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ENERGY PROGRAM

OFFSHORE WIND ENERGY DEVELOPMENT IN BRAZIL

November, 2021

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CEBRI's activities are organized around 12 Thematic Programs, coordinated by members of the CEBRI Board and by Senior Fellows. The Energy Program is one of the most dynamic and its activities are conducted by CEBRI Vice-Chairman Jorge Camargo and by Senior Fellow Rafaela Guedes.

ENERGY PROGRAM

The Program focuses on the future of energy and global energy trends and seeks out solutions to create a competitive and attractive investment environment for Brazil.

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Vice-Chairman of the Board of Trustees of CEBRI and coordinator of the Energy Program. He is a member of the Boards of Directors of the Ultrapar and Prumo Global Logistics Groups. He was Chair of the Brazilian Institute of Petroleum, Gas and Biofuels (IBP) and is today an emeritus member of its Board of Directors. He has held executive positions at Petrobras, including as a member of the Executive Board, responsible for the International Area, and at Equinor, initially as Senior Vice President, at the company's headquarters in Norway, then as Chair of Equinor in Brazil.

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Rafaela Guedes is Petrobras´ Chief Economist. In this role, she is responsible for developing and monitoring Petrobras' corporate scenarios, macroeconomic forecasts, oil and oil products demand outlook and the development of strategic competitive analysis. Her main areas of interest are strategy, energy and climate change. She is currently member of the Oil and Gas Climate Initiative Executive Committee.

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Gregório Araújo has served in the position of Senior Economist at Petrobras since 2008, with management roles in the Strategy and Planning department. Araújo served as Member of the "Future Energy Leaders Program" and of the "Scenarios Committee" of the World Energy Council, as well as Secondee at the International Energy Agency, contributing to the elaboration of the Brazil chapter at the World Economic Outlook's 2013 edition.

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Partnership:

Kingdom of the Netherlands

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Context

Over the last decade, the global offshore wind installed capacity has expanded from 3 GW to 28 GW, which represents an average growth of 28% per year, a rate surpassed only by the expansion of solar photovoltaic installed capacity. According to the International Energy Agency (IEA), offshore wind will continue to increase over the next two decades, helping to decarbonize energy systems and reduce air pollution as it becomes an increasing part of the energy mix. Offshore wind power capacity is set to increase by at least 15-fold worldwide by 2040, becoming a $1 trillion business (IEA, 2019).

Brazil is one of the top countries in the world when it comes to wind resources. According to the Brazilian Energy Research Centre (EPE), Brazilian offshore wind technical potential is around 700 GW in locations with water depths of up to 50 m.

In addition to relevant potential for the development of offshore wind projects, Brazil may also rely on other renewable sources that are currently at a more developed stage of maturity in the country. According to the National Energy Plan (PNE 2050), Brazil's energy resources endowments far surpass its total energy demand. The plan estimates that, just considering energy generated from the most affordable sources, energy demand for the period would be exceeded in 60%. More than half of this potential would come from renewable generation, taking into account biomass thermal plants, hydroelectric plants that do not affect protected areas, solar photovoltaic plants, onshore wind plants, small hydroelectric plants and the potential offshore wind in areas up to 10 km away from the coast.

Thus, the long-term challenge will be to manage that abundance of energy resources. In this context, the use of offshore wind resources is conditional on the technical and economic feasibility of projects, which must balance technological aspects and legal, regulatory, environmental, social, and governmental issues.

Although there have been few studies on offshore wind energy costs in Brazil, the first figures indicate that costs are still high when compared to other energy sources that are currently developed in the country. Brazil can benefit from the international experience, which drives technological advances and causes lower installation, operation & maintenance (O&M) and financing costs. This learning curve will be crucial for the the success of this emerging industry in the country.

