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TRENDS AND DEVELOPMENT OF THE ONSHORE WIND ENERGY INDUSTRY IN TAMAULIPAS, MEXICO

The expansion of renewable energy has not changed, nor the fundamentals which they are ruled with, and their share in world electricity generation reached almost 27% in 2019; currently, solar PV and onshore wind are already the cheapest way to incorporate new electricity generating plants in most countries. Disruptions to the renewable energy supply chain, caused by the COVID-19 crisis, slowed the progress of any project globally during the first six months of 2020, however, plants construction and manufacturing activity intensified again starting in the second half of the year and logistical challenges were mostly resolved with the easing of cross-border restrictions. The purpose of this article is to carry out an analysis of the development of the energy market of the second renewable source with the highest installed capacity in Mexico and the first with highest installed capacity in Tamaulipas: onshore wind and its trends that predominate globally.

Keywords: renewables, wind energy, supply chain, trends.

1. INTRODUCTION

The expansion of renewable energy has not changed, nor the fundamentals which they are ruled with, and their share in world electricity generation reached almost 27% in 2019. According to figures presented by the International Energy Agency (IEA), it is expected

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that 61% of electricity will come from renewable energy by 2030, so this type of energy will have to triple and much of that growth will come from wind energy and solar PV (Hutchinso, Zhao, 2023). Now, for years, renewable energy has been recognized as a fundamental piece for sustainable development, with the purpose of achieving the well-being of the world population without having such a negative impact on the environment, since this is one of the main concerns on the planet and prevent global warming from generating catastrophic effects, by not adopting more sustainable measures in relation to greenhouse gas emissions (GHG emissions) (Pereira, Pulido, 2021).

Currently, solar PV and onshore wind (understood as the energy that is generated by wind turbines located on the mainland and that work through the natural movement of air) are already the cheapest way to incorporate new electricity generation plants in most of countries that seek to implement sustainable economic and energy development models, however, for this to be possible, there are factors that drive them depending on the region that is developing it or is in the transition of generating them (Forum, 2023). In the same way, there are factors that affect the generation of these energies, such as: disruptions to the renewable energy supply chain, caused by the COVID-19 crisis, slowed the progress of any project globally during the first six months of 2020, however, plants construction and manufacturing activity intensified again starting in the second half of the year and logistical challenges were mostly resolved with the easing of cross-border restrictions (Agency, 2021). In addition to that the integration of energy renewable has not been so complex nor expensive as expected in a market accustomed to conventional energy. Furthermore, it has shown its ability to strengthen the resilience and reliability of the network, as well as to provide services network basics.

In the case of the wind energy market, it is led by China, the United States and Europe. Due to the incorporation of storage solutions, the availability of wind and solar energy has increased, thus eroding the advantage that conventional energy sources have held in this regard for a long time. Although the cost of renewables combined with storage solutions is higher, it can offer additional capacity and network services, making it more valuable (Solutions, 2022).

This article aims to carry out an analysis of the development of the energy industry of the second renewable source with the highest installed capacity in Mexico and the first with the highest installed capacity in Tamaulipas: onshore wind power and the trends that predominate globally, within a world that faces unprecedented historical challenges such as post-pandemic geopolitical changes, the confrontation of climate change and the opportunity to create more resilient markets. In the first part of this study is the introduction, presenting the general of renewable energies in the world, besides focusing the main interest and guiding it to the wind energy market, main purpose of the paper. In the central part, an analysis of the current situation on a global, national and regional scale will be made, considering the development presented in the state of Tamaulipas and finally, based on the processed information, presenting the trends with an objective vision.

1.1. Purpose

An analysis of the trends and development of the onshore wind energy industry in Tamaulipas Mexico, through knowledge of its current situation, starting from a global context, going through the national market and concluding with a regional environment, as well as the opportunities and challenges that it presents in the short and medium term in the territory in question. This type of analysis and comparison is extremely important because solar and wind energy have recently passed a new milestone by becoming the

generation technologies with the greatest investment attractiveness. As they reach parity in price and performance with conventional energy sources, they are demonstrating their ability to improve grids and become increasingly competitive with new technologies and overcoming the obstacles and brakes to their implementation.

