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The Importance of the Environmental Licensing Process for Wind Farms in the State of Ceará: Technical and Environmental Aspects According to COEMA Normative Instruction No. 01/2018

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ABSTRACT
The environmental licensing of wind farms is a highly relevant topic in the context of the energy transition and the pursuit of renewable and sustainable alternatives. Wind energy, globally recognized as a clean and efficient source, has experienced exponential growth in Brazil, particularly in the state of Ceará, which stands out for its favorable natural conditions, such as steady, high-intensity winds. However, the installation and operation of these ventures require attention to technical and environmental aspects to minimize ecological and social impacts. In this regard, environmental licensing, governed by regulations such as COEMA Normative Instruction No. 01/2018, plays a fundamental role in balancing economic development with environmental preservation, making it an indispensable tool for promoting sustainable development. This research is characterized as a qualitative analysis employing two research methods: bibliographic and documentary studies. The main objective of this article is to present the technical aspects of studies related to the environmental licensing of wind farms at both federal and state levels. The research highlighted the importance of environmental licensing in ensuring a balance between technological progress and environmental conservation. The study also revealed that compliance with federal and state regulations is essential to mitigate environmental impacts and ensure the region's sustainable progress.

***Keywords**: Wind Farms; Environmental Licensing; Sustainable Development; Environmental Impacts.*

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I. INTRODUCTION

A significant environmental issue arising from globalization and the spread of capitalism is the excessive use of polluting and non-renewable sources for energy generation. This situation has caused various adverse environmental impacts, such as changes in water and air quality, depletion of natural resources, and seasonality in energy supply. Given this problem, there is a substantial demand for new energy sources that are renewable and ensure fewer impacts on the environment throughout their lifecycle, while providing greater security and reliability in supply (Ceretta, 2018).

To encourage the use of cleaner energies, governmental and non-governmental efforts have been developed worldwide with the aim of replacing fossil fuels with less polluting technologies, thereby improving air quality and protecting the environment. Renewable energies are recognized as an important resource for sustainable development (SD), which has gained traction since Eco92. Currently, the progress of renewable sources presents a promising scenario with high potential for both diversified use and advancements in research. In this context, it is important to emphasize that Brazil has one of the largest renewable energy matrices in the world.

According to the Energy Research Company (2018), Brazil has an electricity matrix predominantly derived from renewable sources (80.4% of internal supply), with hydropower being the most significant source (65.2% of internal supply). In Brazil, in 2017, the northeastern region accounted for the largest share of energy generation from wind sources at 84% (33.00 TWh), followed by the southern region with 14.4% (5.84 TWh) and the northern region with 1.4% (0.55 TWh). The five states with the highest generation during this period were: Rio Grande do Norte (13.24 TWh), Bahia (7.79 TWh), Rio Grande do Sul (5.58 TWh), Ceará (5.10 TWh), and Piauí (4.59 TWh) (ABEEÓLICA, 2019).

Among the five states generating the most clean energy, Ceará has stood out significantly. According to studies conducted by Carvalho and Coimbra (2018), this type of clean energy has emerged as one of the fastest-growing alternative sources for electricity production in Brazil, particularly due to the implementation of wind farms in the northeastern region, which has experienced substantial growth over the past decade. The Brazilian Northeast stands out due to its climatic conditions, geographical location, and potential for wind energy generation, contributing to ongoing investments in this type of energy production.

The number of wind energy projects in Ceará is expected to grow steadily, as the inclusion of wind energy in Brazil's electricity matrix is justified by its complementarity with hydropower—a source that does not emit greenhouse gases. In this regard, it is relevant to understand how environmental agencies (SEMACE) conduct the environmental licensing process given the demand for this activity and the complexity involved in analysis. Daily, new horizons are discovered that present themselves as potential sources of both offshore and onshore wind energy, requiring more thorough analysis by environmental agencies regarding parameters for obtaining environmental licenses for these projects. There is an exponential trend in Brazil towards a significant increase in requests for environmental licenses as well as authorizations at both state and federal levels. In 2017, approximately 66.8% of global electricity production was directly related to fossil sources (IEA, 2017).