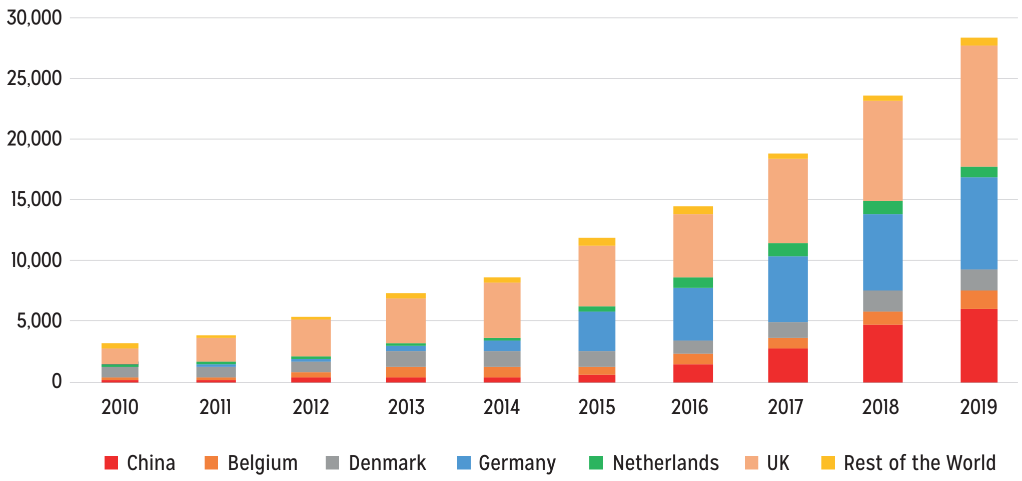
In this context, on August 11, 2021, the Consulate General of the Kingdom of the Netherlands in Rio de Janeiro, in partnership with CEBRI, held the “Offshore Wind Energy Development in Brazil” webinar, which was attended by Niels Veenis, Deputy Consul General of the Netherlands in Rio de Janeiro and co-host of the event on behalf of the Consulate, Ruud de Bruijne, Offshore Wind Energy Project Manager at the Netherlands Enterprise Agency, and Winston Fritsch, a CEBRI trustee. Participants Gustavo Pires da Ponte, Deputy Superintendent at the Brazilian Energy Research Centre (EPE), Élbia Gannoum, CEO at *Associação Brasileira de Energia Eólica* (ABEEólica), André Araújo, President of Shell Brasil, and Verônica Coelho, President of Equinor Brasil, submitted their contributions and promoted an important exchange of knowledge in a debate moderated by Rafaela Guedes, Senior Fellow at CEBRI, and André Bello de Oliveira, Innovation for coordinator at Petrobras.

This white paper presents a synthesis of the discussions held in the webinar and does not necessarily reflect the opinions of the speakers.

Global offshore wind generation

In 2019, there were more than 5,500 grid-connected offshore wind turbines installed in 17 countries (IEA, 2019). Global offshore wind power sums 28 GW of installed capacity that generated 84 TWh of electricity, which accounted for only 0.3% of global generation (IRENA, 2021). Despite this modest share, offshore wind has emerged as one of the most dynamic energy sources in the last decade. From 2010 (first time that global capacity additions of offshore wind power surpassed 1GW) to 2019, offshore wind capacity grew by approximately 28% per year, surpassed only by the growth in installed capacity of photovoltaic solar panels.

FIGURE 1 - GLOBAL OFFSHORE WIND INSTALLED CAPACITY (IN MW)



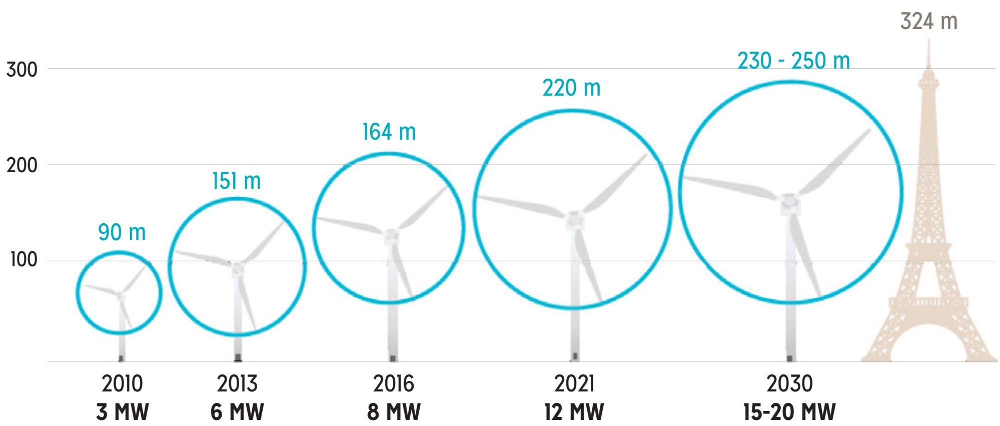
Source: Own authorship, based on IRENA statistics (2021)