2. REFENCE FRAMEWORK

The scientific and technological development that has advanced by leaps and bounds in the world and has brought us enormous benefits in economic, social, cultural and even political matters, however, it is precisely this development that demands a significant increase in energy (Ballesteros, 2016). And it is this energy demand that makes nearly 80% of the world's economies net importers of fossil fuels, which represents approximately 6 billion people dependent on fossil fuels originating in other countries located in distant regions, often making them vulnerable to crises such as the recent 2020 pandemic or to geopolitical impacts. On the other hand, all countries have renewable energy sources whose potential has not been sufficiently exploited. The International Renewable Energy Agency (IRENA) estimates that 90 % of the world's electricity can, and should, come from renewable energies by 2050. Renewables represent a solution to import dependency, contributing to a diversification of economies and protecting them from unexpected price fluctuations in fossil fuels, a necessary source for conventional energy production, while at the same time promoting inclusive economic growth, the creation of new jobs and a reduction in the rigors of poverty, not to mention the fact that they represent an environmental opportunity to reduce greenhouse gas emissions (Nations, 2023).

The wind and solar PV power accounted for 90% of the world's newly added renewable capacity. In part, this high share reflects low growth in hydropower, as several major projects missed expected completion times. This is the reason why they are widely studied and where the countries that dominate the market are, for wind energy: China, USA, Germany, India, Spain, France, Brazil, United Kingdom and Canada, and for the solar energy: China, Japan, Germany, USA, Italy, India and United Kingdom (Agency I.E., 2021).

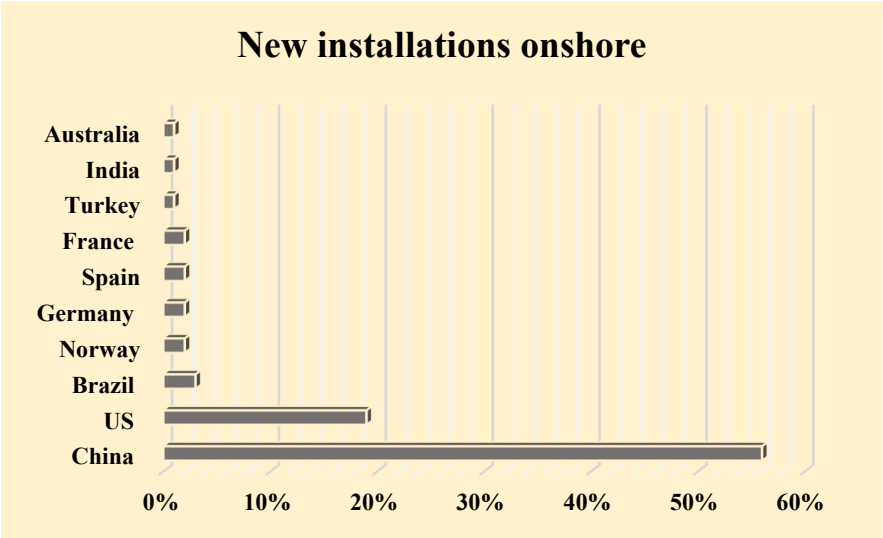
However, the object of this study focuses specifically on onshore wind energy, since it is the one developed in the state of Tamaulipas, Mexico, the area delimited for this research. Installed wind capacity was approximately 906 GW in 2022, of that total, 77.3 GW represented added capacity and the onshore wind market alone added 68.8 GW worldwide last year, with China being the largest contributor and remaining the largest onshore wind power producer for several years in a row (Hutchinso, Zhao, 2023).

2.1. Worldwide environment of onshore wind

Despite the Coronavirus Pandemic, 2020 was the best year for the global onshore wind industry, reaching a growth of 53% than 2019, for the onshore market represented almost 87 GW installed, an increase of 59% than 2019; China and the United States continue to represent the largest market (Lee & Zhao, 2020).