It is well known that the use of fossil fuels for energy production has caused global impacts such as gas emissions—primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (NO_x)—which contribute to the greenhouse effect and consequent global warming (Moreira et al., 2013).

Understanding this energy transition, which began at the end of the 19th century, is crucial to recognizing that modern systems have continuously evolved and taken various forms worldwide with the goal of providing viable and accessible energy for distribution within existing infrastructure. Some existing systems are very complex and reliable, operating at different scales. For example, the United States consists of 8.85 million square miles serving 228 million consumers, in contrast to Ireland's smaller and more isolated system that serves a population of 6.2 million over an area of only 81,638 km² (IPCC, 2012). It is essential to understand that energy demand is linked to the development of emerging countries. Consequently, this topic has gained increasing prominence both in discussions about environmental issues and in political and economic constraints related to expanding energy supply from non-renewable sources (Traldi, 2018).

Furthermore, it is important to discuss environmental issues alongside political and economic constraints given that Brazil is an emerging country like others in South America; it is also necessary to address key socio-environmental issues related to energy production, generation, and transmission so that this context—often politically formed—can be discussed in association with energy preservation efforts. Additionally, it is crucial that this discussion be linked to climate change. Today, it is increasingly observed that climate issues are becoming more relevant in relation to energy concerns, both from the perspective of greenhouse gas emissions and the production of energy and its vulnerability to climate change. Brazil is privileged to have an energy matrix with a significant share of renewable sources, which sets it apart from other developed countries such as Japan, the USA, and the UK; this characteristic is particularly important given that the energy sector was responsible for 18% of total Brazilian emissions in 2021 (SEEG, 2022).

In Brazil, approximately 26% of wind energy capacity has been developed within 5 km of the northeastern and southern coasts (Brannstrom et al., 2018), with the northeastern region accounting for 85.4% of the total energy generated from wind sources (ABEEÓLICA, 2020).

This development is a response to government subsidies, high wind quality, and the increasing national demand for electricity. The installed capacity of wind energy (11.2 GW) positions Brazil as a leader in Latin America and the eighth largest in the world (Global Wind Energy Council, 2019). According to Meireles (2008), the state of Ceará has stood out due to its potential and the concentration of investments from national and international groups, which are linked to the social, economic, and environmental realities of the territories where wind farms are being installed. It is important to highlight that Ceará is leading in the deployment of wind farms, with a trend toward further growth due to favorable climatic conditions for developing this activity. Our state is well represented in terms of renewable energy, both in logistics and in blade manufacturing. Given this scenario, the federal government began to encourage the construction of wind farms through the creation of subsidies and programs that stimulate financial and bureaucratic areas. Examples include state-led auctions, reduced import tariffs, simplified environmental licensing, and financing from the National Bank for Economic and Social Development (BNDES) (Juarez-Hernandez; Leon, 2014).

In order to meet national demand and expand energy generation through the implementation of a renewable matrix without social implications, the establishment of wind farms has been promoted by the governments of confederated states, with an emphasis on the northeastern region, which possesses significant potential.

Kerlinger (2002) states that the construction of wind farms can cause impacts on local fauna and flora during both the construction phase and throughout the operation or exploitation of the project. The recurring impacts include vegetation suppression, soil removal, and soil compaction by machinery.

This research is characterized as a qualitative analysis that applied two research procedures: bibliographic and documentary studies. This research is justified as it addresses a current topic related to the importance of renewable energies today, whose relevance is reflected in three sectors: state, market, and society. For the state, it represents the primary sector responsible for public affairs that should represent the interests of society in general as well as those of local communities. Additionally, it contributes to state efforts through environmental management in developing public policies regarding common goods and wind energy generation while considering biodiversity conservation. Thus, we arrive at the central question of this research: Does the implementation of a wind farm meet all environmental licensing requirements?