Offshore wind expansion has been fostered by European countries, especially those bordering the North Sea (Germany, Belgium, Denmark, Netherlands and United Kingdom). Europe currently makes up for almost 80% of global capacity, which highlights the key role of well-designed public policies, aligned with private initiative, play in the expansion of this energy source. Likewise, China has become one of the global leaders in offshore wind, driven by its 13th Five-Year Plan, which set a target of 5 GW installed capacity, a milestone that the country reached in 2019, one year ahead of schedule.

Above all, public policy must take notice of the main challenges to unlock the country's offshore wind potential by (i) adjusting regulatory framework for the development of new energy source projects; (ii) enabling access to an efficient supply chain; (iii) providing grid connection infrastructure. In the next section, we will discuss the Netherlands example.

Technologies applied to the production of offshore wind energy energy have made impressive improvements since the first turbines were installed in Europe in 1991. These improvements enhanced the size and maximum output of the turbines (tip height and swept area). According to IRENA (2019), turbines in offshore wind farms have grown from an average of 3 MW in 2010 to 6.5 MW in 2019. For 2025, Rystad (2020) estimates turbines in new projects will surpass 13 MW. For 2030, the industry expects even larger turbines, between 15-20 MW, with heights between 230-250 meters, which is equivalent to 80% of the height of the Eiffel Tower (EIA 2019).

FIGURE 2 - EVOLUTION OF THE LARGEST COMMERCIALLY AVAILABLE WIND TURBINES



Source: IEA (2019)

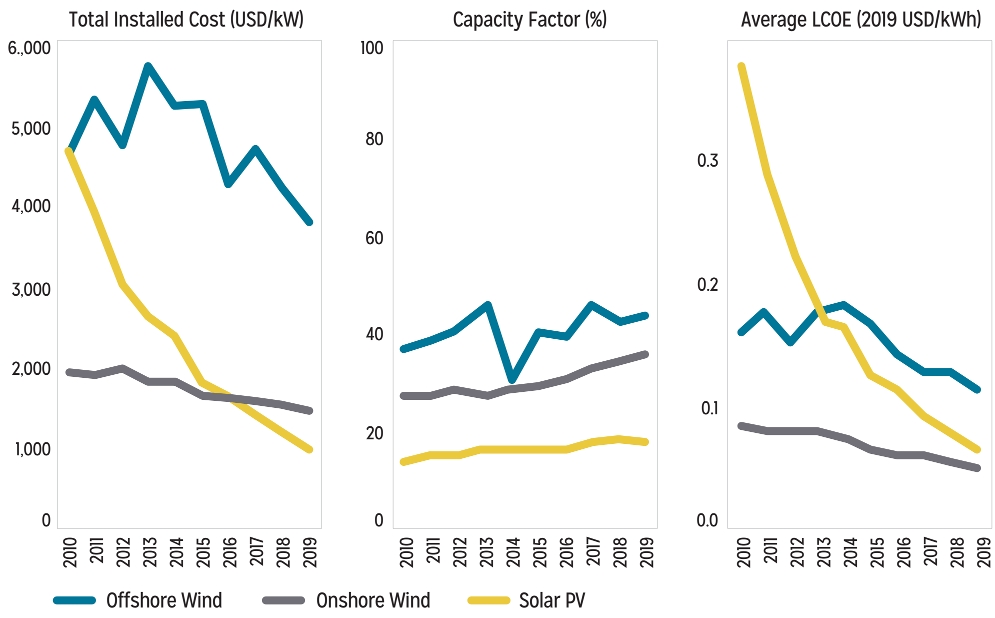
Value chain development and technology evolution led to a relevant drop in the costs of new offshore wind projects beginning in the second half of the past decade. According to IRENA (2020), the levelized cost (LCOE[1]) of new offshore wind projects decreased by 32% between 2015-2019, reaching 0.115 US$/kWh. Nevertheless, it is still approximately twice the levelized cost of onshore wind (0.053 US$/kWh) and of solar photovoltaic (0.068).