2.1.1. World´s statistical

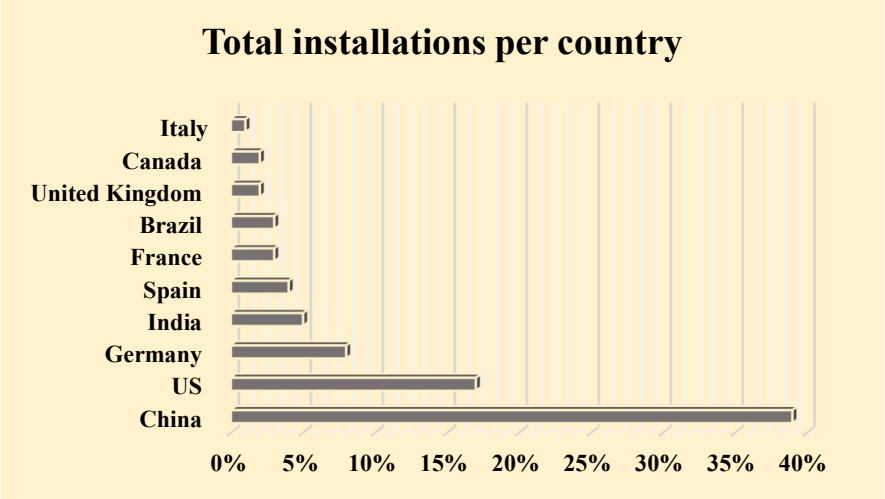
According to data presented by the Global Wind Report 2021, the ten countries with the greatest development of new installations onshore were: China 56% (48,940 MW), US 19% (16,193 MW), Brazil 3% (2,297 MW), Norway 2% (about 1,500 MW), Germany 2% (1,431 MW), Spain 2% (about 1,400 MW), France 2% (1,318 MW), Turkey 1% (1,224 MW), India 1% (1,119 MW), and Australia 1% (1,097 MW) (Drawing 1).



Drawing 1. Global market status 2020 (New Installations)

Source: Global Wind Report 2020.

In addition, total installations per country too were: China 39% (278,324 MW), US 17% (122,275 MW), Germany 8% (55,122 MW), India 5% (38,625 MW), Spain 4% (about 28,000 MW), France 3% (17,946 MW), Brazil 3% (17,750 MW), United Kingdom 2% (13,731 MW), Canada 2% (13,577 MW) and Italy 1% (about 7,000 MW) (Drawing 2).



Drawing 2. Global market status 2020 (Total Installations)

Source: Global Wind Report 2020.

On the other hand, there are new markets to consider, in Latin America, Chile is observed, with exceptional natural resources and Colombia that seeks to complement the hydropower resources with onshore wind. In Asia, Saudi Arabia in 2016, launched an ambitious national program to create a new sustainable economy with alternative ways for energy generation and Vietnam with political strategies necessary to develop the wind industry. Finally, in South Africa, Mozambique has the largest power generation potential.

2.2. Mexico's environment of onshore wind

Mexico is positioned as one of the best places for the generation of electricity from wind energy. The development of the wind energy market in Mexico has important impacts for the national and regional economy, with an investment of 13 billion dollars. There are 70 onshore wind farms in 14 states, representing 7,154 MW in operation, producing 21.14 TWh per year, equivalent to the consumption of 14 million homes. The three states with the highest production are Oaxaca, Tamaulipas and Nuevo León, generating 5,266 MW (Eólica, amdee.org, 2023). The state of Oaxaca is characterized by being one of the best places, not only in the country but in the American continent, for generating electricity through the wind. In that region, the wind has an average speed of 8.5 m /s at a height of 50 m. In particular, the region called Istmo de Tehuantepec, is considered one of the best regions to take advantage of wind energy (Drawing 3).

Drawing 3. Wind energy industry in Mexico

Source: Mexican Wind Energy Association (AMDEE)

According to the figures presented by the Mexican Wind Energy Association (AMDEE by its acronym in Spanish), in 2023, the states that participate in this market are: Oaxaca, Tamaulipas, Nuevo León, Coahuila, Puebla, Yucatán, Zacatecas, San Luis Potosí, Baja California Norte, Jalisco, Guanajuato, Chiapas, Sonora and Quintana Roo (Table 1).

