiting Radars) are suggested.

It is therefore an uncertainty, for there is not enough information about the presence of fractures, cavities etc. in the local rocks, since there have not been conducted drillings or other detail surveys that could enable a consistent analysis of local underground conditions. The probability is low, but the risk can be fatal, as it could derail the construction at the site identified with the presence of cavities, both because of a legal question and security purposes. The solution will induce a change of the wind turbine location site.

RISKS RELATED TO THE PHYSICAL ENVIRONMENT OF BAIXA DO FEIJÃO

GEOLOGICAL CONTEXT

The wind fields of Baixa do Feijão are located in sedimentary grounds, associated with depositional cycles on the coast of the Rio Grande do Norte state. The state's geology is quite complex, formed by very old orogenic belts associated with thermo-tectonic cycles that formed Brazil's geological substrate. The state's crystalline basement has rocks dating from the Archean to the Phanerozoic; the oldest are 3.4 billion years old and more recent granites are 450 million years old. After the thermo-tectonic cycles, the oceanic opening process of the Atlantic provoked the intrusion of basic rocks and the formation of sedimentary basins, due to the opening of rift systems which culminated in the opening of the Atlantic Ocean.

The Baixa do Feijão wind farm is located on sedimentary rocks of the Potiguar basin, associated with the Potiguar rift, which has faults that extend from the edge of the submerged continental shelf up to portions within the continent, from the outskirts of Macau until Apodi. The sedimentary rocks of this basin extend along the entire coast and occupy all of the northern part of the state, where they present sequences of fluvial deposition, fluvial-lacustrine, and continental environments, followed by sediments from marine transgressions (proximal and distal sediments), among which the limestone formations of the Jandaíra Formation stand out (ANGELIM et al., 2007).

Outcropping or covered by eluvial layers, the carbonate rocks of the Jandaíra Formation are described by ANGELIM et al. (2007) as "typically composed of bioclastic calcarenite with benthic foraminifera, sometimes associated with green algae. There are also occurrences of calcilutites with root marks, dismicrite, as well as dolomite and, subordinately, argillites." In these formations the occurrence of cavities is common due to the process of dissolution of the calcium salts that form the rocks (Figure 4).

Figure 4 - Aspect of the carbonate rocks of the Jandaíra Formation, at the opening of the "Ô Loco" cavity, in the municipality of Jandaíra, RN.

SPELEOLOGY

The occurrence of such carbonate rocks in the substrate of the Baixa do Feijão wind farm defines a risk regarding the presence of cavities, caverns or caves or voids (hollow) present in the underground of the area where the foundations of the wind turbines will be built. The risk is imposed on constructive problems connected to the collapsing of cavity ceilings, which can lead to the fall of the wind turbines.

This lithology is classified by the speleological potential survey methodology followed by the National Center for Research and Cave Conservation (CECAV, 2011) as having a high potential (80% to 100%), and the speleological heritage is an important environmental attribute protected by law.

The 6.640/08 Decree establishes that the natural underground cavities in the national territory shall be protected, and they are assigned degrees of importance according to their ecological, biological, hydrological, paleontological, scenic, historical, cultural and socioeconomic attributes (Art. 1 and 2). The methodology for the assignment of the relevance degree is established by the 02/2009 Normative Instruction of the Ministry of Environment. Article 3 of this decree states that the area of influence of underground natural cavities with maximum degree of relevance cannot be subject to irreversible negative impacts, and their use shall be done only under conditions that ensure their physical integrity and the maintenance of their ecological balance. Article 5 of the 6.640/2008 Decree establishes that the studies to define the degree of relevance of the impacted underground natural cavities shall occur at the expense of the party responsible for the enterprise or activity.

Still on this subject, the 347/2004 CONAMA Resolution, which addresses the requirement of IBAMA authorization for the installation of projects in areas next to an important underground natural cavity or its area of influence, must be observed (Art. 4). The same Resolution states that the area of influence of the speleological heritage shall be defined by the competent environmental agency (IBAMA). Until this agency stipulates the area of influence of the natural cavities, it shall be considered as the horizontal projection of the cave added with surroundings of 250 meters in a convex polygonal form.

