WIND ENERGY IN MEXICO: AN ANALYSIS OF THE TECHNICAL AND REGULATORY CHALLENGES

Luis Guillermo PINEDA BERNAL*

I. INTRODUCTION

There is currently no doubt about the direct relationship between burning fossil fuels and the phenomena of climate change and global warming. The global and local risks of ecosystem destruction due to the emission of greenhouse gases (GHG) and other pollutants emanating from burning fossil fuels produce externalities that directly affect society, which implies economic costs that are currently not included in the final cost of energy. The serious environmental and social effects of climate change have led the world towards a process of decarbonization through the so-called energy transition that seeks to reduce GHGs and make greater and more efficient use of renewable energies.

During the previous administration, Mexico sought to take on the role of global player committed to the fight against climate change and the reduction of GHGs. Within the framework of COP21[1] held in Paris, all the parties (countries) were invited to generate Nationally Determined Contributions or INDCs[2] as part of the so-called "Paris Agreement". Mexico has

* Ph.D. in Public Administration from Atlantic International University in the United States of America. Commissioner of the Energy Regulatory Commission.

[1] The Conference of the Parties (COP) refers to the annual Paris Climate Change Conference.

[2] Prior to the ratification of the Paris Agreement on November 4, 2016, the Nationally Determined Contributions were "intended", hence the name Intended Nationally Determined Contributions (INDCs).

actively fulfilled those commitments and set high goals for itself. To achieve the objectives proposed in its INDC,[3] the principal mitigation measures established in Mexico are to generate 35% of energy through clean sources by 2024, 43% by 2030 and 50% by 2050. For these goals, clean energy includes renewable sources, efficient cogeneration with natural gas[4] and thermoelectric plants with CO_2capture[5] to replace heavy fuels with natural gas, clean energies and biomass in the national industry; reduce methane leaks, venting and controlled flaring by 25%; and control black soot particles in industrial equipment and facilities.[6]

In addition, not only has Mexico pledged to fight climate change, reduce GHGs and use renewable energies, but it has also undertaken to attain universal access to electricity services. Currently, Mexico has a 98.75%[7] electricity coverage and, according to the Federal Electricity Commission, the remaining 1.25% are households that have no access to electricity services. Ensuring universal access to these services is also a goal of the United Nations.

The goal of universal access in Mexico is set out in Articles113, 114, 115, 116 and 166 of the Electrical Industry Law, which is the basis of the Universal Electric Service Fund and establishes that the federal government will promote the electrification of rural communities and marginalized urban zones.

One of the sectors most concerned with finding alternative sources of energy that lead to a reduction in GHG emissions is, precisely, that of electricity. Public policy in this area, technological development and the reduction of electricity generation costs using clean technologies have been especially important drivers for solar photovoltaic and wind energies.

In this global context that has led to the development of renewable energies, particularly wind and solar, governments have decided to intervene

[3] The Intended Nationally Determined Contribution of Mexico, available at: *http://www4.unfccc.int/submissions/INDC/Published%20Documents/Mexico/1/MEXICO%20INDC%2003.30.2015.pdf.*

[4] According to the description of the Electrical Industry Law to which the Energy Transition Law makes reference, this cogeneration is in terms of the efficiency criteria issued by the CRE and the emissions criteria established by the Ministry of the Environment and Natural Resources.

[5] This technology is also included in the LIE description.

[6] Gobierno de la República, *Compromisos de mitigación y adaptación ante el cambio climático para el periodo 2020-2030*, 2015, available at: *https://www.gob.mx/cms/uploads/attachment/file/162974/2015_indc_esp.pdf.*

[7] SEGOB, *Electrificación por Entidad Federativa*, Comisión Federal de Electricidad, 2018, available at: *https://datos.gob.mx/busca/dataset/electrificacion-por-entidad-federativa*.

more actively in the energy sector because electrical energy and grid reliability are seen as a public good, since access and supply empower communities and generally benefit them, reason enough to justify regulating the sector.

However, the nature of the electricity sector and the complexity of regulating it must be considered. Josefina Cortés and Eduardo Pérez Motta note that the particular features of these give rise to a process of capitalization and recovery of long-term investment, and even exhibit the presence of natural monopolies (as in the case of transmission and distribution networks) resulting in the need for a regulatory framework that operates under conditions of stability, transparency and with goals consistent with the characteristics of the industry.[8]

In a broad sense, we can speak of the need for State intervention through the creation of legal provisions drafted by competent government authorities, to regulate industry performance in terms of the public interest and social good. That is to say, we are talking about the need for regulation and its continuity as crucial to guaranteeing the investment already made in the sector, as well as for those projected for the future.

There are, however, different approaches to that of State Regulator. Jorge Martínez questions the role of the State in energy production, and particularly in promoting renewable energies.[9] He raises two possibilities that can even describe the dilemma the country is currently experiencing.

The first is the role of the State through minimal intervention where economic agents are allowed to act for themselves, that is to say that market forces are left to determine the participation of different types of energy in the sector —we could say based on the lowest prices and costs—. The second role is one in which the State is much more active and not only permits what is constitutionally and legally established, in this specific case, in the constitutional reform and secondary laws regarding energy, but also incentivizes energy production and energy use reduction through its public policies.[10] This discussion is, however, not the subject of this article.

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[8] Cortés Campos, Josefina and Pérez Motta, Eduardo, "Competencia económica y sector energético: los mercados de la electricidad y del gas natural", in Payan, Tony *et al.*, *Estado de Derecho y Reforma Energética en México*, México, Tirant lo Blanch, 2016, p. 199. On May 15, 2020, SENER publishes an updated document known as a "policy agreement", which describes changes to the functions performed by CRE, CENACE and CFE to increase the influence over those entities. This agreement is suspended by a federal judge at the request of federal competition regulator COFECE.

[9] Martínez, Jorge, *Política energética sustentable en México*, México, UNAM-Porrúa, 2017, p. 20.

[10] Recently, in April 2022, Mexican Chamber of Deputies rejected an initiative sent by President Andrés Manuel López Obrador, this initiative established a very active role from

The intent of this article is to present a brief analysis of the regulatory framework for renewable energies, particularly wind energy, as well as to identify the regulatory and technical challenges that this type of energy presents for Mexico. This analysis will delve into topics such as the integration of renewable energies into the electrical system grid, the problems posed by the intermittent nature of this type of energy, and the environmental and social challenges arising from the deployment of wind farms for generating electricity.

