# ENVIRONMENTAL IMPACTS OF WIND POWER FARMS

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ABSTRACT

This article presents a study on the environmental impacts arising from the construction and operation of wind farm. For this, we conducted research on national and international publications, technical visits to wind farms in several Brazilian states and discussions with the working group on environmental licensing of wind farms on land surface of the Ministry of Environment, which is part of the Feam and that is scoped to the formatting of plans, programs and projects of wind power, as provided in the Charter of the Winds. These surveys were conducted in the last three years and served as the basis for the execution of works related to the theme. The article discusses the environmental impacts on biotic, physical and socioeconomic. It identifies the impacts of the removal of vegetation and the wildlife, even in the physical degradation of the affected area and changing the hydrostatic level of the water table, and even on the socioeconomic environment, focusing on the issue of noise, visual impact, the corona or visual blurring, electromagnetic interference, the effect stroboscopic and the local interference.

Keywords: wind, environmental impact, energy.

## INTRODUCTION

In July 2009, in Brazil, the Charter of the Winds was signed by the Ministry of the Environment (MMA), the Ministry of Mines and Energy (MME), the Forum of State Secretaries for Energy Affairs and other authorities. In July 2009, the Charter of the Winds was signed by the Ministry of the Environment (MMA), the Ministry of Mines and Energy (MME), the Forum of State Secretaries for Energy Affairs and other authorities. In Brazil.

According to Directive VII, MMA was responsible for "Defining, together with the states, guidelines to improve the process of environmental licensing in wind farms" (MMA, 2010). This ministry, aiming at evaluating the procedures for Environmental Licensing and Normatization of electric energy generation enterprises from the wind power source, formed a working group with representatives of state environmental agencies and with IBAMA, so that these analysts, through Systematic meetings and technical visits to wind farms in the national territory, presented studies requested for environmental licensing. This ministry, aiming at evaluating the procedures for Environmental Licensing and Normatization of electric energy generation enterprises from the wind power source, formed a working group with representatives of state environmental agencies and with Brazilian Institute of Environment and Renewable Natural Resources - IBAMA, so that these analysts, through Systematic meetings and technical visits to wind farms in the national territory, presented studies requested for environmental licensing.

State Foundation for the Environment (Feam) participates in the working group, which allowed for an important deepening of the technical knowledge related to the subject, and the elaboration of documents, that are available to the public in its site, as well as in the State Secretariat of the Environment and Sustainable Development of Minas Gerais State (Semad):

- Term of Reference for elaboration of Environmental Impact Study (EIA) and respective Environmental Impact Report (Rima) for wind farms.
- Reference Term for preparation of Environmental Control Report (RCA) for wind farms.
- Reference Term for the elaboration of the Environmental Control Plan (PCA) for wind farms.

- Technical Communication No. 2 (Gemuc / Dped / Feam) - The Use of Wind Energy in the State of Minas Gerais: Technical Aspects and the Environment.

For this article, studies were compiled on the environmental impacts in the means biotic, physical and socioeconomic, not seeking to exhaust the information related to the subject, but to corroborate with the existing studies and provide information to technicians, students and lay people that aim at studies related to the theme.

## RESULTS AND DISCUSSIONS

The use of wind energy is an important alternative in the generation of electricity, especially when dealing with climate change and the need to reduce the emission of greenhouse gases from the energy sector. The environmental impacts generated are mainly related to the visual impact and the impact on the fauna and flora.

### ➢ Main impacts on the biotic environment

Suppression of vegetation

The construction of wind power plants can cause impacts on local fauna and flora during the construction phase and during the permanence of the project or its exploitation, the recurrent impacts are vegetation suppression, soil removal and soil compaction by machines (KERLINGER, 2002).

Deforestation promotes the suppression of the environment with fauna and flora and the local fragmentation of related ecosystems. Studies show that these activities are generally carried out in an environmental system of permanent preservation that can generate extinction of sectors fixed by vegetation, as well as the suppression of ecosystems previously occupied by specific fauna and flora (MEIRELES, 2009).