1. LCOE (Levelized Cost of Energy) is a metric used in the comparison between different sources of electricity generation. It is measured as the ratio between the sum of the project's total costs (CAPEX and OPEX) and the energy generated over its useful life.

One of the challenges for accelerating the offshore wind energy growth is that this source must prove itself competitive compared to other energy sources. Gains of economy scale and technological advances must bring its LCOE closer to onshore wind and photovoltaic solar, which currently lead the expansion of the power system globally. In this regard, IEA (2019) predicts that offshore wind projects will be cost-competitive with fossil and renewable sources within a decade. In the long term, it expects offshore wind's LCOE to decline by around 60%, following a dynamic similar to that of solar photovoltaics this decade.

Furthermore, offshore wind must contribute to the management of operational challenges faced by an power mix with increasing share of intermittent energy sources. In this sense, its higher capacity[2] factor (in comparison with onshore wind and solar photovoltaic) and its lower variability (relative to solar photovoltaic) make the inclusion of offshore wind in an power mix an attractive option to improve the energy security using a renewable source. In fact, new wind projects show capacity factors around 40%-50%, which is close to the load factors of dispatchable fossil fueled thermal plants. In addition, offshore wind capacity factor tends to increase with the grow of turbines size.

FIGURE 3 - OFFSHORE WIND: INSTALLED COST, CAPACITY FACTOR AND LCOE



Source: IRENA (2021)

2. The capacity factor of an electricity generation asset is the ratio between its actual production over a period of time and the maximum total capacity over that same period.

In pursuit of enhanced competitiveness, offshore wind projects are moving further offshore and into deeper waters where the best quality wind resources are available. So far, most commissioned projects have been 50 km offshore. However, several large projects underway are 100 km or more offshore. (IEA, 2019).

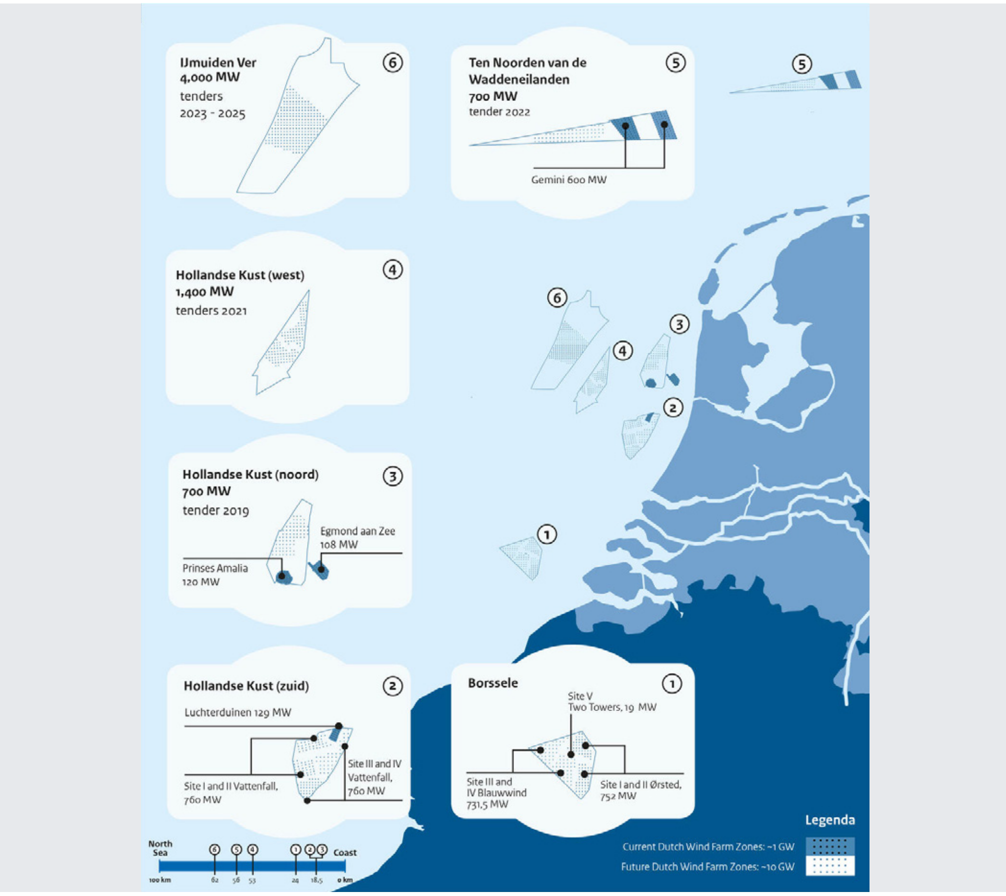
The wind industry has been adapting different floating foundation technologies (Tension Leg Platform, Spar-Submersible, Spar-Buoy) that are successfully used by the oil & gas (O&G) industry. In this sense, as offshore wind expands to deep water, the opportunities to explore synergies with the O&G industry will increase: about 40%-60% of the costs of an offshore wind project closely match offshore O&G industry competencies.