II. Renewable energies and the regulatory framework in Mexico

The search for diversification of the energy matrix has found renewable energies to be one of the best alternatives for sustainable development and growth, especially in a global scenario that tends towards greater electrification. From the perspective of this article and the new energy model, even its use contributes to achieving two essential pillars of the energy policy articulated by Mexico's new administration: energy security and sovereignty, powers that the Energy Ministry has under the current in Article 33, Section V of the Organic Law of the Federal Public Administration Law (LOAPF).[11] In that respect, Dr. Lorenzo Meyer argues that with the energy reform, the independence and sovereignty gained by the energy expropriation and nationalization will be lost, and the country will cease to be less of a State and will consolidate its dependence on the United States.[12]

International experience dictates that technology advances more rapidly than laws, and the case of technological development to harness renewable energies is no exception. For this reason, it is essential to have a regulatory framework that takes into account the inclusion of new technolo gies and provides the necessary incentives for the development, continuation and stability of the industry.

The energy model that arose from the 2013 constitutional reform defined a clear route to resuming growth in the electricity industry and is gen-

Mexican administration such as that electricity generation in Mexico may only have 46% private participation and the rest will be the obligation of the state-owned Federal Electricity Commission (CFE).

[11] Last reform published on November 30, 2018, in the *Diario Oficial de la Federación*.

[12] Meyer, Lorenzo, "Los referentes históricos de la electricidad y de los hidrocarburos en México (versión estenográfica)", in Cárdenas Gracia, Jaime (coord.), *Reforma energética. Análisis y consecuencias*, México, UNAM-Tirant lo Blanch, 2015, pp. 381-390.

erating elements for Mexico to regain its position as a global energy leader, through building competitive markets and a knowledge economy wedded to transparency and accountability.

From a public policy perspective, as Josefina Cortés and Eduardo Pérez Motta suggest, the diversification of energy sources should be encouraged in the electricity sector, ensuring that economic regulation enables the different actors to compete pricewise with the use of different technologies,[13] including those with variable output throughout the day, like wind energy and its intermittent supply.

Alberto Montoya Martín del Campo, former undersecretary of energy and current Commissioner of the National Commission for Regulatory Improvement, argued at the time that with constitutional energy reform, Mexico would lose its independence and sovereignty and even be subordinated to the interests of the United States. In addition, he noted that the changes would lead to energy dependency and the economy would end up in the hands of transnational companies in the sector.[14]

It is worth noting that the new administration is currently focusing its energy policy more in line with the old model. An example of this approach is Raúl Armando Jiménez Vázquez's analysis, in which he describes it as a "regressive regulatory change that led to the dispossession of the Nation's historical rights over the energy assets of Mexicans, in order to transfer them to private investors".[15]

1. *Transition within the Regulatory Framework*

From its creation in 1937 and the enactment of the Electrical Industry Law in 1938, the Federal Electricity Commission (CFE) was under the exclusive control of the State as the sole provider of public electricity. This situation was fully consolidated in 1960 with the nationalization of the electrical industry as part of the growing State intervention in the sector.

Later and under Article 3 of the Public Electricity Service Law (LSPEE) published on December 22, 1975 —which repealed the above-mentioned Electrical Industry Law—, it was established that the generation of electric-

[13] Cortés Campos, Josefina and Pérez Motta, Eduardo, *op. cit.*, p. 200.

[14] Montoya Martín del Campo, Alberto, "Reforma Energética: Golpe de Estado contra la Constitución. Traición a México", in Cárdenas Gracia, Jaime (coord.), *Reforma energética. Análisis y consecuencias*, *cit.*, p. 285.

[15] Jiménez Vázquez, Raúl Armando, *Valoración constitucional de la Reforma Energética*, Mexico, UNAM, 2016.

ity for self-supply, cogeneration or small production; generation by independent producers for sale to the CFE; and generation for export, derived from cogeneration, independent production or small production, among others, not considered public service activities.[16] Amendments to the LSPEE on December 22, 1992, allowed for the participation of the private sector through the figure of Independent Energy Producers, known as PIEs.

Against the backdrop of these regulatory changes, it is important to note the creation of the Energy Regulatory Commission (CRE) a year later, on October 4, 1993, which at that time emerged as a decentralized administrative body of the then Ministry of Energy, Mining and Parastatal Industries (now the Energy Ministry). The creation decree set out that the CRE would be the technical body responsible for resolving issues on electrical energy arising from the application of the regulatory provisions of Article 27 of the Constitution.

By 2013, the CFE was still the State electricity monopoly although its role had been limited by the reforms of the 1990s that allowed private interests to participate in electricity generation in various legal ways: independent energy producer, cogeneration and self-supply.[17] The LSPEE and its most recent amendment[18] state that these new generators must be authorized by the CRE and are empowered to generate electricity for sale exclusively to the CFE.

The legal framework on renewable energies was structured and strengthened in 2008 when the Mexican Congress passed three laws on the issue: the Law for the Use of Renewable Energies and the Financing of the Energy Transition (LAERFTE),[19] the Sustainable Use of Energy Law, and Law on Promotion and Development of Bioenergy.[20]

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16 Cámara de Diputados, Ley del Servicio Público de Energía Eléctrica, *Diario Oficial de la Federación*, December 22, 1975.

17 The figure of self-supply will gradually disappear over the following years, as its Legacy Interconnection Contracts expire, in accordance with current legislation. However, this has been the subject of discussion in recent years due to various regulatory and legal changes aimed at limiting its scope, and even revoking the issued permits in advance. This is evidenced by different CRE resolutions issued in May and October 2020, the reform to the LIE approved in March 2021, as well as the recently rejected constitutional Energy Reform initiative.

18 Cámara de Diputados, Ley del Servicio Público de Energía Eléctrica, *Diario Oficial de la Federación*, December 22, 1975.

19 Cámara de Diputados, Ley para el Aprovechamiento de las Energías Renovables y el Financiamiento de la Transición Energética, *Diario Oficial de la Federación*, December 28, 2008.

20 Cámara de Diputado, Ley de Promoción y Desarrollo de los Bioenergéticos, *Diario Oficial de la Federación*, February 1, 2008.

