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# Generation of wind energy in the state of Bahia, Brazil: challenges and possibilities

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**A B S T R A C T**

Bahia has been gaining more and more relevance in the Brazilian energy scenario. The state has been attracting investments in the wind generation sector and has became a national leader in the sale of wind farms in energy auctions. In addition to the wind farms distributed throughout its territory, Bahia has a base industry focused on the production of equipment for the wind sector. This paper performs a critical analysis of the socioeconomic impacts of the wind industry implementation on research in the State of Bahia, considering the state's development in both the scientific and technological fields, and the problems faced by the sector. The methodology used was based on descriptive and qualitative research, seeking regional and national references on the subject, which was then analyzed and critically discussed. The results indicate the existence of a well-established base industry, with the prediction of a gradual increase in the participation of wind generation in the Brazilian electricity matrix. Bahia has important research agents that enhance research in the state. The main problem for the development of research is still the distancing of industry from the academic environment. However, the need for new energy sources still encourages the search for further research.

# Geração de energia eólica no estado da Bahia, Brasil: desafios e possibilidades

**R E S U M O**

A Bahia tem ganhado cada vez mais relevância no cenário energético brasileiro. O estado tem atraído investimentos no setor de geração de energia eólica e se tornou líder nacional na venda de parques eólicos em leilões de energia. Além dos parques eólicos distribuídos por todo o seu território, a Bahia possui uma indústria base voltada para a produção de equipamentos para o setor eólico. Este trabalho realiza uma análise crítica dos impactos socioeconômicos da implantação da indústria eólica na pesquisa no estado da Bahia, considerando o desenvolvimento do estado nos campos científico e tecnológico, bem como os problemas enfrentados pelo setor. A metodologia utilizada foi baseada em pesquisa descritiva e qualitativa, buscando referências regionais e nacionais sobre o assunto, que foram posteriormente analisadas e discutidas de forma crítica. Os resultados indicam a existência de uma indústria base bem estabelecida, com previsão de aumento gradual na participação da geração eólica na matriz elétrica brasileira. A Bahia possui importantes agentes de pesquisa que fortalecem a pesquisa no estado. O principal problema para o desenvolvimento da pesquisa ainda é a distância entre a indústria e o ambiente acadêmico. No entanto, a necessidade de novas fontes de energia ainda estimula a busca por mais pesquisas.

## Introduction

Among the various types of renewable energy, wind energy has become increasingly a more viable option to replace the generation of electricity based on fossil fuels, and, consequently, contributes to mitigate global climate change (Sayed et al., 2021). The expansion of wind energy around the world has been especially considered as fundamental to meet the growing demand for energy and ensure security of supply, which is essential to economic and industrial growth (Diógenes et al., 2019).

In December 2009, the first exclusive competitive auction for energy from wind sources, held by the National Electric Energy Agency

(ANEEL) took place in Brazil. After a decade, Brazil ranks 8th in the World Wind Capacity Ranking (GWEC, 2020) and the largest energy producers by this source.

In 2019, two energy auctions were held in Bahia had wind power registered: the A-4/2019 with 260 projects with a generation capacity of 7,782 MW and the A-6/2019 with 298 projects for total generation of 25,158 MW (ONS, 2021). It is noteworthy that there were no auctions for wind generation projects in 2020, therefore, the most current data are from the year 2019.

Bahia has gained more relevance in the national energy scenario, in addition to its position as an hydroelectric source, it has considerably increased its capacity for wind generation. Over the last decade, the state has attracted investments in the wind generation sector that have made it the national leader in wind farm marketing in ANEEL's energy auctions (ANEEL, 2021). Bahia stands out as the largest wind energy producing state in the country, with 32,64% of all contracts, and leading both production and installed capacity (ANEEL, 2021). Consolidated data from 2020 show that wind generation in Bahia totaled 16,22 TWh, representing 28,45% of the national production by this source (ONS, 2021).