Fauna

Among the impacts on the fauna, the implantation of a wind power plant can directly and indirectly generate damage to the birds as a risk of collision with the wind turbines (rotors, shovels and support towers); collision with the energy transmission lines;

alteration of breeding success; migration disruption (changes in migration patterns); loss of breeding and feeding habitat; changes in habitat movement and habitat patterns due to disturbance associated with the presence of turbines.

According to Tolmasquim (2004), wind farms off of immigration routes do not disturb birds, and that they tend to change their flight path between 100 and 200 meters, passing above or around the turbine. Wind turbines for wind power generation pose a major threat to bat populations. Turbine rotation causes a drop in atmospheric pressure in the region near the end of the blades, and when a bat passes through this zone of low pressure, its lungs undergo a sudden expansion, which results in the rupture of the capillaries of the organ causing internal hemorrhage, something similar to what happens with divers who experience sudden changes of pressure. Although some are affected by direct blows from turbine propellers, the main cause of death is this sudden drop in pressure near wind turbine structures.

Birds are less impacted than bats because, thanks to their more robust respiratory system, they do not suffer with the problem of depressurising (VILLEY MIGRANE, 2004).

Painting the blades in more visible colors can increase their visibility by reducing the number of collisions. But in terms of bird mortality, the location of the wind farm is undoubtedly the most important.

The correct location of wind farms can reduce the negative effects on the environment in some faunistic groups. However, studies focusing on these impacts are still recent. The implantation of the wind farm may imply interference of the terrestrial fauna, first by reaching its habitats, and, secondly, by the increase of movement and noise in the implantation phase, which tends to drive away the fauna to other localities, being able to suffer trampling in the highways. However, we can see the return of the terrestrial fauna when the works are finished.

Technical visits in land areas that received the construction of wind power plants show the good conviviality of animals with the towers (Figure 1).

Figure 1 - Convection of animals with aerogenerators
Source: ENERFÍN, 2011.

- **Main impacts on the physical environment**

Degradation of the affected área

Wind power plants, when in operation or in the process of being installed, can considerably degrade the occupied area due to deforestation, topography, and earthmoving processes, since it is necessary to create and maintain a network of access roads for wind turbines. The impacts generated by the earthworks are related to the removal and burial of the vegetation cover, opening of transverse and longitudinal cuts and embankments, opening of access roads, maneuvering area for trucks, mechanical shovels and track tractors, and preparation of ground for the installation of the construction site.Another impact is the introduction of sedimentary material for waterproofing and soil compaction, at the stage of the implantation process aiming to provide vehicular traffic on the network of access roads to the aerogenerators, the construction site, the deposit of materials, the office and warehouse.

The implementation of wind power generating plants can promote interference in archaeological sites, which means that in addition to previous technical studies, there is a need to monitor the affected area.

Alteration of the hydrostatic level of the water table

The earth moving activities can change the hydrostatic groundwater level, influencing groundwater flow, since the cut and fill will be possibly subjected to engineering works to the stability of embankments and roads compacted to provide continuity of truck traffic. Another factor of alteration of the hydrostatic level of the water table is linked to the production of concrete for confection of the foundations of the wind towers, since the volume of material to be used is high. That is, there is interference in the local water availability due to the high water consumption in the concrete manufacturing.

The set of environmental impacts may interfere with erosion control, hydrostatic dynamics and availability of fresh water, habitat suppression and landscape alterations related to scenic and leisure aspects.

- **Main impacts on socioeconomic environment**

Of the advantages attributed to wind energy is that it does not use water as a key element for the generation of electricity, it does not present radioactive waste or harmful gas emissions. In addition to these aspects, it is important to point out that about 99% of the area used for the implementation of the wind power plant can be used for other purposes such as agriculture, livestock, etc.

The main negative impacts on the socioeconomic environment caused by wind power generation are related to the following aspects:

- noise emission;
- visual impact;
- visual crown or glare;
- electromagnetic interference;
- stroboscopic effect;
- local interference.

These aspects can be minimized or even eliminated through proper planning and studies, along with advances and technological innovations that are always under development.