Table 1. Megawatts generated per state

State	Megawatts generated
Oaxaca	2,758 MW
Tamaulipas	1,715 MW
Nuevo Leon	793 MW
Coahuila	397 MW
Baja California Norte	303 MW
Puebla	287 MW
Yucatan	244 MW
Zacatecas	230 MW
San Luis Potosi	200 MW
Jalisco	179 MW
Guanajuato	105 MW
Chiapas	49 MW
Sonora	2 MW
Quintana Roo	1,5 MW

Source: Mexican Wind Energy Association (AMDEE).

2.3. Tamaulipas and onshore wind industry

In the state, there is the Tamaulipas Energy Commission (CETAM by its acronym in Spanish) which is a Decentralized Public Organism of the State Government created through the Government Decree published in the Periodico Oficial del Estado on February 17, 2017, with its own legal personality and assets, which aims to establish policies, strategies and guidelines that contribute to the development of non-renewable energy and the use of renewable energy in Tamaulipas, to objectively contribute to the State Development Plan and its goals within an energy regulatory framework as sector coordinator (Tamaulipas, 2022). According to its information in Tamaulipas there are 13 onshore wind farms in operation and 2 onshore wind farms under construction, with a total

Table 2. Wind Farms in operation in Tamaulipas, Mexico

Number	Name	Place	A.C. * (MW)	Wind Turbines
1	El Porvenir	Reynosa	54	30
2	Victoria	Guemez	50	15
3	La Mesa	Guemez	50	15
4	Tres Mesas Fase 1	Llera/Casas	63	23
5	Tres Mesas Fase 2	Llera/Casas	85	22
6	El Cortijo	Reynosa	183	61
7	Reynosa	Reynosa	424	123
8	Salitrillos	Reynosa	100	30
9	Tres Mesas Fase 3	Llera/Casas	50	50
10	Vicente Guerrero	Guemez	118	33
11	Mesa La Paz	Llera/Casas	300	85
12	Tres Mesas Fase 4	Llera/Casas	95	24
13	Santa Cruz	Reynosa	138	60

* Authorized Capacity

Source: Tamaulipas Energy Commission (CETAM).

Table 3. Wind Farms under construction in Tamaulipas, Mexico

Number	Name	Place	A.C. * (MW)	Wind Turbines
1	San Carlos	San Carlos	198	No information
2	Declaro	Reynosa	117	No information

* Authorized Capacity

Source: Tamaulipas Energy Commission (CETAM).

authorized capacity of 2025 MW and an investment of $3,088.00 million dollars. These farms are installed mainly in the municipalities of Reynosa, Llera de Canales, Guemez and San Carlos (Table 2) (Table 3) (Tamaulipas, CETAM/UPVI/DGP/2019/128, 2020).