The goal of the LAERFTE was to regulate the use of renewable energy sources and clean technologies to generate electricity for purposes other than provision of a public service, as well as to establish a national strategy and instruments to finance the energy transition, as well as to define renewable energies in Mexico as defined in its Article 30, Section II. The Law for the Sustainable Use of Energy[21] contained only 33 clauses and, in its first article, established its objective of promoting the sustainable use of energies by optimizing their use in all processes and activities.

Finally, in 2013, the constitutional energy reform and its respective secondary laws complemented and formalized the opening of the electrical industry that had begun in the 1990s and modified the role of the State as the sole buyer and generator. As a result, the new 2014 Electrical Industry Law (LIE) regulates Articles 25, fourth paragraph; 27, sixth paragraph; and 28, fourth paragraph of the Political Constitution of the United Mexican States (CPEUM).

Full legal certainty for private investment was granted by definitively eliminating from the constitution any reference to State monopoly over the generation, distribution and supply of electrical energy intended for "providing a public service", leaving the nation only with strategic control over planning and control over the national electrical system, and over the public services of transmission and distribution of electricity, deregulating the generation of electricity, with the exception of generating it through nuclear energy.

This opening of the electricity market, together with the clean energy goals to which Mexico has committed itself in the international arena, have led to an accelerated development of renewable energies, especially because of the economic incentives such as the electricity auction schemes in tandem with the best international practices,[22] that have resulted in the lowest electricity prices globally, without forsaking the great potential the country has.

Within the framework of the 2013 constitutional reform, which was published by decree on December 20 of that same year, the 17th Transitory

[21] Cámara de Diputados, Ley para el Aprovechamiento Sustentable de la Energía, *Diario Oficial de la Federación*, November 28, 2008.

[22] On February 2019, the National Center for Energy Control (CENACE) canceled the 2018 Long-Term Auction (SLP-1/2018), which had been suspended since December 3, 2018. As indicated by the Ministry of Energy (SENER), the need to proceed with the cancellation of SLP-1/2018 was carried out in compliance with the current legal framework and technical, economic and energy planning considerations.

Article of the CPEUM stated that the amendments to the legal framework should establish the bases upon which the State would seek the protection and care of the environment in all processes related to the scope of the decree in question, among others, in terms of reducing the generation of greenhouse gases (GHGs) and compounds.

In 2014 the LIE was approved and in 2015 so was the Energy Transition Law (LTE), which repealed both the LAERFTE and the Sustainable Use of Energy Law. Its goal, set out in the first article, is "to regulate the sustainable use of energy as well as the obligations related to clean energies and the reduction of polluting emissions of the Electricity Industry".[23] This law continues the same guidelines mapped out in the laws it repeals since the idea of a Transition Strategy to Promote the Use of Cleaner Technologies and Fuels is considered programmatic and organic and leads to a National Program for the Sustainable Use of Energy and a Smart Electrical Grid Program.

The LTE defines renewable energies as those whose source resides in natural phenomena, processes or materials that can be transformed into usable energy for humans, that regenerate naturally and are available continuously or periodically and that do not emit pollutants when generated.[24] Renewable energies recognized by Mexican legal framework are wind, solar, geothermal, hydroelectric, tidal and bioenergy.

Different countries have different definitions and categories of renewable energies, although they do not diverge much from one another. The U.S. Energy Information Administration defines renewable energy as that arising from sources that are naturally replenishing but flow-limited; they are virtually inexhaustible in duration but limited in the amount of energy available per unit of time.[25] Additionally, biomass,[26] ethanol, biodiesel, hydroelectric, and geothermal, wind and solar energy are all considered renewable energies.

With regard to strict technical and economic regulation, the 17th transitory article of the CPEUM mandates that on the issue of electricity, the law will establish clean energy and polluting emission reduction obligations for those participating in the electricity industry. In this sense, Chapter V of the

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23 Cámara de Diputados, Ley de Transición Energética, *Diario Oficial de la Federación*, December 24, 2015.

24 Cámara de Diputados, Ley de Transición Energética, *op. cit.*

25 IEA, *Renewable Energy Explained*, U.S. Energy Information Administration, 2018, available at: *https://www.eia.gov/energyexplained/?page=renewable_home.*

26 This includes wood and wood waste, municipal solid waste, landfill gas and biogas.

Fourth Title of the LTE refers to Clean Energy Certificates[27] (CELs), stating in Article 68 that "with the goal of encouraging growth in Clean Energies referred to in […] Law and under the terms set out in the Electrical Industry Law, [SENER] will establish prerequisites for acquiring Clean Energy Certificates",[28] which, in accordance with Article 3rd, Section V of the same law, names the CEL as the title granted by the CRE in compliance with the guidelines of the LIE.

2. *Renewable Energies Development Potential for Mexico*

To date, it can be affirmed that Mexico has a solid legal and regulatory framework that allows strengthening and expanding the use of renewable energy to generate electricity. In spite of this, it must be noted that the renewable resources are not evenly distributed across the nation and are located in areas without infrastructure due to their topographical characteristics or due to possible social conflicts, making it difficult or technically and/or economically impractical to develop renewable energy projects.

José Juan González points out that it was not until recently that non-traditional energy sources such as wind power began to be used. He rightly adds that consequently, the judicial framework in this field is also young, which means it needs to be strengthened to accelerate the use of more environmentally friendly energy sources.[29] However, the regulatory framework just analyzed provides an important foundation upon which to develop these energies.

The geographic characteristics of Mexico mean that there is significant potential renewable energy, specifically in the case of wind power. According to INERE, Mexico has a proven wind generation potential of 25, 104 GWh annually and possibly 87,600 GWh per year.[30] Currently, Mexico has 45 wind power plants with an installed capacity of 4, 199 MW, or 6% of the total installed capacity.

An example of this great potential and growth is the Reynosa wind farm which, once finished, will be the largest in Latin America and with

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27 On October 28, 2019, the Ministry of Energy issued a regulatory change in the Official Gazette of the Federation (DOF) regarding the recognition criteria for CELs for generators. This change implies that a good number of clean power plants that have come into operation before the Reform will also be able to accredit CELs.

28 Cámara de Diputados, Ley de Transición Energética, *op. cit.*

29 González, José Juan, *Nuevo derecho energético mexicano*, México, UAM, 2017, p. 298.

30 SENER, *Inventario Nacional de Energías Renovables*, México, SENER, 2017, available at: *https://dgel.energia.gob.mx/inere/*.

a capacity up to 424 MW. Wind farms in Mexico contributed with 10,620 GWh or 3% of the total national power generated in 2017.[31]

In comparison, Figure 1 shows information from the 2017 Global Wind Energy Council report, which depicts the worldwide cumulative wind generation capacity for that year.