According to the reports of the National Electric System Operator – ONS (2021), in 2020 Bahia presented an average wind power capacity factor of 43,6% which is higher than the national capacity factor of 40.6%. De Jong et al. (de Jong et al., 2017) estimated that the average annual capacity factor of wind farms installed up to 2020 in Bahia could reach up to 50%. Moreover, he consolidated values for the months of 2021 already indicate growth for the year.

According to ANEEL (2021), Bahia has 208 parks in operation (5,395 MW), and investments of more than R$ 15 billion. A further 77 parks are still under construction (2,346 MW) and 81 in the uninitiated construction phase (3,047 MW). Investments totaling R$ 7 billion are planned and there is an estimate of over 23,000 jobs being generated, directly and indirectly Also, it is believed to benefit more than 24 municipalities in the state (ABEEOLICA, 2020; SDE, 2019). In addition to the wind farms distributed in the semi-arid interior of its territory, Bahia also has an industrial park (basic industry) aimed at the production of equipment from the wind sector located in the coastal region.

Assuming the hypothesis that wind energy generation has played a significant role in the state of Bahia (Azevedo et al., 2022) and that, despite this evident role, the sector still faces challenges for its expansion and consolidation in the region (Lima, 2018), to better understand these difficulties, it is primordial to analyze the chain of supplies that sustains the system in its magnitude. Understanding the challenges faced by the wind energy sector in Bahia is essential to identify strategies and solutions that can boost its expansion and contribute to the consolidation of this renewable energy source in the region. To this end, the following relevant questions were problematized: what is the support structure for wind generation installed in the state of Bahia? What are the problems imposed on the expansion of wind generation in the region?

Based on these questions, this article aims to present an overview of the infrastructure dedicated to wind power generation in Bahia, identify the main challenges imposed and reflect on possible solutions to expand and consolidate the sector in the region.

**Methodology**

The methodology used for the development of this work is based on descriptive and qualitative research. Descriptive research aims to describe and analyze characteristics and phenomena related to the topic under investigation, while qualitative research aims to understand perceptions and analyze qualitative data.

To search for regional and national references on the topic in government and academic publications, a bibliographic survey was conducted in scientific databases such as Scopus, Web of Science, Google Scholar, as well as repositories of government and academic publications, such as CAPES Journal Portal, digital libraries of universities, and government agency websites, particularly those related to the energy sector.

For data collection, the databases of the National Electric Energy Agency - ANEEL, the Energy Research Company - EPE, and the National Electric System Operator - ONS were consulted. These databases contain all the information on auctions, investments, planned works, concessions, production, and installed capacity of all wind farms in the country.

The information gathering took place in December 2022, to obtain the most recent data for each aspect studied. The investigation in the ANEEL and ONS databases was based on the keyword "wind energy" in each of the investigated sectors (concessions, generation auctions, projects, and concession contracts) for the base year 2019.

In addition, content analysis was performed according to the methodology suggested by Bardin (2011) for reports and technical documents from agencies, state secretariats, ABEEólica, technical notes from state and private research institutes, as well as international reports on renewable energy.

For theoretical complementation, selected articles were analyzed in electronic databases such as the Scientific Electronic Library Online (SciELO), Web of Science, Scopus, and the National Library of Theses and Dissertations. The articles were searched using the keyword "wind energy" and variations of this term using the "AND" connector, with a publication year considered from 2010 onwards.

The selection of articles was based on peer review criteria, content analysis, geographical scope (Bahia and Northeast Brazil), and direct relevance to the research topic based on criteria of relevance, timeliness, and scientific quality, seeking references that were regional and national, related to the research topic. Data analysis was performed using a qualitative approach, identifying emerging themes and patterns in the selected references.

This methodological approach allowed for a comprehensive overview of government and academic publications related to the topic under investigation, with a focus on regional and national characteristics, contributing to a deeper understanding of the subject and providing a theoretical foundation for the work.

The obtained results were classified into the following categories: census; research and development; and challenges faced by the sector. These categories served as the basis for the construction of the following subsections, which aim to build a panorama of the reality of the wind energy sector in Bahia, infer strategies to address sectoral problems, and suggest and support further research in the field.