Particularly within the limits of the Baixa do Feijão wind farm and on its surroundings, there are three cavities registered by the CECAV: Alcaroba, Bode and Caldeirões, within the limits of the wind fields. If we also consider their areas of influence of 250 meters from their horizontal projection, this can lead to factors which can be conditioning, impeding (for part of the project) or even become a fatal issue, especially in relation to the collapse of cave ceilings during the construction process.

However, it should be noted that the lack of detail studies and specific speleological surveys in the study area still defines an uncertainty in this regard, and the suggestion is a deepening of field studies, expeditious and with the use of GPR (Ground Penetraiting Radar), in accordance with the 6,640/2008 Decree.

GEOTECHNICS

From the geotechnical point of view, the area has a flat topography and low rainfall, and the only risk it presents is associated with the collapse of cavity ceilings, which has been mentioned above.

PALEONTOLOGY

According to Morais et al. (2005) the Jandaíra Formation "includes calcarenite with mollusk bioclasts, green algae, bryozoans and echinoids. There is also the occurrence of calcilutite with root marks, dismicrite and contraction cracks. The depositional environment is described as a tidal flat, a shallow lagoon, a shallow platform and open sea", therefore being highly propitious to the occurrence of fossils. In a gastropod fossils study, Cassab (2003) states that four fossiliferous associations were identified in the Jandaíra Formation.

During the construction of wind farms, this sets a high risk of interventions on paleontological heritage, which is protected by law since 1942 by the 4146 Decree-Law. But it does not constitute a fatal risk if due care is taken and there is technical support for the removal and preservation of fossils found during the excavation work, done according to a Paleontological Heritage Rescue Program, included in the environmental licensing phase.

HYDROGEOLOGY

The sedimentary formations, especially carbonate rocks, are potentially good aquifers, with a large groundwater storage capacity. In the case of the Jandaíra Formation, the study by Morais et al. (2005) states that "the Jandaíra aquifer covers an area of approximately 15,598 km2, including the areas covered by the Barreiras Group, river drifts and dunes, totaling approximately 5,980 km2. (...) The Jandaíra aquifer is located in the upper portion of the carbonate sequence of the Jandaíra Formation, is disposed sub-horizontally, and its thicknesses range from 50 to 250 meters (IPT, 1982). It is an essentially free aquifer, heterogeneous, hydraulically anisotropic and with karstic circulation in its interior". Because it is a free aquifer, rainwater infiltration occurs on the surface and recharges the aquifer's body and its karstic flow systems within cavities and caves.

RISKS RELATED TO THE PHYSICAL ENVIRONMENT OF AVENTURA

GEOLOGICAL CONTEXT

The Aventura wind farms are located in sedimentary grounds, associated with depositional cycles in the coast of Rio Grande do Norte. The state's geology is quite complex, made up of very old orogenic belts associated to thermo-tectonic cycles which formed Brazil's geological substrate. The state's crystalline basement has rocks whose datings range from the Archean to the Phanerozoic, with the oldest dating from 3.4 billion years ago and more recent granites dating from 450 million years ago. After the thermo-tectonic cycles, the oceanic opening process installed by the Atlantic imposed basic rock intrusions and the formation of sedimentary basins due to the opening of rift systems which culminated in the opening of the Atlantic Ocean.

Aventura Wind Farm is located on sedimentary rocks of the Barreiras Group, formed by sedimentary deposits that spread through much of the Brazilian coast, reaching the state of Rio de Janeiro. ANGELIM et al (2007) state that in Rio Grande do Norte the sediments of the Barreiras Group occur along a belt next to the coast in a tabular shape, sometimes constituting coastal cliffs (Figure 5). The description of their facies range from sediments associated with interlaced river systems and transitional facies in alluvial fans to coastal plains (tidal lagoon). These sediments overlay basement lithotypes both from the Precambrian and from the Apodi Group of the Potiguar Basin. Specifically in the Aventura wind farms, the Barreiras group lies on the limestone of the Jandaíra Formation, where the occurrence of cavities is common.

Figure 5 - Appearance of the sandstones and claystones of the Barreiras Group on the coast of Rio Grande do Norte (Ponta do Mel, Areia Branca municipality, RN).