3. TRENDS AND DEVELOPMENT

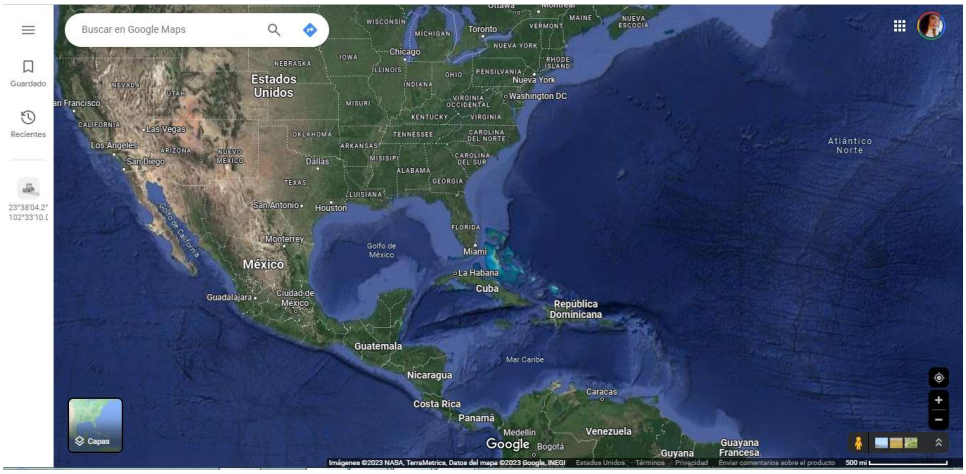
Onshore wind energy was considered as one of the most precious renewable energy sources globally as of 2020. Although it must be taken into account that the offshore wind sector has been gaining ground in the wind energy market and is expected to experience significant growth in the near future. The Asia-Pacific region is one of the most consolidated and competitive in the wind energy market, with a large participation from China and India, and it is considered that the development of new projects in the wind power sector will continue to drive growth in the region. The emerging markets of Africa and South America present a strong commercial opportunity for wind power project operators and equipment suppliers, as countries like Brazil, South Africa, Chile, etc., are leading the industry. Here it is worth noting the important moment that Brazil is experiencing with its wind energy revolution and all the conditions that are being created to continue favoring its development (Intelligence, 2023).

A survival necessity is to develop supply chains that are more resilient (and also value chains, which will be addressed in this study later), able to cope with disruptions as they arise, a key global supplier that supports the entire value chain and adds innovation, designs and more advanced technology. In other words, countries seek a reconfiguration in the value chain. Commercial trends such as nearshoring are also present in the wind energy industry, seeking commercial exchanges with countries closer to the country of origin and with them reduce costs, increase sources of employment in the region and prevent future disruptions such as the recent case. of the 2020 pandemic (Feinberg, 2022).

Mexico has extremely attractive territories for wind energy, located between latitudes 14°N and 33°N and longitudes 86°W and 119°W. Therefore, the industry is expected to present a CAGR of more than 8% within the period between 2020-2025, in the same way a growth of more than 25% of installed capacity was expected due to the implementation and consolidation of new projects, in addition that the costs of the technologies used for renewables in general are showing a decrease, however, the absence of initiatives and public policies that favor the sector have hindered progress in the Mexican market (Drawing 4) (Intelligence M., 2022).

However, for the northern region of the country, specifically the state of Tamaulipas, it is considered that it has a wind potential equivalent to 38% of the country's effective electricity generation capacity (Economista, 2019). On the other hand, this region has been object of estimation due to its natural characteristics, its geographical position with respect to the Gulf of Mexico and for the interest that arouses the be close to producer states wind

energy in the United States special with Texas who is the eldest producer in that country (Drawing 5) (Perales, García, Mata, 2021).



Drawing 4. Mexico location

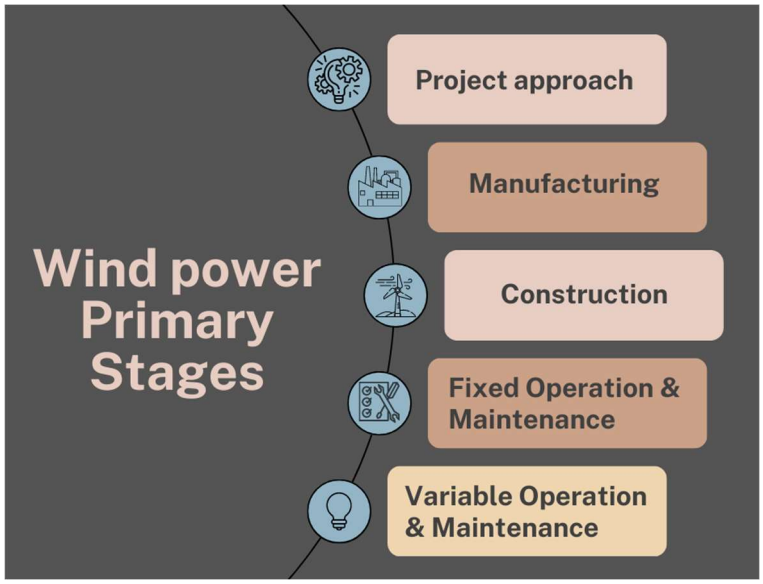
Source: Google Maps.