## Results and discussions

Wind scenario in Bahia

Exclusive auctions for energy from wind sources, carried out by the National Electric Energy Agency – ANEEL, began in 2009. Among the states with the highest number of contracts, three stood out, as shown in Figure 1.

According to the ONS report, the average wind capacity factor in Bahia in 2020 was 43.6%, above the national capacity factor of 40.6%, as shown in Figure 2.

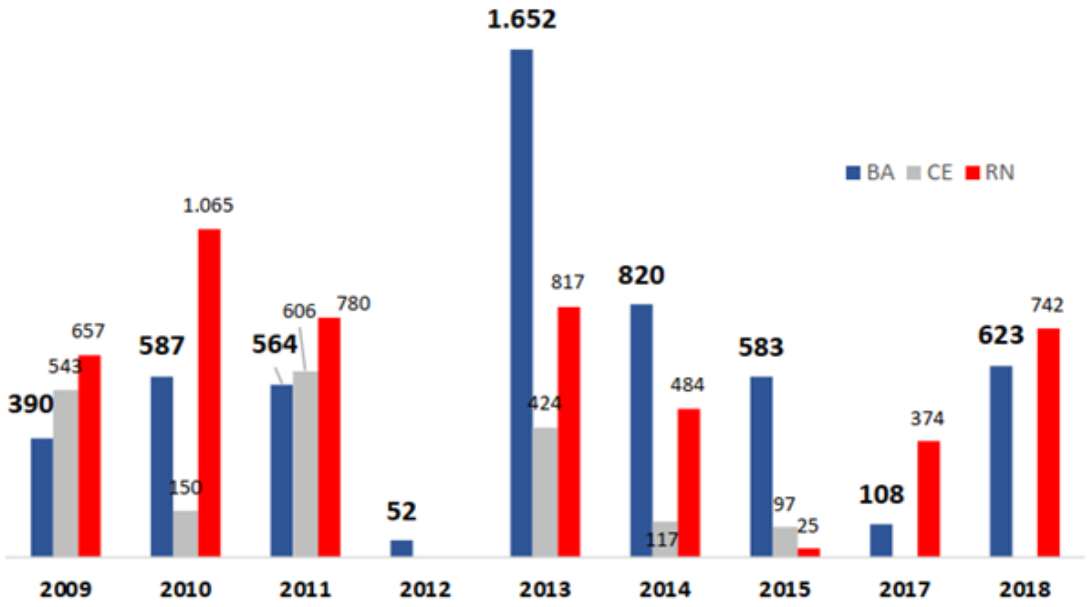


Figure 1 – Power contracted in MW at ANEEL Wind Energy Auctions. Adapted from ONS (2021).

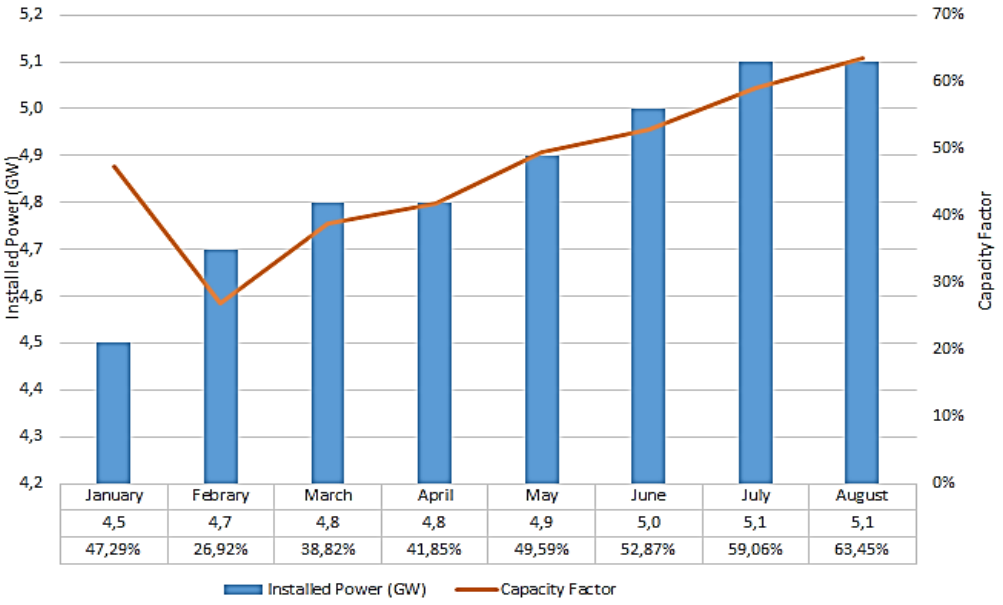


Figure 2 - Capacity Factor of the State of Bahia in 2021. Adapted from ONS (2021).