SPELEOLOGY

The rocks of the Barreiras Group do not present high potential for the occurrence of cavities, caverns or caves or voids (hollow) present in the subsurface of the area where the foundations of the wind turbines will be built. According to Cruz et al. (2007), the Barreiras formation overlays approximately 20% of the state of Rio Grande do Norte and presents a nearly null likelihood of occurrence of caves. Particularly at the edge of the Aventura wind farm there is no occurrence of caves registered in CECAV, so that there is no risk configured to the project.

However, considering the proximity of lithological contact with the Jandaíra Formation (carbonate, with high occurrence of caves), it is necessary to pay attention to the depth of the deposits of the Barreiras Group. According to local interviews, the bedrock is covered by sandy sediments that reach up to six meters deep, and limestone has been found during well drillings and during the excavation for the fixation of wind turbine towers in neighboring farms.

With the occurrence of carbonate rocks in small depths, the probability of the occurrence of cavities in not too distant depths must be considered, as well as the consequent risk of them being hit during excavation works, or even having their ceilings collapsed by the fixing of heavy foundation for the wind turbine towers. However, the lack of detail studies and specific caving surveys in the study area still defines an uncertainty in this regard, and a deepening of field studies, expeditious and with the use of GPR (Ground Penetraiting Radar), is suggested.

GEOTECHNICS

From the geotechnical point of view, the area has a flat topography and low rainfall, presenting as its sole risk the above mentioned collapse of cavity ceilings.

HYDROGEOLOGY

The sedimentary formations of the Barreiras Group, especially the arenites, are potentially good aquifers, with large groundwater storage capacity. The infiltration of rainwater occurs on the surface, so that the aquifer is free and can be easily contamined.

SEISMIC ACTIVITY IN RIO GRANDE DO NORTE

The risk of seismic activity is the same for all of the analyzed wind farms, so they have not been separately identified in this section. Seisms are not uncommon in Brazil, but they do not have large magnitudes, since the Brazilian territory has a relative stability in the present. Quakes in the country are reflections of strong earthquakes occurred mainly in the Andes, as well as the reactivation and movement of ancient geologic faults. In any case, the odds of Brazil being reached by a catastrophic earthquake are remote. Most of Brazilian earthquakes have small magnitude (<5 mb) and they commonly occur at shallow dephts (<30 km), therefore being felt just a few kilometers from the epicenter.

However, due to the occurrence of lines of faults, the region in which Rio Grande do Norte is located is among the Brazilian states that have seisms of greater magnitude and frequency. A quake reported in the municipality of João Câmara has reached 5.1 on the Richter scale in 1986 (OBSIS, 2001), which affected building structures and damaged houses.

The catalog of seisms kept by the Institute of Astronomy, Geophysics and Atmospheric Sciences at the University of São Paulo – IAG shows that during the 20th century there were registered thousands of quakes with an epicenter in Brazil, with magnitudes reaching up to 6.6 on the Richter scale, such as the earthquake registered in Mato Grosso in 1955 (Porto dos Gaúchos). However most of these seisms do not exceed the magnitude of 4.0 mb, and typically carry little observable effect on the surface.

The wind farms which are subject to this study and highlights the epicenters of earthquakes that occurred since 2000 aligned close to the faults in the João Câmara and Poço Branco region, which are already known for this condition. The Aventura fields are located at a distance of less than 30 km from the epicenters, which sets a high risk of feeling of quakes in the facilities of the wind farms. Despite the earthquakes having low intensity, deeper engineering studies are recommended to present solutions for the construction of the towers, associated with risk and contingencies management plans. But it should not be an impediment to the planned facilities.

FINAL CONSIDERATIONS

The physical environment risks have the potential of causing damage to the environment and are fatal in many cases. This type of risk, if poorly managed, can also cause delays in the ambiental licensing process and generate protests from neighboring communities.

For the purposes of this study, the most important risks with a purely geotechnical nature impact the region where Macambira I and II are located, since it is an area bounding plateaus, which are protected by environmental law as Permanent Protection Areas because of their steepness and the occurrence of local springs (CONAMA Resolution 303/2002).