Based on this question and seeking elements to help answer it, the following objectives were formulated: General Objective: to present the technical aspects of studies related to environmental licensing for wind farms at both federal and state levels. The Specific Objectives are outlined as follows: to discuss wind energy globally and in Brazil along with its prospects; to elaborate on energy-generating infrastructures; and to comment on environmental licensing procedures for wind projects in Ceará.

The article is structured into four sections aimed at providing a comprehensive analysis of the importance of environmental licensing. The first section, Introduction, presents the central theme of the study while contextualizing the relevance of environmental licensing. The second section, Methodology, describes the methodological approach adopted for the research, including data collection strategies and analysis of researched sources. The Theoretical Framework, which constitutes the third section of this chapter, offers a review of key concepts, theories, and studies related to environmental licensing. Finally, the Conclusion section synthesizes the main findings of the research, highlighting practical implications of environmental licensing and suggesting directions for future investigations in this field.

II. MATERIAL AND METHODS

The present research is characterized as a qualitative study that applied two research procedures: bibliographic and documentary analysis. The documentary study drew from current legislation, specifically Normative Instruction 01 of COEMA/SEMACE, as well as official documents from the following national and international institutions: ABEEÓLICA (2019; 2020), GWEC (2019), and IPCC (2012).

Piana cites Pádua (1997), who states: "Documentary research is conducted using documents, whether contemporary or retrospective, considered scientifically authentic (not fraudulent); it has been widely used in social sciences and historical investigation to describe/compare social facts, establishing their characteristics or trends [...]"

Regarding the bibliographic study, it involved an in-depth analysis of theses and other scientific publications. Notable contributions from this study include works by Cartaxo (2020), Palma and Lessa (2022), Cox and Madeira (2023), and Maia, Basso, and Souza (2024).

Gil (2017) argues that bibliographic research is a preliminary step in nearly any academic inquiry, adding that almost every thesis or dissertation developed today includes a chapter or section dedicated to it. This constitutes a literature review with the dual purpose of providing theoretical grounding for the work and determining the current state of knowledge on a particular topic. This qualitative research approach underscores the importance of both documentary and bibliographic studies in enriching the understanding of the subject matter and informing future investigations.

III. THEORETICAL FRAMEWORK

The theoretical framework presents the state of the art regarding wind energy and environmental licensing, divided into three topics: Wind Energy in the World and Brazil; Energy Generating Infrastructures; and Environmental Licensing Procedures for Wind Projects in the State of Ceará.

3.1 Wind Energy in the World and in Brazil

The development of economic activities has historically been based on the use of fossil fuels, which are responsible for most of the environmental problems we face today, particularly those related to global warming (IPCC, 2012). Global warming is the climatic phenomenon characterized by the increase in average temperatures worldwide. The daily survival of societies depends on energy, as there is an ever-growing need for secure, reliable, and environmentally suitable energy sources. The strong trend toward the search for alternative energy sources emerged due to the global energy situation, as the use of fossil fuels and their combustion for energy generation have led to "environmental problems [...] caused by the emission of gases and greenhouse effects that consequently harm the Earth" (Mesquita et al., 2018, p. 11).

According to this researcher, one of the solutions for the "substitution" of fossil fuels would be the use of wind energy, derived from wind movement, which is considered clean and sustainable: Wind energy is the kinetic energy contained in moving air masses. Its utilization occurs through the conversion of the translational kinetic energy into rotational kinetic energy, using wind turbines, also known as aerators, for electricity generation, or through windmills and mechanical mills for water pumping (ANEEL, 2002, p. 63).

Among renewable energies, wind energy is one of the fastest-growing alternative sources for electricity production in Brazil, especially in the northeastern region, where this type of project has been highlighted with the installation of wind farms. According to Traldi (2018), energy demand is linked to the development of emerging countries, which are those that have ceased to be underdeveloped and are now growing, such as the countries in Latin America. This issue has been gaining significant attention both in environmental debates and in political and economic restrictions related to the expansion of energy supply from non-renewable sources. Currently, the energy required for human activities comes from non-renewable sources such as oil, gas, coal, and natural gas (Freitas; Dathein, 2013).