Noise emission

Wind turbines produce two types of noise: mechanical noise from gears and generators, and aerodynamic noise from blades. Mechanical noise has been virtually eliminated through insulation materials. Aerodynamic noise is produced by the rotation of the blades generating a hissing sound that is a function of the tip speed. The modern designs of wind power plants are being optimized with scope to reduce aerodynamic noise. Noise inside or around a wind farm varies considerably depending on a number of factors, such as: plant layout, installed turbine model, terrain relief, wind speed and direction, and background noise.

The increase in sound emissions from wind turbines is related to increased wind speed. However, background noise, which normally increases faster than the turbine sound, tends to mask noise from wind turbine noise (NOISE ASSOCIATION, 2002).

Noise levels decrease as the distance between wind turbines increases and are most commonly expressed in dB (A), decibels measured on the metering scale (A), as the scale closest to human perception of noise. The predictions of sound levels in future wind farms are of extreme importance in order to predict the impact of noise.

When there are people living near a wind farm, care must be taken to ensure that the sound of the wind turbines is at a reasonable level relative to the ambient sound level in the area. Due to the large variation in individual noise tolerance levels, there is no completely satisfactory way to measure their subjective effects, or the corresponding reactions of annoyance and dissatisfaction (NOISE ASSOCIATION, 2002).

Individual annoyance for noise is a very complex subject, but studies have shown a correlation between disturbing noise with visual interference and the presence of intrusive sound characteristics. Likewise, the nuisance is greater in the rural area than in the periphery and also higher in complex terrain compared to flat ground in a rural environment (WINDS ENERGY, 2012).

Low-frequency noise (RBF), also known as infrasound, is used to describe sound energy in the region below 200 Hz. RBF can cause discomfort and discomfort for sensitive people and so has been extensively analyzed. The most important finding is that modern wind turbines with the rotor placed against the wind produce very low levels of infrasound, generally below the threshold of perception (LEVENTHALL, 2003;

HEPBURN & EDWORTHY, 2005, apud WINDS ENERGY, 2012 ). A survey of the results in published wind turbine infrasound measurements concludes that with upwind turbines, infrasound can be neglected in assessing environmental effects (JACOBSEN, 2005).

In Brazil, noise emissions are regulated by technical standards of ABNT nº 10.151 and 10.152. Several studies have demonstrated the dangers of this type of decibel to human health. B-type and C-type disorders, called infrasound, although inaudible, are felt as a vibration in the body, even inside the house, being harmful to health as much as or more than Type A, and may cause sleep deprivation, nausea, dizziness , headaches, increased blood pressure, aggression and others.

An observer, if exposed for a short time to noise is limited to an instantaneous perception of them, but is unable to assume the true long-term effects. Exposure distributed over a period of time of at least two weeks can cause most of the effects felt in humans. Noise impacts depend on several factors: wind direction and strength, wind height and type, topography, air pressure, obstacles and specific physical phenomena (NOISE ASSOCIATION, 2002).

The French environmental agency, *Agence de l'Environnement et de la Maîtrise de l'Energie - ADEME*, suggests a minimum distance of 250 m between the wind tower and a human residence, however, this distance defined in a public hearing. The National Academy of Medicine of France and the United Kingdom Noise Association recommends a distance of 1.5km (VILLEY MIGRAINE, 2004). Several studies have reported a common set of adverse health effects of people living near wind turbines. These symptoms began after the operation of wind power plants, and include:

- sleep disturbances;
- headache;
- ringing in the ears;
- pressure in the ear;
- nausea;
- dizziness;
- tachycardia;
- irritability;
- concentration and memory problems;

- panic episodes with an internal or shaken heartbeat that appear when awake or asleep.

These disturbances have their main cause the effect of the low frequency of wind turbine noise on the inner ear organs. Table 1 shows a summary of the surveys carried out on the distance to be defined between the wind tower and nearby residences, these values being mostly practical, since not all were regulated.