Since ANEEL's first wind energy auction in 2009, Bahia has been in the process of generating energy projects. Figure 3 shows that, since 2009, wind companies have been arriving in the state, generating qualified employment and economic development in the countryside.

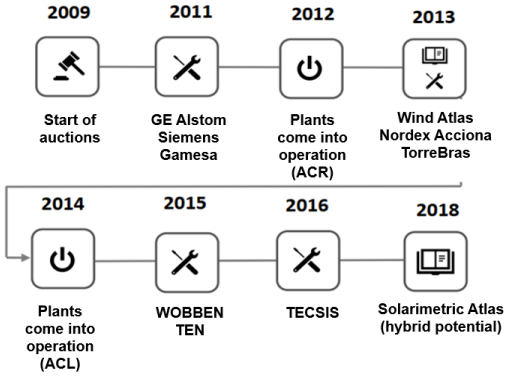


Figure 3 - Wind power timeline in Bahia. Adapted from SDE (2019).

ANEEL's first wind energy auction was destined for Bahia, 18 of the 71 approved projects. In 2011, two base equipment industries were deployed to Bahia, GE/Alstom and Siemens/Gamesa, and, in 2012, the first wind power plant went into operation (Regulated Market – ACR). The following year, two more equipment factories were installed from Nordex/Acciona and TorreBras. Also in 2013, the Wind Atlas of Bahia was launched, which showed the mapping of the potential of winds towers up to 150 meters high, serving as an instrument of energy planning and attraction of investments in the sector (SDE, 2019).

The milestone of 2014 was the operation of the first wind power plant to be marketed in the free market operation (Free Market – ACL). In 2015, they were installed from the two other factories, TEN and Wobben and in 2016, it was TECSIS' turn. In 2018, the hybrid generation potential between wind and solar was mapped in the Solarimetric Atlas of Bahia (SDE, 2019). Today, the industrial park is made up of six major outstanding projects that together add up to investments of R$704 million (SEPLAN, 2019), consolidating the Bahian territory as the main national hub in the manufacture of these components.

The state's wind energy potential, considering a hub height of 100m above ground, is estimated at 70,000MW, according to the Bahia Wind Atlas (SECTI, 2013). Combined with energy storage technologies, this potential could, theoretically, supply the total electricity demand of all the Northeast and North regions. With such expressiveness, these figures still do not take into account the potential of offshore wind generation. The Brazilian Wind Energy Atlas (CEPEL, 2017) itself has only data from offshore wind speed simulations since there is no measured data in offshore anemometric stations available.

According to the 10-year Energy Expansion Plan 2027 – PDE 2027 (EPE, 2018), the option for expanding energy production by wind power has proved extremely competitive in the

face of other technologies. This growth will increase to 12% of the capacity installed in the National Integrated System - SIN in 2027. For this reason, it is relevant to show that the creation of strategies for the development of windfarms in a continuous and harmonious way with the industrial panorama of the region (EPE, 2018).

On the context of electricity generation by hydroelectric source in the Region of Bahia, the hydrological conditions of the São Francisco River basin and the development of wind expansion in the Northeast can cause a significant portion of this expansion to be located in Bahia (de Jong et al., 2019). Therefore, it is necessary to develop integrated studies of generation and transmission that allow the evaluating of the capacity of the electrical system to play this role (EPE, 2018).