Drawing 5. Onshore wind farms

Source: Cluster Internacional de Energía Tamaulipas-Texas.

In the same way, another fundamental aspect to consider is the structure of the value chain within the wind energy industry (as noted about supply chain) which comprises two large sectors: manufacturing, and services and civil works (Martínez Mendoza, 2018). And five primary stages can be identified that give rise to a series of secondary activities, but of vital importance to develop a successful project and are mentioned below (Drawing 6) (Carbono, 2016):

- Project approach.
- Manufacturing.
- Construction.
- Fixed Operation and Maintenance.
- Variable Operation and Maintenance.



Drawing 6. Wind power, Primary stages

Source: Coordinación General de Cambio Climático y Desarrollo Bajo de Carbono.

Focusing on global value chains allows specifying the functions performed by each element and company involved in the development of any industry (Parrilli, Álvarez, Elola, Lorenz, Rabellotti, 2012), the impact it has on the sector and the trends that may arise in the future and that is why they are considered for this study.

In the case of Mexico, in 2016 (Carbono, 2016), 63 companies were reported involved in activities for any of the five stages of wind projects, approximately half of these companies have been identified as national, however, the participation of foreign companies is large, in which those of Spanish, German and Italian origin. To date, Mexico does not have a manufacturing of wind turbines, however, a certain number of companies have national manufacture of components such as generators, blades and, mainly towers. In this sense and more precisely, it is pointed out that in Mexico the following is carried out (Promexico, 2021):

- Manufacture of generators by the companies Potencia Industrial, a 100% Mexican company located in the center of the country, designs and manufactures motors and electric generators with a high level of efficiency for special applications, produces wind generators for Clipper, Vestas and Gamesa turbines with more than 3000 MW of installed capacity; and the company Dynamik Kontroll located in Guadalajara Jalisco.
- Manufacture of towers the companies Trinity Industries, Tubac, CS Wind and Speco, are producing steel towers for the Mexican wind market.
- Manufacture of blades, started with the company Mitsubishi Heavy Industries de México, S.A. de C.V. in Ciudad Juárez for export to the United States wind market. The Vientek company (a joint venture between Mitsubishi and TPI Composites) also started with the production of blades for turbines. And currently in the country there are 5 blade manufacturing plants by TPI Composites, 4 located in Cd. Juárez, Chihuahua and one in Matamoros Tamaulipas, whose region is the object of this study, and a plant by the Nordex Acciona company in Matamoros, Tamaulipas.
- Other components for wind energy the companies Kaydon and Liebherr manufacture bearings and bearings for wind energy.

In summary, for this article, the current trends of the wind energy industry and the development of the sector were considered from three approaches: infrastructure: identifying the onshore wind farms that exist in Mexico and specifically in the Tamaulipas region, the investment that The sector has been injected, in second place with respect to the supply chains, in relation to the resilience and adaptability that they must develop and finally the value chains that need to be launched to consolidate the activities necessary for the industry to continue operating.

4. METHODOLOGY

Theoretical and empirical methods such as analytical-synthetic and inductive-deductive were used to collect information on the current situation, statistics and data related to the development of the onshore wind energy industry as well as the trends and challenges it presents using primary sources. such as the request for data through an official request to the commission in charge of the sector in the state of Tamaulipas, Mexico and secondary sources such as databases or magazines, to proceed with the respective analysis on this.

The purpose of the study was taken into consideration to carry out a bibliographic review of the most relevant reports, articles, reports and authors to obtain adequate information that provides a relevant research work. Scientific articles were studied through digital libraries and repositories such as: ScienceDirect, JournalsRAS, etc. this in order to obtain a holistic structural and operational overview of what this sector represents in the region and its impact on the country and the world.