Other authors confirm that there is a high dependence on non-renewable energy sources, which has led to not only ongoing concerns about their depletion but also the emission of toxic and polluting gases. It is important to note that gases released into the atmosphere directly affect the greenhouse effect. According to the IPCC (2012), the greenhouse effect leads to an increase in Earth's temperature, caused by the greater retention of infrared radiation in the atmosphere due to the higher concentration of certain gases with this property, such as carbon dioxide, methane, chlorofluorocarbons, and nitrous oxide. The proposed solution to mitigate the impacts of emissions from global warming due to fossil fuel combustion is to implement environmental licensing with mitigating measures and to invest more in alternative, less polluting energy sources, with wind energy being considered clean and less impactful on the environment. This type of energy has emerged as one of the most prominent alternatives for electricity generation in Brazil, due to favorable climatic conditions, strong winds, and geographical location. The potential for energy generation in the Northeast region has facilitated its implementation, contributing to its constant growth (Cartaxo, 2020).

Wind energy presents numerous benefits when compared to other energy sources. In addition to being a renewable energy source, it does not emit pollutants into the atmosphere or produce waste. However, it is important to remember that, generally, all forms of energy production, on some scale, generate impacts of varying degrees (Jaber, 2013).

Wind energy is defined as the energy generated by the movement of air masses in the atmosphere (winds), transforming mechanical energy into electrical energy. As defined by Nascimento and Alves (2016, p. 646), wind energy generation "originates from the capture through blades that rotate due to the direct impact of the wind, transforming kinetic energy into mechanical energy, and later into electrical energy through a rotor installed in each turbine."

3.2 Energy Generation Infrastructures

This section will address the various types of electricity generation, particularly wind energy, as well as their main environmental impacts. Thermoelectric plants (TEP) use fossil fuels, such as coal, petroleum derivatives (oil and natural gas), nuclear elements like uranium and plutonium, and biomass (derived from energy forests and sugarcane bagasse) as sources for electricity generation. The environmental impacts of this type of electricity generation are primarily associated with thermal pollution, caused by the high temperatures of the water used in the process and discharged into water bodies. Hydroelectric Plants: The electricity generation from large-scale hydroelectric plants is considered a clean energy by many. However, from an environmental perspective, it cannot be regarded as an ideal ecological solution. These plants drastically interfere with the environment due to the construction of dams, which cause flooding in vast forest areas and disrupt human settlement. The flooding of forests leads to the decomposition of submerged vegetation, altering biodiversity and releasing methane, one of the gases responsible for the greenhouse effect and the depletion of the ozone layer (Palma; Lessa, 2022).

Solar Energy is the most abundant and inexhaustible form of energy on the planet, originating from sunlight. It is expected that by 2024, it will be the most important and significant renewable energy source for Brazil, as it can be used for electricity production through solar panels, solar thermal systems, and photovoltaic cells (Palma; Lessa, 2022).

In Brazil, the abundant sunlight throughout most of the year encourages the use of this resource, especially in the Central-West and Northeast regions, where sunlight availability is greater, and there are fewer problems with cold weather and heavy rainfall during the year. Photovoltaic generation (PV), which involves the direct conversion of sunlight into electricity, has been and will continue to be one of the most fascinating technologies in the energy field. Its development began in the 1950s due to its use in the U.S. space program.

Today, the technology is more economically viable, though it remains relatively expensive, and market acceptance is entirely dependent on the reduction of production costs and the increase in cell efficiency. In recent years, there have been significant advances in the efficiency of this technology, including advancements in low-cost materials, resulting in efficiencies greater than 30% (Tolmasquim, 2004).