In summary, the decarbonization efforts that will be necessary to achieve a net zero carbon emissions trajectory by mid-century are enormous. It will be essential to mobilize all available energy resources. Offshore wind energy has shown a robust trend towards cost reductions. Innovations and learning curve will accelerate this process in the coming decades. Furthermore, the technical aspects of offshore wind mean that this source represents a valuable alternative for managing the challenges of an increasingly renewable and variable power mix. In this regard, IEA (2019) estimates that offshore wind power will increase by at least 15-fold worldwide by 2040, becoming a $1 trillion business.

The Dutch Experience

The Netherlands benefits from numerous favorable aspects when it comes to the development of the offshore wind industry. In addition to adequate wind resource, the country has a strong supply chain and excellent ports. Shallow water depth (around 40 meters) and suitable soil type facilitate the installation of monopile-type foundations, which are currently the least expensive alternative.

FIGURE 4 - DUTCH OFFSHORE WIND FARMS ZONES



Source: Government of the Netherlands - https://www.government.nl/topics/renewable-energy/offshore-wind-energy

Additionally, the load center in the Netherlands is close to the coast, reducing the cost of electrical connections. The current roadmap points to an offshore wind generation of 11.5 GW by 2030. However, there is an ambition to add capacity from 2 GW to 10 GW. Considering that energy consumption in the Netherlands is close to 15 GW, it is estimated that by 2030, between 70% and 80% of electricity will come from renewable sources, especially wind and solar.

The first offshore wind auction – the 752 MW Borssele project - had a price of 70 €/MWh and was won by Ørsted. The second auction, just a year later, was won by a consortium with Shell participation for 45 €/MWh, which is competitive in light of the market price of 50 €/MWh. In this context, subsequent auctions took place without subsidies. The success in lowering costs can be associated, in part, with the drop in investors' perception of risk and the dialogue process, through which the government and stakeholders discussed an adequate system for the development of the offshore wind industry. The planning also allows the industry to advance investments in dedicated vessels and larger turbines to reduce cost, while standardization and electrical infrastructure facilitate the flow of energy.

With a long-term vision (Roadmap 2040), the government works with a projection of 27 GW of offshore wind, associated with the production of hydrogen (H_2) as a form of energy storage and for decarbonization of the industrial sector. With hydrogen production based on electrolysis using electricity originating from renewable sources (green H_2) and on natural gas with carbon capture (blue H_2), the infrastructure for this new energy system provides for the reuse of depleted gas reservoirs for H_2 storage or carbon capture.

The creation of artificial islands that work as energy hubs with the generation of electricity and H_2 from offshore wind flowing to different countries is an object of international cooperation.

The Netherlands case highlights the vital role that public policies (in association with private initiative) can play in unlocking a country's offshore wind potential, including action to establish a long-term vision and roadmap, organize an efficient auction design, as well as adequate regulation regulation for grid connection.

The Netherlands' success in rapidly dropping costs and eliminating subsidies can provide important lessons for Brazil. Dialogue with the private sector in regulation development, opening the market to take advantage of the global supply chain and reducing the main risks for entrepreneurs were fundamental in this trajectory. The government's role in reducing risks and long-term planning has proven to be crucial, serving as an example for other countries that want to introduce offshore wind source in their energy matrix.