With the trend of increasing participation of the national electric matrix of other renewable sources such as wind, it is also important to evaluate other climatic variables in order to identify possible risks and impacts on the supply of electricity in the future. The studies available so far tend to agree with the projection of an increase in availability of wind resources for power generation in climate change scenarios (de Jong et al., 2017).

Climate change mitigation requires more emission-free electricity generation, such as the use of more hydroelectric generation. However, another effect of climate change projected and already observed in the São Francisco basin is the reduction of hydroelectric potential of the São Francisco River, due to reduced rainfall and water flow (de Jong et al., 2017, 2018).

This water scarcity will generate a conflict over the use of water between hydroelectric generation, irrigation, family agriculture and human consumption, in addition to the impact on the environment. In addition, hydro and wind power are interdependent, because the storage and flexibility of energy provided by hydroelectric plants are ideal for integrating variable renewable sources, while wind power can partially replace lost hydroelectric energy (Azevedo et al., 2022).

The scenario of the production chain and wind capacity of the state of Bahia is very promising, but also indicates the need to expand research in the sector, especially with regard to the optimization of wind power generation conditions and improvements of devices with a view to better production performance. Another relevant aspect to be investigated is the integration between the generation of energy by renewable sources such as the wind, solar and the hydroelectric, which have great potential to be in a balanced way in a viable way to meet the demand for electricity in Bahia.

For all the above, it can be affirmed that it is not possible to draw a clear picture about wind power generation in the state of Bahia without exploring the evolution of scientific and technological research that has paved the entire trajectory of consolidation of this sector in the region. Section 3.2 is intended to explore the most important aspects of scientific and technological development dedicated to the wind sector.

Evolution of scientific and technological research

The production chain of the wind sector in Bahia presents a structure that includes assembled units of wind turbines and factories of components and subcomponents, managed by foreign companies that have the knowledge of these processes, which implies that technological development is still restricted to the technologies of the world's leading wind market countries (Diógenes et al., 2019; Lima, 2018).

Wind turbine manufacturers receive components manufactured by other companies and only carry out the assembly process of the parts, meeting the manufacturing specifications of the wind turbine designer. Because of this, the arise of new companies and innovations in the sector is difficult (Diógenes et al., 2019).

In an attempt to solve this problem, the technological and industrial complex "CIMATEC Industrial" is being developed in Bahia. This complex will meet the needs of the market, supporting part of the unmet demands that have been identified by the industry, such as the execution of tests for engines and shovels during the certification process in the wind industry of Brazil, which will provide the training of people in the state and the creation of new job opportunities (SFIEB, 2019).

The Technological Park of Bahia is another institution that contributes to the technological development of the state, allowing the public authorities, academic community and the business sector to work in an integrated and cooperative way, focusing on the development of products and processes that have positive and relevant regional impacts in the science, technology and innovation (CTI) niche. One of its areas of activity is energy and engineering, which seeks to stimulate work in the applicability of new sources for power generation as wind (SECTI, 2021).

In addition to these centers, it is important to highlight the role of the Bahia State Research Support Foundation (FAPESB), which is also an

incentive for the development of research and technology, at the state level, since it offers scholarships for the continued training of researchers and professionals in order to develop technological training.

Due to the opportunities created by these agents to promote technological development and with the growth of industry in the wind sector, there was also the creation of training courses in Bahia's universities and the increase in the formation of research groups in the area, which can be corroborated by the 2016 Census of the National Council for Scientific and Technological Development. This census counted 1,821 research groups, 7,762 lines of research and 15 higher education institutions in the state (CNPq, 2017).

The creation of SINAI CIMATEC PARK, the support of all science and technology institutions in the state, and the wind sector represents a commitment of public agents and deprived them with the development of the sector and with the reduction of dependence on the foreign market. This movement also exposes a dimension of recognition that investment in research is essential for the optimization of processes at all levels, from the production of devices and supplies, through the choice of location and other installation requirements, to the generation of wind power itself.

- Perspectives for the research and development of the wind sector

As in any productive sector, technological development in the wind energy segment is essential. Each technological gain reflects on improvements in the sector as a whole: efficiency, cost reduction, less frequent maintenance, longer service life. As it is a relatively new sector, the need for scientific research for these technological gains to occur is superior than to other areas.