5. RESULTS AND MAIN CONTRIBUTION OF THE PAPER

The purpose of this work is to project a general panorama of the wind energy industry, starting from a global context to end in the northern region of Mexico, in the state of Tamaulipas, because this is the second most developed state in the country. in the sector and with great growth potential, it has a privileged geographical location and its proximity to the United States of America is a determining factor for attracting foreign investment. Included in this study are the main trends that accelerated during and after the 2020 pandemic.

The year 2020 was very particular and with many challenges, but the wind industry is not only resilient but also necessary for the development of a more sustainable and green energy generation and that contributes to the Sustainable Development Goal 7 Ensure access to affordable, reliable, sustainable, and modern energy for all. The most favorable strategies for this industry could be summarized as: fair policies and a regulatory framework by governments for a real and constant industry growth and better grid connection in the current, emerging, and new markets, that is mean, invest in infrastructure and plan transmission. However, the following trends that could mainly be observed for the coming years are:

- The global wind industry outlook remains positive, expecting to reach almost 4 percent average growth per year until 2025, according to the Global Wind Report 2020.
- As stated in the International Energy Agency report "Renewables 2020", delayed projects in Europe (especially in France, Germany, Sweden, and the Netherlands) are expected to accelerate to onshore wind capacity additions in 2021 as well as faster growth in India and Latin America.
- Decreasing costs and favorable policies are expected to be the main support of wind industry deployment in the next five years.
- New technologies in wind turbine design and supply chain management are expected to help increase market development opportunities.

The most relevant results, regarding infrastructure approach, Tamaulipas found that there are 15 active wind projects: 2 in its construction phase or about to start works and 13 in operation. It mapped your location and established a pattern, in where most of the parks are concentrated around Ciudad Victoria and Reynosa, which represents an investment of $3.088 billion from Spain, Italy, France, Denmark and nationally. This allows the state to be in relation to the opportunities that could arise at the national level with respect to attracting investment from other countries.

Regarding the supply chain and value chain approach, there are operators such as:

1. Nordex Acciona, of German origin, coming from a global operator dedicated to clean energy, with more than 30 years of experience in the sector and presence in more than 20 countries on five continents; The Nordex Acciona plant located in Matamoros Tamaulipas is dedicated to the production of blades for wind turbines that are distributed throughout the country both in wind farms within the same state, as well as in Nuevo León, Jalisco and Oaxaca, the installation of said plant has four production lines, generates 800 direct jobs and had an approximate investment of 1,200 million dollars.
2. Tpi Composites, a global supplier of structural composites and the largest manufacturer of wind blades, headquartered in Scottsdale Arizona, United States, with operations in the US, Mexico, China, and Turkey. The plant in Tamaulipas is also located in the municipality of Matamoros, supplying product to the national territory.

This allows the State to be in relation to the opportunities that may arise due to commercial competitiveness with respect to supplies, processes and the entities involved.

And finally, it is worth mentioning the challenges that, in short, could affect any of the three approaches mentioned above:

- Legal certainty and respect for the law.

The energy sector is long-term, because it requires significant infrastructure that will operate for tens of years to provide a service to different types of users, and to recover investment in these projects, time is needed. For the development of infrastructure projects, it is important to be certain that the rules will not change over time, affecting the projections that the developments require to recover the investment made.

- Long-term visibility.

Given the long-term perspective of this sector, there must be a clear vision of long term that involves the creation of much more resilient and adaptable supply and value chains.

- Strengthening and expansion of the electrical network.

The economy constantly demands electricity and, to supply it, as well as to guarantee its availability in the future, it is necessary to invest in having a transmission and distribution network in accordance with current consumption needs and local and regional development expectations. Although electricity generation capacity has been growing hand in hand with more competitive investments and technologies, historically the network has grown at rates below the growth in demand.

- Rules and transparency in the market.

The market has a series of rules and manuals that govern its operation and that are available and apply to all participants. There is a natural evolution of said rules that should occur based on an open dialogue between the regulator, the electricity system manager and market participants. This would allow solving the problems identified in a timely manner, giving clarity and transparency to everyone about the changes, avoiding unduly favoring one participant over the others and benefit all consumers with quality, reliability, and competitiveness.

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