Tabela 1 - Distância da Torre para as Residências/Política Adotada

| COUNTRY | Distance from the tower to the residences / Adopted policy |
|---|---|
| Belgium | 150 a 500 meters |
| Czech Republic | 400 a 800 meters |
| Denmark | 4 times the height of the tower |
| France | 250 a 500 meters, as Ademe |
| Germany | -"Calm region" [35 dB (A)]: 1000-1500 m<br>- "Mid-range" [(40 dB (A)]: 600-1,000 m<br>- "Standard region" [(45 dB (A)]: 300-600 m |
| Italy | Some regions have defined distances, others have not. Calabria and Molise: 5 times the height of the tower. Basilicata: 2,000 meters. Campania: 10 times the height of the tower. Molise: 20 times the height of the tower. |
| Netherlands | 4 times the height of the tower |
| Northern Ireland | Minimum of 500 meters |
| Romania | 3 times the height of the tower, may be lower according to decision in public hearing |
| Scotland | - Bankend Rigg (awaiting approval): just over 1,000 m<br>- Chapelton (awaiting approval): 750 m<br>- Dungavel (awaiting approval): 1,000 m<br>- Whitelee (built): about 1,000 m<br>- Gathercauld Ceres (awaiting approval): 572 m<br>- Auchtermuchty (Approved): 650 m |
| Spain | National: legislation applied according to noise level. Regional: Wind energy policies are varied. Examples: Valencia: 1,000 meters of any piece of land that can be used. Andalusia: 500 meters. |
| Sweden | Legislation applicable depending on the noise level [40 dB (A)]. In practice, 500 meters are used. |

| | |
|---|---|
| Reino Unido | There is a bill with the following content: if the height of the wind turbine generator is: greater than 25 meters, but not to exceed 50 meters, there is minimum distance requirement is 1000 meters; more than 50 meters, but not exceed 100 meters, there is minimum distance requirement is 1,500 meters; exceeding 100 meters, but not exceeding 150m, there is minimum distance requirement is 2,000 meters; more than 150 meters, the minimum distance requirement is 3,000 meters. The height of the wind turbine generator is measured from the ground to the end of the blade tip at the highest point. There is no minimum distance requirement if the height of the tower does not exceed 25 meters. |
| Suíça | Documentation of Suisse Eole mentions 300 m from the tower, but every Canton is still working on a policy of its own. |

Source: Authors, 2013

Despite the absence of conclusive studies, the precautionary principle justifies the cessation of operation of any wind farm in inhabited areas, even if the local community has accepted it.

Visual impact

Modern aerogenerators, with towers heights greater than 100 m and blade lengths over 30 m are obviously a visual alteration of the landscape. Environmental impact studies should identify, describe and evaluate the direct and indirect effects of the project on the landscape.

It is noted that the visual impact decreases with distance. The areas of theoretical visibility can be defined as (UNIVERSITY OF NEWCASTLE, 2002, apud WINDS ENERGY, 2012):

- Zone I - Visually dominant: the turbines are perceived as large and the movement of the blades is obvious. The immediate landscape changes. Distance of up to 2 km.
- Zone II - visually intrusive: turbines are important elements in the landscape and are clearly perceived. The movement of the blades is clearly visible and can attract the eyes. Turbines are not necessarily the dominant points in vision. Distance between 1 and 4.5 km, in conditions of good visibility.
- Zone III - Remarkable: the turbines are clearly visible, but not intrusive. The wind farm is noticeable as an element in the landscape. The movement of the blades is visible in good visibility, but the turbines

seem small in the global landscape. Distance between 2 and 8 km depending on weather conditions.

- Zone IV - Element in the distant landscape: the apparent size of the turbines is very small. Turbines are just like any other element in the landscape. The movement of blades is usually imperceptible. Distance more than 7 km.

Although the visual impact is very site specific at a particular wind farm, some design and deployment features can be identified to minimize its potential visual impact:

- The similar size and type of turbines in a wind farm or several adjacent ones.
- Design selection of wind turbines (tower, color) according to landscape characteristics.
- Neutral color selection and anti-glare paint for towers and blades.
- Camouflage paint next to military installations, to avoid that the wind turbines constitute points of reference.
- The use of three blades rotating in the same direction.
- The visual landscape improves with the distribution of in-line turbines.

Visual Crown or Obfuscation

Visual crown or glare is the amount of electromagnetic radiation leaving or reaching a point on a surface. It can be minimized using opaque paints on towers and blades.