3.3 Licensing Procedures for Wind Farms in Ceará

The environmental licensing of wind farms in the state of Ceará follows the Normative Instruction COEMA No. 1, dated November 13, 2018, which establishes procedures for generating electricity from solar photovoltaic and wind energy sources on terrestrial surfaces. Among the various requirements, each company planning to develop a wind farm must present proposals with mitigating and compensatory measures for negative environmental impacts, as well as the evolution of beneficial environmental impacts caused by the project to be licensed, considering the planning, installation, and operational phases.

3.3.1 Care with Environmental Impacts during the Implementation and Operation Phases

According to Resolution CONAMA No. 001, dated January 23, 1986, environmental impact is any alteration of the physical, chemical, and biological properties of the environment caused by any form of matter or energy resulting from human activities that, directly or indirectly, affect: health, safety, and well-being of the population; social and economic activities; biota; aesthetic and sanitary conditions of the environment; and the quality of environmental resources. In addition to the criteria for evaluating environmental impact, pollutant factors include installed power, location, and the size of the wind farm. Several studies by various authors have highlighted environmental and socio-environmental impacts arising from the installation of wind farms. These impacts occur not only in the state of Ceará but also in other northeastern states, where these projects typically span multiple municipalities.

According to Cuadra et al. (2019), the installation of wind farms has become increasingly viable; however, in some cases, it can provoke environmental, social, economic, and technological impacts that are often overlooked by the developers during both the implementation and operational phases. The socio-environmental impacts associated with both the construction and operation of wind farms include: direct interference with flora and fauna due to changes in vegetation cover; direct interference with fauna due to collisions with turbine blades (birds and bats); disturbances in traffic during the transportation of turbine components; increased demand for services and infrastructure; noise production; changes in the landscape; and increased economic dynamics. It is important to note that the significance of these impacts varies depending on the regional and local characteristics of the wind farm sites (Fernandes; Arrais Júnior, 2017).

3.3.2 Environmental Licensing of Wind Farms in Ceará

The environmental licensing process follows a well-defined procedure that involves analyzing environmental, social, and economic impacts, as well as approval by regulatory bodies. The main steps of the environmental licensing process for wind farms are:

1 Preliminary License (LP) Objective: To evaluate the environmental viability of the project. Steps: Presentation of the Environmental Impact Study (EIA) and the Environmental Impact Report (RIMA), when required. Review by the state (SEMACE) or federal (IBAMA) environmental agency, depending on the project's impact and location. Public hearings are held to discuss the project's impacts with the local community. Outcome: Issuance of the Preliminary License (LP), which approves the environmental viability of the project but does not authorize its installation (Munõz-Torres et al., 2018).

2 Installation License (LI) Objective: To authorize the commencement of construction of the wind farm. Steps: Submission of detailed projects, including technologies, construction methods, and approved environmental impact mitigation plans. Review by the licensing agency to verify compliance with conditions set in the LP. Analysis of the impacts generated by the construction, such as soil movement, noise pollution, and impacts on local ecosystems. Outcome: Issuance of the Installation License (LI), which authorizes the construction of the wind farm (Silva; Becker; Martins, 2015).

3 Operation License (LO) Objective: To authorize the commencement of the wind farm's operations. Steps After construction is completed, an inspection is conducted to verify that all conditions and mitigation measures have been implemented. The company must submit an Environmental Compliance Report to demonstrate that the project is in compliance with legislation. Outcome: Issuance of the Operation License (LO), which allows the start of energy generation (Silva; Becker; Martins, 2015).

4 Monitoring and Inspection: During the operation of the wind farm, the developer must monitor environmental impacts and submit periodic reports to the licensing agency. SEMACE, IBAMA, or other regulatory bodies conduct periodic inspections to ensure compliance with environmental measures (Silva; Becker; Martins, 2015).

5 License Renewal: Licenses are valid for specified periods, and the Operation License must be periodically renewed according to the criteria set by the environmental agency (Silva; Becker; Martins, 2015).