According to the Mexican Wind Energy Association (AMDEE) by contrasting several methodologies it was possible to quantify Mexico's technical and economic wind energy potential, for which an installation goal of 12,000 MW was set for 2020,[32] although it is mentioned that it could be higher. It should be noted that the auctions held in Mexico reached extremely competitive prices, demonstrating the economic feasibility of implementing wind projects in the country.

The countries with the largest installed capacity in wind farming are China, the United States of America, Germany, Spain and the United Kingdom, with which they produce 65% of the world's wind energy. These countries, too, have the highest percentage of research and knowledge generation regarding wind power generation and wind farm integration into the electricity system. Mexico is among the top 20 countries with the highest wind power generation.

According to data from the Renewable Energy Policy Network for the 21st Century (REN21), China, the United States and Germany are at the top of the list in terms of total clean generation capacity.[33] By the end of 2016, more than 90 countries were developing wind energy projects and, in the same year, at least 24 countries were meeting 5% or more of their annual electricity demand with wind energy and at least another 13 were covering more than 10% of their yearly demand.[34] According to the *Wind in Power 2017* report, Spain, Germany, and the United Kingdom accounted for 58% of Europe's accumulated wind energy installed capacity.[35]

31 SENER, *Programa de Desarrollo del Sistema Eléctrico Nacional*, México, SENER, 2018, available at: *https://www.gob.mx/cms/uploads/attachment/file/331770/PRODESEN-2018-2032-definitiva.pdf.*

32 AMDEE, *El potencial eólico mexicano. Oportunidades y retos en el nuevo sector eléctrico*, available at: *https://www.amdee.org/Publicaciones/AMDEE-PwC-El-potencial-eolico-mexicano.pdf.*

33 REN21, *Renewables 2018. Global Status Report*, Renewable Energy Policy Network for the 21st Century, 2018, available at: *http://www.ren21.net/wp-content/uploads/2018/06/17-8652_GSR2018_FullReport_web_-1.pdf.*

34 REN21, *Avanzando en la transición mundial hacia la energía renovable,* Renewable Energy Policy Network for the 21st Century, 2017, available at: *http://www.ren21.net/wp-content/uploads/2017/07/17-8399_GSR_2017_KEY-FINDINGS_Spanish_lowres.pdf.*

35 WindEurope, *Wind in Power* 2017. Annual combined onshore and offshore wind energy statistics, 2018, available at: *https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2017.pdf.*

The use of this renewable resource has spread rapidly throughout the world. The World Energy Outlook 2017 says that in 2016 alone generation assets based on renewable energy sources accounted for two-thirds of new capacity investment[36] worldwide. To transfer this technology to new markets, the theoretical knowledge and practical experience accumulated by the most advanced countries in this field are required.

In the field of wind energy, new markets continue to be opened across the globe and technological innovation is enabling accelerated development. The auction schemes adopted in several countries to boost renewable energies have been successful, as in the case of Mexico. Nevertheless, to avoid negative consequences when implementing winning projects, it is essential that there be a link between regulation, planning and the formulation of industrial development policies.

III. Technical challenges in incorporating wind energy into the electrical grid

1. *Problems in the electricity grid associated with wind generation*

As mentioned before, wind generation has grown rapidly in importance as a means of producing electrical energy given that, although distinct from other conventional means and intermittent in nature, it is compatible with the current design of electricity systems. Now that private players can participate in generation, it is important to analyze the challenges and obstacles that they may face in Mexico.

One of the most important challenges of wind energy is its variability —intermittency— and uncertainty of the primary source of the energy.[37] Due to this uncertainty, wind energy generation entails operational problems in the delivery of electricity which could reduce the reliability of the electricity system, which is why electrical energy companies in countries such as the United States, Spain, China and Denmark, among others, are cooperating to find a solution to these problems.[38] To date, one of the alternatives proposed in different electricity markets globally is an energy backup through storage, a subject that will be discussed later.

[36] OECD and IEA, *World Energy Outlook 2017*, International Energy Agency, 2017.

[37] Smith, J. C. *et al.*, *Utility Wind Integration and Operating Impact Sate of the Art*, IEE Transactions on Power Systems, vol. 22, núm. 3, 2007.

[38] Smith, J. C. *et al.*, *Wind Power Impacts on Electric Power System Operating Costs: Summary and Perspective on Work to Date*, NREL, 2004.

To help with alternative solutions to these challenges, several countries have established "Grid Codes" (Mexico included), which can basically be understood as a technical interpretation of national laws to create regulations, standards and minimum technical requirements for the interconnection of power plants (including wind farms) and loads on electricity grids.[39] In Mexico, the current Grid Code was issued by the Energy Regulatory Commission in 2016.[40]

Abrupt departures from a large load center cause over or under voltage surges in the grid. Conventional power plants are perfectly capable of buffering these transient conditions (up to certain limits). However, wind turbines do not do so naturally, although techniques that can help them do so already exist.

In Mexico, in Sections 4 and 5 of the Regulatory Manual of Technical Requirements for the Interconnection of Power Plants to the National Electricity System, the Grid Code contemplates the regulation of asynchronous power plants —those whose rotation speeds are not coupled to the electrical frequency of the system (60Hz in Mexico) and of which much of the wind power technology is a part— therefore obliging them to support the recovery of the electrical system in case of imbalances in the grid caused by load or generation variations.[41]

Many studies on the effect that connecting wind farms has on the reliability of the system to which they are connected have already been published.[42] Methods have also been analyzed to study the operational impact of the interconnection of wind generation on the grid,[43] as well as how it influences the quality of the grid's energy,[44] understanding energy quality as the minimum standard that the electrical energy supplied to the user must meet in terms of voltage level, frequency and availability, among other things.

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39 Ackermann, Thomas, *UWIG Short Course on the Integration and Interconnection of Wind Power Plants into Electric Power Systems, Session 10, Grid Codes*, 2009, pp. 14-17.

40 Comisión Reguladora de Energía, "Disposiciones administrativas de carácter general que contienen los criterios de eficiencia, calidad, confiabilidad, continuidad, seguridad y sustentabilidad del Sistema Eléctrico Nacional: Código de Red, conforme dispone el artículo 12, fracción XXXVII de la Ley de la Industria Eléctrica", *Diario Oficial de la Federación*, December 31, 2021.