Other geotechnical risks are related to cavities. In the case of Macambira I and II, these risks are uncertain, since there is not enough information about the presence of fractures, cavities etc. on the local rocks, for there have not been made bores or other detail surveys that would enable a consistent analysis of local underground conditions. Particularly on the boundaries of the Baixa do Feijão wind farm and its surroundings there are three cavities recorded in CECAV: Alcaroba, Bode and Caldeirões, located within the limits of the wind farms. If we also consider their areas of influence of 250 meters from their horizontal projection, this condition can lead to constraining and impeding factors (for part of the project), because it can even cause fatalities due to the collapse of cave ceilings in the construction process. On the other hand the Aventura field is located on the rocks of the Barreiras Group, which do not have a high potential for the occurrence of cavities, caverns or caves or voids (hollow) present in the subsurface of the area where the foundations of the wind turbines will be built.

In regard to the risks linked to Paleontology, the Jandaíra Formation can be defined as having a high risk of intervention on paleontological heritage, protected by law since the 1942 Decree-Law 4146, during the construction of the wind farms. However, this does not constitute a fatal risk if due care is taken and there is technical support for the removal and preservation of fossils found during the excavation work, in accordance with a Paleontological Heritage Rescue Program, included in the environmental licensing phase. As noted, the seismic activities in Rio Grande do Norte do not offer particularly relevant risks for the project.

In relation to hydrogeology, the issue of contamination of local aquifers is a risk to the whole enterprise. Despite the fact that wind power generation deals with few toxic substances in its installation and operation, caution with oils and greases of the equipment is recommended, as well as the emptying of construction sites. However, these actions define low risk as the technical requirements are met, according to the environmental control plan on the impact studies.

But a risk worth considering, albeit low, is the assignment of responsibility to the entrepreneur for the current state of contamination of the regional aquifer, which is due to existing uses such as gas stations, farm mills etc., and especially sanitation in the region, that discards waste in the city's lagoon (according to informal interviews carried on site), so that the company may be accused of such contamination. In this sense, we suggest that a previous study of the quality of the water is conducted, registering the "zero hour" of the enterprise. At the same time, from the point of view of the company's environmental responsibility, this risk may be considered as an opportunity to promote the sanitation of the region.

Finally, we conclude that in the actual space sustainability finds different conditions, which a pasteurized and trivialized speech does not meet. Beyond the image of a clean and renewable energy source, the exploration fields should be analyzed in their relation to the geographical area where they operate, which is not an empty space, but characterized by its uniqueness and particularities, and one that must be grasped in its multiple dimensions. This way the boundaries between the human (socioeconomic) and the non-human (physical environment) become permeable and non-absolute. In this context, the study of risks, by highlighting weaknesses in the social relations, presents itself as a fundamental tool for the realization of projects whose balance is sustainable for the various actors involved.

BIBLIOGRAPHIC REFERENCE

ANGELIM, LA A; NESI, J.R.; TORRES, H. H. .F; MEDEIROS,V. C.; SANTOS, C.A.; VEIGA JUNIOR, J.P.; MENDES, V.A. **Geologia e recursos minerais do Estado do Rio Grande do Norte** - Escala 1:500.000. - Recife: ANGELIM ET AL - Serviço Geológico do Brasil, 2007

CRUZ, J.B.; COELHO, D.C.; SILVA, F.J.; FREITAS, J.I.; CASTRO, T.J.; CAMPOS, U.P.; Diagnóstico Espeleológico do Rio Grande do Norte, **Anais do XXIX Congresso Brasileiro de Espeleologia**, Sociedade

Brasileira de Espeleologia, Ouro Preto, MG, 2007, 87-95pp.

MORAIS, F.; MELO, J. G. de; MEDEIROS, J. I. de; SRIVASTAVA, N. K.; DINIZ FILHO, J. B.; LOPES, V. L.; OLIVEIRA, J. A. de; VASCONCELOS, M. B.; **Comportamento das bacias sedimentares da região semi-árida do Nordeste brasileiro**. Avaliação do aqüífero Açu na borda sul da bacia Potiguar – Trecho: Upanema-Afonso Bezerra, CPRM/FINEP, 2005

http://www.icmbio.gov.br/cecav/index.php

http://www.mma.gov.br/port/conama/res/res02/res30302.html

http://www.obsis.unb.br/index.php

http://www.sismo.iag.usp.br/sismologia/boletim.php

Submitted january 2016

Accepted february2016