The presence of foreign companies in Bahia is fundamental for the transfer of know-how and technology. SENAI/CIMATEC is one of the institutions that help in this transfer in order to bring development and basis of generation of projects, measurements, characteristics of generators, among other aspects essential to the adaptation and creation nanotechnologies molded to the characteristics of the local winds of Bahia's territory.

In addition to research into new technologies for the installation and generation of wind power, a matter of particular importance for Bahia's territory is the search for adequate ways to use wind and solar energy in an integrated way. It is known that the region also has great capacity to generate solar energy and, therefore, the integration of both energy sources has enormous potential to meet the demand of the state and who knows, in the future, ensure energy self-sufficiency.

Research is already being conducted to determine the ideal relationship between wind energy and solar power generation, which would maximize the penetration of these technologies in Bahia. The combination of these renewable technologies could, a priori, reduce dependence on hydroelectric plants and the costly and unsustainable generation of energy from fossil fuels. In addition, it would save water in the São Francisco River for other uses such as irrigation and urban water supply (de Jong et al., 2019).

Another aspect that directly impacts the wind landscape is the training of personnel. It is notorious that the growth of an economic and technological segment of any kind involves skilled and motivated labor. To do so, there needs to be a dedicated and sector-specific training infrastructure.

- Personnel Training

With the great prominence of the State of Bahia in the Brazilian wind scenario, the results from the creation of jobs along the productive chain of the sector stand out. Jobs are categorized in three ways: the ones generated in technological development (investments in R&D and equipment manufacturing), whose volume of employment is considered medium; the ones generated in the installation and commissioning of plants (planning, project management, transportation and construction of plants), with high volume of stations generated; the ones generated in Operation and Maintenance (O&M), which include the generation and distribution of energy, considered a low volume of occupations (Aldieri et al., 2019).

The average total jobs per year, which represents the sum of direct and indirect jobs generated by MW installed in the wind energy sector, is around 15. Of the categories of job creation, the construction stage is the one that generates the most jobs, followed by the manufacture of wind turbines, O&M and transportation (ABEEOLICA, 2020).

Most part of the jobs has a temporary character, such as the generation of jobs in civil construction in the parks, being considered the phase that most employs in the process of implementing a park, reaching more than 3,000

people. However, in the operation phase this number does not reach 30 (Lima, 2018; Cavalcanti et al., 2021).

Bahia's territory has 184 projects in operation, where it is estimated that more than 58,000 jobs were generated along the chain. Considering that there are projects to be built, it is expected to generate 22,800 more direct and indirect jobs (SDE, 2019).

However, there are significant difficulties in occupying some more qualified work positions, especially engineers for maintenance and technicians in the specific area of wind. This phenomenon leads wind industry industries to offer training courses, or to take employees to other countries to conduct more specific training (Diógenes et al., 2019).

A very common strategy used by the companies implementing the park is the qualification of the local workforce with training courses for the community, such as electrotechnical and electronics, which can provide the creation of new business for the residents of these regions.

SENAI/CIMATEC develops several programs to support technological advancement and education, such as technical, undergraduate, and graduate courses, which contribute to the economic, human resources and development of the state (Plano de Desenvolvimento Institucional 2019 - 2023, 2018).

The initiatives presented are interesting, because they invest in the development of local professionals and foster a network that can promote the development of other secondary economic sectors. In addition, it provides cost reduction with recruitment of staff from other regions and creates new opportunities for professional growth for young people who are still looking for professional positioning.

Despite the positive perspectives, it is worth mentioning that the dependence of foreign companies installed in the region imposes an additional difficulty for professionals who wish to enter the sector, the language barrier. The use of the English language is very common in equipment, manuals, and other study documents. In this sense, in the dimension of personnel training, special attention needs to be paid to english language training, especially to young people who wish to enter the area.

Problems faced in the development of research and the implementation of new projects

The problems in the development of new research for the Bahian wind sector are related to the fact that a large part of the research is still restricted to postgraduate programs not integrated with the needs of the industry, and also because the industry develops its research as an industrial secret. This gap between academic research and industry research means that the industry's need does not translate into lines of research in Bahia universities.