41 Código de Red, conforme dispone el artículo 12, fracción XXXVII de la Ley de la Industria Eléctrica, *op. cit.*

42 Larsson, Åke, *Power Quality of Wind Turbine Generating Systems and their Interaction with the Grid, Technical Report No. 4R,* Chalmers University of Technology, 1997.

43 Parsons, B. *et al.*, *Grid Impacts of Wind Power: A Summary of Recent Studies in the United States*, European Wind Energy Conference and Exhibition, 2003.

44 Bialasiewicz, J. T. and Muljadi, E., *The Wind Farm Aggregation Impact on Power Quality*, 2nd Annual Conference of the IEEE Industrial Electronics Society (IECON'06), 2006.

All these analyses have led to successful integration of these technologies in different electrical systems around the world. Although it has its peculiarities that distinguish it from other systems, the Mexican one is no exception. In general, the impact that wind power generation has on the electrical system to which it is connected can be divided into global impact (in the system as a whole, the National Interconnected System, in the case of Mexico) and the local effect (on the electrical installations close to the interconnection node of the wind farm).[45]

A. *Global impact on the grid*

Connecting wind generation sources has an effect on the overall grid in aspects like voltage stability, which can be compromised. Since wind turbine construction is different from that of conventional generators and reacts differently to disturbances that may occur in the electrical grid, it can alter the voltage level to the point of exceeding the Grid Code parameters established in Section 2.2.2 of the Regulatory Manual of Operating States of the National Electricity System.[46]

Countries such as the United Kingdom, Germany, Denmark, Australia, Ireland, the United States and Belgium already have their grid codes. Although the specifications of these codes vary significantly in form and detail,[47] there are several common elements to them:

Low Voltage Ride Through (LVRT).

Power factor, most grid codes agree to maintain a power factor of ±0.95.[48]

Providing data to the grid operator, which implies the inclusion of SCADA systems, *i. e.*, supervisory control and data acquisition to monitor wind farms.

B. *Local impact on the grid*

In the vicinity of a wind farm, this type of generation can mainly impact the following aspects:

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45 Anaya-Lara, Olimpo *et al.*, *Wind Energy Generation: Modelling and Control*, John Wiley & Sons, Ltd, 2009.

46 Código de Red, conforme dispone el artículo 12, fracción XXXVII de la Ley de la Industria Eléctrica, *op. cit.*

47 Ackermann, Thomas, *op. cit.*, pp. 115-142.

48 Johnson, Gary L., *Wind Energy Systems*, Manhattan, KS, 2001.

> Increase in voltage level. This phenomenon is typically associated with variable speed wind turbines, which have electronics associated with local increases in voltage level. These increases are mainly due to the fact that the electronic components that make up the turbines can produce an effect known as harmonic distortion, which is a modification of the sinusoidal waveform of electrical voltage or current. This alteration can cause voltage increases. Another case of voltage increases that can occur in the presence of harmonic distortion and that can cause many problems is the case of wind generators installed at sea, far from the coast (offshore).[49]
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> Protection strategies. Protection strategies aim to safeguard the integrity of operating personnel, as well as the devices connected to the electrical system in the event of failure. Normally, the protection device is an integral part of the turbine control system.

Due to the sensitivity of the electronic devices installed in the wind turbines, they must be disconnected quickly from the grid if there is a failure that causes a current surge, so as not to damage these devices. This could become a problem if the applicable guidelines established in the Grid Code need the turbine to remain connected for a certain period of time in the event of a failure,[50] as established by in Section 5 of the Regulatory Manual of Technical Requirements for the Interconnection of Power Plants to the National Electricity System of the Mexican Grid Code.[51]

Currently, wind turbine technology makes it possible to comply with the provisions of the Grid Code without damaging damage the equipment. This is an example of how technology can also evolve to comply with regulations.

2. *Pending regulatory issues. Energy storage*

The variable, intermittent and difficult (though not impossible) to predict nature of the wind resources used today to generate electricity means that energy storage systems are being considered as a response to power fluctuations (and the well-known problems of quality of energy delivered) that, as a result of the variability of the resource, can occur at the interconnection points of the generating plants that are considered clean. This

[49] Johnson, Gary L., *op. cit.*

[50] Smith, J. C. *et al.*, *op. cit.*

[51] Código de Red, conforme dispone el artículo 12, fracción XXXVII de la Ley de la Industria Eléctrica, *op. cit.*

phenomenon could spread throughout the electricity grid increasing the number of the affected elements and users.

We must remember that, from a very simple perspective, a transmission system carries energy through physical space; that is, it supplies energy where it is needed, moving it from where it is abundant to where it is scarce. Conversely, an energy storage system (understood here to mean any system that stores energy in electromagnetic, electromechanical, kinetic, chemical or any potential form that can be later released as electrical energy) supplies energy when needed; that is, moving it in time from when it is abundant to when it is scarce.

Transmission has been considered a part of the value chain of the electrical industry since the market was conceived; storage is beginning to be a part of this value chain in several electricity markets around the world, and Mexico should consider including storage in its regulations, not only technical, but also economic, if it intends to efficiently achieve its goal of 35% penetration of clean energies in the National Electricity System. One of the regulatory challenges that storage raises is whether it is defined as a transmission, distribution or even generation asset.

We face a very important technical challenge, since clearly, integrating more than 30% of clean energy generation into Mexico's electricity system will have an impact on it, hence the need to prepare the way from a regulatory standpoint. In this sense, the Energy Regulatory Commission is already working on general administrative provisions on electrical energy storage[52] and on regulating auxiliary services that do not form part of the Wholesale Electricity Market.

IV. Administrative, environmental and social regulatory challenges

1. *Administrative processes and project location*

Long and complicated processes can be seen as obstacles or barriers for wind project developers to enter the market. These processes, generally related to the approval and scope of environmental and social impact assessments, local

[52] On January 29, 2019, the plenary session of the Energy Regulatory Commission approved the "Acuerdo por el que la Comisión Reguladora de Energía establece de manera enunciativa más no limitativa, los productos y los servicios que pueden ofrecer los integrantes de la industria eléctrica que desarrollen actividades de almacenamiento de energía".

land use permits, the number of players and authorities involved and issues such as social acceptance of the projects can even result in the death of a project. However, the issues of administrative processes and the location of wind projects are an area of opportunity for local governments to push the development of generation projects using this type of energy, aligning local legislation with federal objectives. Facilitating land use processes and institutionalizing planning for renewable projects can aid in generating greater social acceptance.