Electromagnetic interference

Wind turbines, in some cases may reflect electromagnetic waves. This implies that they may interfere with and disrupt telecommunication systems. The electromagnetic fields of wind turbines can affect radio and telecommunications quality as well as microwave, cellular, internet and satellite communications. The impact assessment should address the problem, but it can not always guarantee the safety of the optimal distribution of the magnetic field. Electromagnetic interference with aeronautical communication will not be a problem created by the wind power plant, provided that the project contemplates a minimum distance from the airport and also an area of radioelectric servitude of wind tower action in relation to the navigation route of the aircraft.

stroboscopic effect of wind turbines

The strobe effect is due to the passage of the blades before the sun occurs at the beginning or end of the day when the sun is lower in the sky. The degree of intermittent shading depends on tower distance, latitude, time of day, and year. It becomes more relevant the smaller the distance of the blades and the receiver, as well as the fact of being at the same altitude.

According to surveys, intermittent shadowing can cause nuisance and harm people suffering from epilepsy, as well as nausea and headaches in affected residents. It's called stroboscopic effect (PIRES, 2010). The effect is felt at a distance up to ten times the diameter of the blades and depends on the direction of the wind turbines of residences. The effect is well documented in several countries of the world, but poorly regulated.

Local interference

For the population located around the area of direct influence, the most significant impacts generated by the construction of the wind farm are related to the local interference and the expectations generated due to the implementation of the project.

The implantation causes some temporary discomfort to the resident population close to the works, as well as may interfere with the daily life of the local community: increased traffic flow, noise pollution, traffic insecurity, temporary increase in local population density, job creation, increase in real estate speculation. The increase in the flow of vehicles, especially heavy vehicles, can generate drivers insecurity due to traffic diversions and interruptions.

In order to reduce the inconvenience, the engineering company responsible for the execution of the work must prepare a detailed plan of the procedures related to the movement of vehicles, establishing a schedule that guides the flow of these in a rational way, such as the signs of the works, the necessary insulation, security devices and the dissemination to communities of activities that may interfere with traffic. In this plan the support capacity of the pavement must also be observed, transporting as much as possible loads with compatible weight, thus avoiding damages to the pavement of the roads, as well as to the residences.

For partial or total use of existing roads and accesses, in addition to a transport logistics plan, improvements must be evaluated so that roads and accesses can guarantee permanent traffic, including changes and new constructions in the road structure. These improvements can be a legacy of the enterprise to the local population, since they can facilitate the flow of goods and access to the properties. The temporary increase in the local population density is a worrying factor, since it can generate problems of homelessness, vandalism and prostitution. To do so, it is necessary to implement a plan of measures to be implemented by the company responsible for the works and the local city hall, aiming to soften these problems, raise awareness of the population and employees and ensure employment priority for the local population.

Another impact to be managed by the company responsible for the execution of the works relates to solid and liquid waste from construction site activities and construction activities. Solid waste must be handled appropriately according to its characteristics, that is, differentiating hazardous waste, non-inert waste and inert waste.

To mitigate this impact, the Environmental Management Program for Solid Waste and Liquid Effluents should be implemented, which will cover the design and construction of liquid effluent treatment systems and the execution of a service contract with a licensed company to collect waste generated in the implementation of the wind power plant.

In Brazil, with respect to waste from civil construction, the normative instructions regarding the packaging, transport and final disposal of the different types of waste generated during construction are followed, in particular the Normative Resolution of the National Environmental Council - CONAMA n. 307/2002.

**CONCLUSION**

The generation of electricity from wind energy has been increasingly inviting, either because it constitutes the use of a renewable source or because it does not present the magnitude of the environmental impacts generally associated with other forms of energy use.

However, the environmental impacts resulting from the implementation and operation of a wind farm can not be neglected. Being explicit the need of the location of the plant and the distribution of the wind turbines that compose it are defined based on an accurate environmental study.

After the construction phase there is a natural tendency to recover vegetation, which favors the return of the fauna to its habitat. Another interesting point observed are the environmental education and monitoring projects of the plant area, which tend to add tourism to the municipality.

It should be noted that the economic return generated by the hiring and use of areas within farms is highly attractive, and does not necessarily prevent the cessation of exploitation of agriculture, livestock, or other existing ones. Several farms have sought to join wind farms in order to increase revenue and improve the security of their environment.

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