Another obstacle is in the training of professionals for the sector. Even the training courses (technical, undergraduate, specialization) aimed at production in the wind energy sector, offered by educational institutions, are directed to the technical function, that is, few research on topics that apply to real situations of industry or operations are developed.

It is important to highlight that the national dependence on foreign technologies restricts the development of the sector to the dynamics of market forces (Chagas et al., 2020), that is, basic research in the area is practically non-existent. Thus, scientific knowledge about wind sector technologies is still restricted and considered strategic only for companies in the field (Diógenes et al., 2019), which causes the dissemination of this knowledge in the academic environment, where new technologies could be improved or even developed.

Opportunities for these partnerships to be signed will not be lacking, since the wind industry tends to develop in the territory of Bahia even more, as demonstrated by PDE 2027 (EPE, 2018) which predicts that 80% of all wind growth in the country will be installed in the region, thus there are still many challenges in the implementation of new projects and in the studies of new areas used for wind power generation. To this end, it is necessary to establish already strategic partnerships between universities and development agents of the sector such as CIMATEC and the Technological Park of Bahia; and that FAPESB and CNPq function as an integrative element of these partnerships.

As for industrial-based research, the turbine manufacturers established in Brazil endured the transfer of technology to support the construction and operation and maintenance (O&M) of wind farms, which has made the domestic wind industry undeveloped. This resistance makes wind developers dependent on turbine manufacturers because both the construction of highly customized foundations and towers and O&M services require access to the

manufacturers' essential technological information (Diógenes et al., 2019).

The growing infrastructure of research and development, and personnel training in Bahia has the potential to modify and this reality of dependence. This needs to be a union of state and private forces that are willing to make large long-term investments. In the short term, the strengthening of the inside market can occur by filling gaps in the sector, especially at this post-pandemic moment when the dynamics of global supplies have not yet been fully regulated.

According to Lima and Cavalcanti (Lima, 2018; Cavalcanti et al., 2021), the other difficulty of the sector involves the latest global trends of wind turbines that point to the increase in the height of the towers, and consequently the radius of the blades, which brings a great technological challenge, mainly in the logistics part. This is a challenge not only for Bahia, but at the world level, since it will be necessary to evaluate how these items would be transported, it would be necessary to consider things such as the size of the ships, the radius of curvature of the truck, and primarily the road network.

A major challenge to be faced in the coming years is related to the increasing socio-environmental and land complexity for the implementation of new transmission projects for decentralized wind farms. This condition contributes so that the transmission works indicated in the planning do not go into operation on the date of their effective need, causing electrical problems that vary according to the purpose of the installations (Herrera et al., 2019).

- The role of auctions

The continuous technological and economic development of this sector is directly linked to the contracts in the respective energy auctions promoted by ANEEL. To do so, there must be a minimum distribution structure for projects to come into operation.

Between 2009 and 2015, auctions took place regularly, however, the auction was cancelled in 2016 due to the political and economic crisis, which reduced electricity demand in the country. Due to the constant cancellations, the government's credibility with wind energy developers has decreased significantly.

In 2015, several lots of transmission line lines had an empty result, without attracting interested parties due to the economic scenario of that year and adjustments in regulation. This result directly influenced wind power auctions that also performed rather poorly.

Already in 2016 Bahia was withdrawn from the wind generation auction of December 16 by the technical note prepared by the EPE, ONS and ANEEL together under the justification of the lack of flow capacity of power generation.

Situations such as these directly affect the sector both with regard to investments aimed at creating new wind projects and the promotion of new research in the area. Therefore, for the wind sector to consolidate in the region, it is necessary that the responsible government agencies commit themselves to conducting periodic auctions to increase the interest of investors in the region. Periodic projects represent for investors a forecast of the availability of contracting and, therefore, greater possibility of carrying out strategic planning of investments, which also tends to attract new investors.

**Conclusions**

The present work aimed to present an overview of the infrastructure dedicated to wind power generation in the state of Bahia, with a focus on identifying the main challenges imposed and reflecting on possible solutions aimed at expanding and consolidating the sector in the region.