Cities around the world face economic, social and environmental challenges caused by the impact of global warming. In Mexico, local governments have no clear instruments to integrate their actions into the national goals of fighting climate change and increasing renewable energy generation. However, some of them have taken the initiative to introduce energy-related measures to address both the administrative and environmental challenges.

One such example is what happened in the states of Morelos and Sinaloa where certain laws were amended to regulate the operations of service stations (gas stations) and thus respond to the new regulatory framework on energy.[53] Morelos amended, among others, the Land-Use Planning and Sustainable Human Development Law and the Public Works and Related Services Law, while Sinaloa changed its Environmental Law and Urban Development Law.

In the same vein, Mexico has also seen progress at the local level with the creation of state energy agencies that seek to promote, attract and consolidate investment in their states, as in the cases of Tamaulipas, Veracruz, and Campeche.

2. *Wind project interconnection process for wind projects*

In Mexico, the administrative process for wind project interconnection has exposed some obstacles. The flexibility of the energy matrix, the proper functioning of the electricity market, the geographical distribution of wind resources, transmission capacity (including the issue of bottlenecks and the

[53] In the case of the state of Morelos, the Municipal Organic Law, the Ecological Equilibrium and Environmental Protection Law, the Land-Use Planning and Sustainable Human Development Law and the Public Works and Related Services Law were amended. In the case of the state of Sinaloa, amendments were made to the Environmental Law and the Human Development Law.

size of the control areas) are features that exert significant influence over the integration of wind energy generation into the grid.

Any electricity generating plant that intends to sell its energy to the Wholesale Electricity Market must pass through an interconnection process which, broadly speaking, consists of a request on behalf of the wind project to interconnect to the system operator, in this case, the National Energy Control Center (CENACE). This interconnection request is made once the project has already complied with issues such as project location, ensuring there are sufficient wind resources, and land use permits, among others.[54]

CENACE carries out various studies to determine if the project has the necessary characteristics for interconnection as well as if the proposed interconnection point is capable of receiving the energy coming from the turbines. If the existing conditions within the grid adjacent to the requested interconnection point are inadequate, CENACE must present the technical evidence proving the impossibility of interconnection and propose the necessary modifications or reinforcements in the grid, or suggest a new interconnection point so the project can be interconnected.

Among the criteria that establish the specific characteristics of the infrastructure required for interconnecting power plants and connecting load centers, Interconnection Studies are defined as the set of studies carried out to determine the necessary works for interconnecting a power plant.[55] CENACE may request reinforcement works; however, it is still unclear as to what can be considered technically and economically feasible works. This may extend the interconnection process beyond the original time estimates.

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54 On March 30, 2022, the Energy Regulatory Commission (CRE), through the Official Gazette of the Federation (DOF) issued the ["Acuerdo Núm. A/006/2022 de la Comisión Reguladora de Energía por el que se expiden las Disposiciones Administrativas de Carácter General (DACG) que establecen los términos para presentar la información relativa al objeto social, capacidad legal, técnica y financiera, así como la descripción del proyecto, y el formato de la solicitud de permisos de generación de energía eléctrica"], which requires, in the event of interconnection of the power plant, digitized original of the document issued by CENACE indicating the result of the Impact Study or quick version impact as appropriate with the procedure for the attention of the Request for Interconnection of Power Plants or Connection of Load Centers, among other new requirements. Available at: *https://www.dof.gob.mx/nota_detalle.php?codigo=5647325&fecha=30/03/2022#gsc.tab=0*.

55 Secretaría de Gobernación, "Criterios mediante los que se establecen las características específicas de la infraestructura requerida para la Interconexión de Centrales Eléctricas y Conexión de Centros de Carga", *Diario Oficial de la Federación*, June 2, 2015.

Among the recommendations collected by Ana Lilia Moreno,[56] is one proposed by José María Lujambio[57] in which he notes that although the regulatory framework has promoted, to some extent, the development of the renewable energy industry, there are still barriers hindering the complete adoption of these energies. Therefore, Lujambio continues, bureaucratic barriers must be urgently eliminated, in the areas of electricity generation permits and interconnection contracts.

In many electricity markets, the cost of grid access is considered a barrier to entry, a long interconnection process that generally goes hand in hand with an unnecessarily complex and inefficient administrative procedure. In the European Union, for example, the administrative cost associated with an *onshore* wind project represents on average 2.9% of the total, and for *offshore* projects, 14%.[58] In Mexico, streamlining the applicable regulation should be a priority to accommodate emerging projects and prevent administrative processes from becoming entry barriers to these projects.

3. *Environmental impact*

Although wind energy is presented as one of the best alternatives for reducing GHGs and replacing fossil fuels in electricity generation, if Environmental Impact Manifestation processes —for determining environmental viability— and Social Impact Assessment and their respective community consultations are not carried out correctly, wind projects can have negative impacts both socially and environmentally.

One example of the environmental impact is the noise produced by wind turbines, which is caused by four main factors: the first is the rotation of the turbine rotor; the second is the wind friction with the wind turbine support structure (nacelles, tower, etc.); the third is the turbulence produced in the air between the tower and the blade every time one of the blades passes near the tower; and fourth, the power train of the wind turbine.

This is an issue that has not been directly addressed in Mexico, but it is under discussion. It can be seen in Mexico that wind farms are located far

[56] Moreno González, Ana Lilia, "El nuevo marco jurídico y regulatorio del sector eléctrico mexicano: posibilidades de inclusión para PyMES", *Estado de derecho y Reforma Energética en México,* México, Tirant lo Blanch, 2016, p. 261.

[57] For more information see: Lujambio, José María, "Sobre la Agenda Verde", *Mexican Energy Law*, 2015, pp. 2, 13-18.

[58] EWEA, *Wind Barriers. Administrative and grid access barriers to wind power*, The European Wind Energy Association, 2010, available at: *http://www.ewea.org/fileadmin/files/library/publications/reports/WindBarriers_report.pdf.*

from residential areas, but it is expected that this will change in the future. Two examples of this possible problem are found in Wales and Scotland, two countries that have even regulated the distance between wind farms and residential areas in order to avoid noise pollution.