Brazilian outlook

In light of the offshore wind expansion identified internationally in recent years, *the* Brazilian Energy Research Centre (EPE) has made efforts to include this source in the Brazilian energy planning. The first document published by EPE that addresses this issue was the **Energy Resources**, a 2018 survey that was part of the **National Energy Plan – PNE 2050** and that presented an outlook of the long-term energy resources available in the country.

In 2020, the offshore wind source was also included in the medium-term horizon and, for the first time, it was deemed a candidate source for expansion in the analyzes carried out within the scope of the **Ten-year Energy Expansion Plan – PDE 2029**. In April 2020, EPE drafted **Offshore Wind Brazil Roadmap**, a survey whose main goal was to identify possible barriers and challenges to the development of offshore wind sources in Brazil.

In addition to the EPE surveys, it is also worth highlighting IBAMA's initiative in drafting the **Standard Terms of Reference (TR) for Offshore Wind Energy Farms (sea)**, published on November 17, 2020. The TR describes the information that developers must present in their environmental impact studies to verify the viability of this type of renewable energy venture, bringing more clarity and security to the environmental licensing process.

Two initiatives should be highlighted relative to the area concession's rules for offshore wind. The first is the Bill of Law **PLS 484/2017**, which defined the framework for the concession of areas through auctions organized by the Federal Government. The second is the Bill of Law **PL 576/2021**, submitted on February 24, 2021, which proposed two alternatives for the concession of areas for the development of offshore wind projects.

The first model involves an independent grant model, in which the investor, at its own risk, requests the grant of the area and develops the project, but also includes a public call for identification of possible competitors for the area, as well as the evaluation of the feasibility of the project before the grant is finalized.

The second model involves planned grant, which requires surveys, delimitation of areas and the holding of an auction by the Federal Government. The winning bidder will be the entrepreneur who pays the highest subscription bonus. It should be noted that PL 576/2021 addresses the apportionment of revenues originating from signature bonuses among the Federal Government, the States and the Municipalities, but fails to address a fundamental aspect, that is energy marketing methods.

Despite the doubts regarding costs and energy marketing methods, there are already requests for licensing from IBAMA (Brazilian Institute for the Environment and Natural Resources)[3] for 42 GW offshore wind projects. This number is about twice as high as the 23 GW of onshore wind projects registered for participation in the next onshore wind auction and is also higher than the current 19 GW installed onshore wind capacity.

The current water crisis underscores the need for greater diversification of energy sources in the country. Offshore wind energy, with projects from the North to the South of the country that are supplementary to the generation of energy from hydroelectric plants, can be a great alternative to increase the reliability of the Brazilian energy mix.

It is also worth noting the concentration of a large number of onshore wind and photovoltaic solar projects in the Northeast region. Offshore wind projects are large-scale and the flow of this energy to other regions will require important investments in energy transmission infrastructure. As the connection infrastructure must be planned, a crucial point in the regulatory framework is to define who will be responsible for reinforcing the country's energy transmission systems to enable the flow of offshore wind energy. One of the possibilities for reducing the risk for entrepreneurs is the segregation of generation and transmission auctions. Some countries have successfully adopted this strategy, promoting the reduction of total project costs.

An alternative to solve the need to expand the transmission infrastructure is the conversion of offshore wind energy into Hydrogen (H_2). Like the Netherlands, Brazil is also considering the production of H_2 as part of the energy solution in a transition scenario. In February 2021, EPE launched the "**Bases for Consolidation of the Brazilian Hydrogen Strategy**" and recently submitted to the National Energy Policy Council (CNPE) the guidelines for the National Hydrogen Program.

In this context, it is worth mentioning the recent partnership between the Government of Ceará and the Federation of Industries of the State of Ceará (FIEC), the Federal University of Ceará (UFC) and the Pecém Complex (CIPP S/A). Decree No. 34,003, of March 24, 2021, formed a Work Group with the goals of developing public policies on renewable energy for sustainable development and for the configuration of a Green Hydrogen HUB in the State of Ceará. At the same time, Porto de Açú in Rio de Janeiro also announced its interest in the production of H_2.

The participation of ports is important not only for the H_2 production chain, but mainly to enable the construction of offshore wind farms in the country. Brazil has an important port structure. However, it will need to be adapted to meet the logistics needs of the large pieces of equipment required by the offshore wind energy industry.