First, it was found that there is already a well-established wind industry (base industry) in the State of Bahia that provides the development of technological and scientific research since 2011, motivated by the large number of contracts signed in ANEEL's energy auctions from 2009, which have allocated a large part of the projects to the state. The 10-year Energy Expansion Plan 2027 (EPE, 2018) indicates the option for the expansion of energy production by wind source to 12% of sin. This brings research opportunities on wind use in a continuous and harmonious way with the industrial landscape.

Another promising aspect observed is the possibility of the integration between the generation of energy by renewable sources such as wind, solar, and hydroelectric power, which have great potential to be balanced in viable way to meet the demand for electricity in Bahia. In addition, this integration is desirable to assist in mitigating climate change that points to a reduction in hydroelectric potential in the São Francisco River, due to reduced rainfall and water flow.

These aspects draw a promising scenario for the wind sector in the region. To expand this scenario, we sought to analyze the research and development actions in the sector. The data

obtained showed that the people contributing to the development of new research, such as the Bahia Technological Park and the Bahia State Research Support Foundation, work in Bahia's territory to allow the public authorities, the academic community, and the business sector to work in an integrated and cooperative manner, the creation of several training courses and training of research groups was observed.

According to data analyzed, the wind sector production chain in Bahia creates an estimated 15 jobs per MW installed, with an average of 69,000 jobs directly and indirectly. However, most occupations are concentrated in the installation phase through temporary posts. In addition, there is a great difficulty in finding professionals with high training for more qualified vacancies.

These points signal a limitation of the wind sector in promoting the generation of large volumes of jobs, since in the installed plants the average is 30 workers. As for staff training, it was observed that although companies' initiatives to promote training courses tend to reduce the costs of recruiting staff from other regions, it is still pressing to need investments in Training them in English, since foreign companies are predominant in the region.

In addition, the training courses (technical, undergraduate, specialization) aimed at production in the wind energy sector, offered by companies and educational institutions, are directed to the technical function, that is, they do not stimulate the development of new research on topics applied to the situations of industry or wind operation.

It is also clear that a major obstacle that is in the attraction of investments for the wind sector is the uncertainty of auctions that promotes instability in the energy market, driving away investors due to the difficulty of carrying out the fundamental strategic planning for carrying out projects in the area.

From the evaluation of all the challenges this sector faces, it is possible that there is an aspect that permeates and paves the territory of obstacles of the sector. In this sense, the main challenge identified for the development of the wind sector in the State of Bahia is the concentration of the means of production, operation and strategic information of the sector is owned by foreign companies, with consequent reduction in the dissemination of expertise by other science and technology production agents. This phenomenon restricts the growth capacity of the sector in the internal market and the creation of new national technologies. In addition, it widens the gap between academia and industry, which prevents essential works to promote improvement and promotion of innovation.

Obviously, it is not possible and not interesting to extinguish foreign participation in the sector. However, it was observed that the entire wind production and operation chain is completely dependent on foreign investment and technology. After the moment of global collapse experienced due to the Covid-19 pandemic, it is essential that there is a strengthening of the domestic market and that Brazilian investors are attracted to the situation.

With the growing infrastructure of research and development, and personnel training in Bahia, there is a potential to modify this reality of dependence. This needs to be a union of state and private forces that are willing to make large long-term investments. Finally, in the short term, the strengthening of the inside market can occur by filling gaps in the sector, especially at this post-pandemic moment when the dynamics of global supplies have not yet been fully regulated.

Furthermore, wind energy has emerged as a promising source of renewable energy that can play a significant role in the transition to a more sustainable energy future. One potential application of wind energy is the production of green hydrogen. By harnessing the advantages of wind energy, such as its abundance, scalability and environmental benefits, and by addressing the associated challenges, wind energy can play a crucial role in helping to achieve a greener and more sustainable future. However, socio-environmental studies will be necessary (geomorphology, phytogeography, surface and sub-surface water conditions, impacts on communities and fauna) that will actually enable the sustainable use of energy.

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