The World Health Organization recommends that for people noise exposure should be kept below 85 decibels (dB) for a maximum of 8 hours per day.[59] In Mexico, the wind turbines are found at an average height of 100 m, and a wind turbine operating at a height of 84 m generates 51.4 dB, compared to an airplane take-off, which emits 150dB, and a horn, 90 dB. Therefore, despite the debate around noise pollution from wind turbines, the noise levels found can still be considered permissible.

Another issue linked to environmental impact is the death of birds due to colliding into wind turbines. In December 2006, SEMARNAT published in the Federal Official Gazette (*DOF*) the Official Mexican Standard (NOM) project, PROY-NOM-151-SEMARNAT-2006,[60] which sets out the technical specifications for the protection of the environment during the construction, operation and abandonment of wind power installations in agricultural, livestock and wasteland areas. However, on February 19, 2014, the cancellation of PROY-NOM-151-SEMARNAT-2006 was published in the same medium because in response to comments received in the public consultation process, it was determined that more information was needed on synergistic and cumulative environmental impacts, as well as the monitoring of birds and bats and their migratory routes, in order to issue a regulatory instrument with the necessary environmental specifications. This same NOM project made reference to NOM-081-SEMARNAT-1994, which establishes the maximum permissible noise emission limits for fixed sources and their method of measurement. In this NOM, the maximum permissible noise level limits are 68 dB during the day and 65 dB at night.

It must be mentioned that no energy authority participated in drafting this last Official Mexican Standard. Neither this NOM nor any other has been taken up again, and if they were, energy agencies should be involved since the growth and development of wind energy in Mexico is on an upward trend.

Some of the above problems associated with conventional wind energy generation by using turbines with blades (horizontal axis), like the level of

[59] WHO, *Escuchar sin riesgos*, World Health Organization, available at: *http://www.who.int/pbd/deafness/activities/MLS_Brochure_Spanish_lowres_for_web.pdf.*

[60] Semarnat, PROY-NOM-151-SEMARNAT-2006, *Diario Oficial de la Federación*, December 28, 2006.

noise and visual pollution and environmental impact, as well as the maintenance costs of these machines, the effects that friction of the rotating components have on generator efficiency, and the mechanical fatigue the blades experience, have driven the technological development of new means for harnessing wind to generate electricity.

The result of this technological development is the vortex wind turbine, which consists of a linear generator (non-rotating) that uses permanent magnets and coils to transform the vibration produced by a pendulum made of a tube or hollow cone that vibrates in the wind.[61] This type of wind generator uses neither blades nor rotating elements (which lowers maintenance costs) and has been built and tested on a small scale at low heights (usually on building roofs),[62] making it ideal for microgrids in the distributed generation mode.

This relatively new technology has some disadvantages such as low efficiency, low power output levels, mechanical structure instability (which limits its ability to scale up to higher capacities) and noise.[63] Even so, in its current state of development, the technology qualifies for installation along highways and roads with heavy motor vehicle traffic or in places where the terrain is too limited for conventional turbines (on rooftops for example). However, in Mexico, according to CRE data, requests for interconnection of small and medium-scale wind power plants (all with capacities below 500kW), still do not exceed 0.024% in this power scale and interconnection mode. Solar technology continues to be dominant, as shown in Chart 2.

Another environment-related regulatory challenge are the issues in the Escazú Agreement,[64] access to information, public participation and access to justice on environmental matters. The aim of this agreement is to fight against inequality and discrimination, as well as to guarantee the rights of all people to a healthy environment and sustainable development. In addition, the agreement gives special importance to vulnerable people and groups.

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61 Salvador, C. S. *et al.*, "Design and Construction of Arc Shaped and Disc Shaped Pendulum for Vortex Bladeless Wind Generator", *2017 25th International Conference on Systems Engineering (ICSEng)*, Las Vegas, NV, 2017, pp. 363-369.

62 El-Shahat, A., M. Hasan and Wu, Y., "Vortex Bladeless Wind Generator for Nano-Grids", *2018 IEEE Global Humanitarian Technology Conference (GHTC)*, San Jose, CA, 2018, pp. 1 and 2.

63 Prasanth, V. *et al.*, "Green Energy Based Inductive Self-Healing Highways of the Future", 2016 IEEE Transportation Electrification Conference and Expo (ITEC), Dearborn, MI, 2016, pp. 1-8.

64 Adopted on March 4, 2018, in Escazú, Costa Rica.

The Escazú Agreement has an innovative approach, as it seeks to guarantee the "right to access", understood as the right to access environmental information, the right to public participation in environmental decision-making processes, and the right to access to justice in environmental issues. In Mexico, this continues to be an underexplored field and its regulation is almost non-existent. However, it should be considered that the rights to a healthy environment, sustainable development, and health protection, among others, have already been taken into account. If we consider that as defined by the National Commission on Human Rights (CNDH), human rights are "the set of prerogatives based on human dignity, whose effective implementation is essential for the full development of the person", we can also conclude that renewable energies provide a key element in the search to guarantee these rights.

4. *Social Impact*

Wind projects are more linked than ever to the issue of human rights. It is worth recalling that on June 11, 2011, the reform on human rights went into force. These rights, recognized in international treaties signed by the Mexican State, were elevated to constitutional rank, thus establishing "the State's obligation to promote, respect, protect and guarantee human rights; the universality, interdependence, indivisibility and progressiveness of rights".[65]

Mexico is a signatory to International Labor Organization (ILO) Indigenous and Tribal Peoples Convention No. 169 and the United Nations Declaration on the Rights of Indigenous Peoples. Both instruments speak of the right of indigenous peoples to be consulted and taken into account when making decisions that can affect their way and quality of life. Likewise, the General Assembly of the Organization of American States (OAS), to which Mexico belongs,[66] adopted Resolution 2888 on the Rights of Indigenous Peoples,[67] which has three key articles. Paragraph 1 of Article XIX on the right to protection of a healthy environment establishes that "indigenous peoples have the right to live in harmony with nature and to a healthy, safe,

[65] Constitución Política de los Estados Unidos Mexicanos, reforma de junio de 2016, available at: *http://www.diputados.gob.mx/LeyesBiblio/htm/1.htm.*

[66] Mexico voted in favor of this declaration.