6 Additional Considerations: In addition to the EIA/RIMA, supplementary studies may be required, such as impact assessments on fauna, flora, water resources, and local communities (Silva; Becker; Martins, 2015; Munõz-Torres et al., 2018).

6.1 Consultation with Traditional Communities: If the wind farm affects areas of traditional communities, such as quilombolas or indigenous populations, consultation with the affected populations is mandatory, following the guidelines of ILO Convention No. 169 (Munõz-Torres et al., 2018).

6.2 Environmental Compensation: In the case of significant impacts, the developer may be required to implement environmental compensation, which could include environmental recovery projects or support for conservation units (Munõz-Torres et al., 2018; Cox; Madeira, 2023).

These procedures aim to ensure that the development of wind farms occurs sustainably and with respect for the ecosystems and communities affected.

3.3.3 Responsible Agencies

In Ceará, the authorization processes for wind farms are conducted by various agencies, both state and federal, in addition to entities specializing in environmental analysis and regulation. The main agencies responsible for licensing wind farms in the state are:

1 State Environmental Superintendency (SEMACE): SEMACE is the state entity responsible for evaluating and granting environmental licenses in Ceará. It conducts studies on environmental impacts and issues preliminary, installation, and operational licenses for projects such as wind farms (Costa et al., 2019).

2 Ceará State Environmental Secretariat (SEMA): SEMA is involved in creating environmental policies and can engage in discussions and processes related to licensing and environmental conservation in wind energy projects (Costa et al., 2019).

3 Brazilian Institute of Environment and Renewable Natural Resources (IBAMA): This federal agency is responsible for licensing wind farms if the project affects federal jurisdiction areas, such as coastal zones or indigenous territories. IBAMA issues environmental licenses for projects that cause large-scale impacts or span multiple states (Cox; Madeira, 2023).

4 National Electric Energy Agency (ANEEL): ANEEL oversees the Brazilian electric sector and is responsible for authorizing the construction and operation of energy generation projects, such as wind farms (Maia; Basso; Souza, 2024).

5 National Indian Foundation (FUNAI): If the wind farm affects indigenous territories, FUNAI is involved in the environmental licensing process, analyzing the consequences for these communities. These entities ensure that projects are executed sustainably and in compliance with environmental and social laws.

IV. DISCUSSION AND CONCLUSION

The study on the environmental licensing process of wind farms in Ceará, based on the technical and environmental criteria established by Instrução Normativa COEMA No. 01/2018, highlighted the strategic importance of wind energy in the global, national, and state contexts. It was understood how this renewable energy source has emerged as a sustainable option for power generation, favoring the diversification of the energy matrix and contributing to the reduction of greenhouse gas emissions.

The research also emphasized the specificities of wind energy generation infrastructures, highlighting the technical and operational challenges associated with the construction and management of wind farms. Regarding environmental licensing in Ceará, the defined processes were examined, underscoring their relevance in ensuring a balance between technological progress and environmental preservation.

The study revealed that compliance with federal and state regulations is crucial to mitigate environmental impacts and ensure the sustainable development of the region. The objectives set at the beginning of the study were fully achieved.

The main goal, which was to expose the technical aspects of studies related to the environmental licensing of wind farms at both federal and state levels, was accomplished by providing a broad and detailed perspective on the subject. Similarly, the specific objectives were achieved, as the study analyzed the progress of wind energy globally and in Brazil, discussed the infrastructures associated with its production, and described the licensing processes in the context of Ceará. To move forward, future studies are suggested that further evaluate the socioeconomic effects of wind farms on local communities, as well as comparisons between environmental licensing processes in Ceará and other states in Brazil.

Additionally, research into new technologies and methods to improve environmental licensing is recommended, promoting greater efficiency and sustainability in wind energy projects. Therefore, it is hoped that this study will contribute to the advancement of public policies and the consolidation of wind energy as a key foundation for Brazil's sustainable progress.

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