3. https://www.ibama.gov.br/phocadownload/licenciamento/2021-07-21-CEOffshore.pdf

Synergies between O&G and offshore wind industries

Familiarity with the seabed, the best routes for laying cables and pipelines, anchoring techniques, types of foundations, the most suitable materials for conditions in offshore environments and inspection techniques, as well as expertise in the execution of offshore and capital-intensive projects are some examples of synergies between the O&G and offshore wind industries. In this context, some O&G companies consider the development of offshore wind projects as part of their decarbonization strategies.

Shell has been operating in the Brazilian market for 108 years and has developed important businesses in the oil and gas (O&G) and biofuels sectors. Recently, it identified Brazil as a strategic country for the development of offshore wind energy. The company's actions in offshore wind in Brazil are still in an early stage, but it is already operating in this segment in the Netherlands and in the United States. The company's fifty years of experience in project development in an offshore environment and twenty years of experience in the wind market are important assets for accelerating knowledge in the offshore wind market. There are many similarities in the challenges faced by the O&G industry and by the offshore wind industry, especially in projects in greater water depths and with wind turbines installed on floating bases.

Shell made its first investments in offshore wind in 2000, as part of the consortium that installed the first wind turbines off the coast of the United Kingdom. Currently, the company ranks the offshore wind business as one of its growth areas, with a view to expanding its clean energy portfolio, which includes approximately 6 GW of installed or developing capacity.

As for the cost reduction, Shell believes in adapting the naval sector that supports O&G activities to serve the wind industry, promoting important synergies. Partnerships and innovation are also relevant aspects of Shell's plans, which include the investment of around 30% of R&D (research and development) resources in Brazil in the renewable energy and decarbonization sector.

Equinor has been operating in Brazil since 2001, with a presence in the O&G sector and plans to increase its investments in renewables. Brazil is considered a core area for the company's global strategy. By 2030, the company plans to invest around 50% of its total CAPEX in renewable energy and low-carbon solutions, in order to reach 12 GW to 16 GW of installed capacity, around two-thirds of which in offshore wind energy. It has projects in Norway, United Kingdom, Germany, South Korea and Poland and is a pioneer in the implementation of floating foundation technology with the Hywind Scotland project. In January 2021, it was selected by the State of New York to be part of the pool of companies that will develop a wind farm with a 3.3 GW capacity, in one of the largest renewable energy auctions in the US.

In Brazil, Equinor started the environmental licensing of a 4 GW project in Rio de Janeiro and Espírito Santo. In the company's view, offshore wind can be an alternative for the supply of energy close to the consumer market. Near large urban centers, in general, there are land availability restrictions for onshore wind projects.

Both companies believe that dialogue and collaboration between government, investors, supply chain and society is the best way to develop this new source of energy in the country.

Final Considerations

Brazil has started the identification of institutional and regulatory challenges related to cost, infrastructure and competitiveness, to include the offshore wind power in the energy mix. The country has also begun to evaluate the opportunities associated with the development of public policies based on the dialogue between government and the productive sector, synergy with the oil and gas sector and the contribution of the international experience of companies operating in Brazil.

The regulatory framework for areas of concession, energy commercialization and expansion of transmission infrastructure are considered fundamental for reducing the risk for investors and to increase the competitiveness and to accelerate the development of the offshore wind industry in Brazil.

As for cost reduction, a pipeline of long-term prospects of projects is considered important for the supply chain to anticipate future demand, preparing the supply side of this new industry. Another important aspect is the use of the global supply chain, relying on the best skills existing in the country and in the world. Specific auctions for the offshore wind projects also help reducing risks and raising funds.

Collaboration between different players is also necessary to promote the adequacy of the Brazilian port system, synergies with the O&G industry, identification and implementation of reinforcements in the energy transmission infrastructure, which are relevant to enhance the competitiveness of this energy source.

The selection of the best areas for project development, the completion of environmental surveys, the measurement of the quality of the winds and soil studies conducted by the government help in the process of reducing project risks and costs.

The Netherlands' experience can accelerate the advancement of the offshore wind industry in Brazil. Regarding possible partnerships for the development of supply chain and technologies, please refer to the websites listed below.

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