[67] American Declaration on the Rights of Indigenous Peoples, approved on June 14, 2016, at the plenary session of the OAS, available at: *https://www.oas.org/es/sadye/documentos/res-2888-16-es.pdf.*

and sustainable environment, essential conditions for the full enjoyment of the rights to life and to their spirituality, cosmovision and collective well-being". As such, we see that Mexico has not only a commitment to guarantee a healthy environment in general terms, but also a very special obligation to indigenous peoples, which takes on special significance when conducting consultations.

The second article is XXV, which speaks of traditional forms of property and survival. Paragraph 4 of this article stipulates that States must give legal recognition and protection to these lands, territories and resources, within a framework of due respect to their customs, traditions and land tenure systems. Lastly, Article XXIX on the right to development establishes in paragraph 4 that "States shall consult and cooperate in good faith with the indigenous peoples concerned…".

The 2013 constitutional reform took up those principles and laid down some guidelines to guarantee the environmental and social viability of renewable projects. Articles 120 of the Hydrocarbons Law[68] and 119 of the Electrical Industry Law[69] state that SENER must implement the necessary free, prior and informed consultation procedures[70] in order to ensure that the interests and rights of the communities and indigenous peoples in whose territories energy sector projects are being developed are taken into account. The purpose of these consultation procedures is to reach agreements or, where appropriate, obtain the free, prior and informed consent of the indigenous peoples. Both secondary laws also establish the obligations of public and private infrastructure projects of the industry, in this case the renewable energy projects, to present a Social Impact Assessment (SIA) in the process of obtaining a permit or authorization to conduct a project.[71] This assessment must include the identification, characterization, prediction and assessment of the social impacts that could arise from proj-

68 Cámara de Diputados, Ley de Hidrocarburos, *Diario Oficial de la Federación*, August 11, 2014.

69 Cámara de Diputados, Ley de la Industria Eléctrica, *Diario Oficial de la Federación*, August 11, 2014.

70 The legal basis for the right to consultation is found in Articles 1 and 2 of the CPEUM; 6, 7 and 15 in ILO Indigenous and Tribal Peoples Convention No. 169; 1, 21 and 23 of the American Convention on Human Rights; 19 and 32, paragraph 2 of the United Nations Declaration on the Rights of Indigenous Peoples; Articles 119 of the LIE and 89, 90, 91 and 92 of the Regulations of the Electrical Industry Law, as well as Article 120 of the Hydrocarbons Law.

71 SENER, "Disposiciones administrativas de carácter general sobre la Evaluación de Impacto Social en el Sector Energético", *Diario Oficial de la Federación*, April 2018.

ect activities, as well as the corresponding mitigation measures and social management plans.

And so, José Juan González's observation stands out in the sense that energy reform not only sought to open up the sector to private investment, but also had the double goal of granting legal certainty to private investments by guaranteeing that landowners or organizations would not oppose the project and would make these players feel like part of the decision-making process,[72] applying all the mechanisms and based on the aforementioned international law issues. However, the challenge in Mexico remains great. Communities are burdened by various factors, including the issue of private property for developing renewable energy generation projects. The social, cultural and environmental consequences that wind generation projects present to these communities are a constant challenge in spite of the regulations and mechanisms established to carry out consultations and assessments that judge the feasibility of these projects.

There are instances of projects that successfully integrate the population through labor incentives and economic development for the community. There are also projects in which, despite having carried out prior and informed consultations, operations are halted or hindered for economic or political reasons in an attempt to obtain other incentives, different from those originally agreed upon. This has caused companies to mull over investment in some regions of Mexico.

There is also criticism on human rights aspects of the energy reform. Raúl Jiménez Vázquez, for example, argues that "the human rights of indigenous peoples to prior, informed and good faith consultations, established in Article 6 of ILO Convention 169 are restricted". However, as stated before, these rights are enshrined in several secondary laws of the reform.[73]

V. Conclusions

Legal certainty and the stability of a regulatory framework are some of the main concerns for investors. So, in this context, which seeks to promote the development of clean energies, the regulatory framework plays a crucial role in attracting new investments and achieving a significant level of penetration for this type of energy. The same regulatory framework with simple permit and interconnection processes and the removal of possible barriers to entry are essential to promoting the progress of such projects.

72 González, José Juan, *op. cit.*, p. 403.

73 Jiménez Vázquez, Raúl Armando, *op. cit.*, p. 40.

The standardization of local and federal laws is necessary as many of the energy projects are hindered by local legislation, whether municipal or state, particularly in the area of land use and collecting fees for construction licenses and their requirements, which can be very onerous and administratively complex due to time and compliance requirements. This discourages investment.

Any electricity system with a high penetration of renewables will face problems different from those of a conventional system. The technical study of these is sufficiently advanced so as not to be a major limitation for renewables to be successfully integrated into the National Electrical System.

From a regulatory perspective, it is necessary to consider and anticipate the implementation of storage systems to back up intermittent generation in the different segments of the electricity system, fine-tuning and clarifying the rules and calculation methods for remuneration.

The right to consultation and to free, prior and informed consent for wind power projects resonate internationally because of the tensions and confrontations that have erupted between communities and the projects. The existence of pertinent regulations does not guarantee that they will be fully complied with, which is why it is necessary to create mechanisms to monitor compliance with the Social Impact Assessment process, as well as Environmental Impact Manifestations.

Finally, the new administration has a great challenge ahead, as access to electrical energy has a direct impact on the quality of life of the population as a whole. The national and international debate on whether the right to electricity a human right is will have to be taken into account since it is an essential resource on which we depend to have access to other fundamental rights such as education, health, communication, food, free transit, and work, among others, as well as to cover basic needs in our homes, offices, factories and hospitals.

The current new political context in Mexico offers an area of opportunity to advance in a transformation that is necessary but must be accompanied by respect for the rule of law. In addition, it must ensure respect for the current legal framework, which provides certainty to both investors as well as citizens that their rights are guaranteed. Lack of this kind of legal certainty has led several investors to reevaluate their expectations of growth in the country.

It is worrying to note that in spite of the statements made by the new administration on the importance of continuing the drive for private investment in energy projects, mainly in the electrical sector, the decisions and

actions carried out point to a drift towards criticism of energy reform, since these have implied cancelling out market mechanisms and energy projects. Such is the case of the fourth long-term auction and the bids for the direct current transmission lines from the Isthmus of Tehuantepec to the center of the country and the interconnection of the Baja California system with the rest of the country. All this despite the country having received nearly 8,600 million dollars in investments as a result of 3 long-term auctions.

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