# Towards the liberalization of the energy market

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# Towards the liberalization of the energy market: structural changes and implementation challenges of the 2013 Mexican energy reform insights in the energy nexus

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ABSTRACT

Through the decades Mexico has gone through different transition stages in its national energy sector, aiming to adopt the best practices from Europe and North America. Since the 2013 energy reform implementation, strategic and structural changes have been made to strengthen the energy transition process. This research analyses the structural changes in the energy industry due to a reform that promotes a transition from a vertical scheme directed by a state monopoly to a liberalized scheme allowing private sector participation through new market mechanisms. In this way, a review of the legal and regulatory framework is presented where new bodies are created or assigned to manage and regularize the several agencies and actors in the sector. Additionally, a multi-axial analysis of the main challenges of implementing renewable energy mega-projects is proposed, considering a structural and socio-cultural approach based on case studies. This analysis reveals that these challenges have political, economic, socio-cultural, and environmental implications, which should generate mechanisms built by the wide variety of stakeholders engaging with the sustainable transition.

*GLOSSARY OF TERMS*

| | |
|---|---|
| ASEA | Agency for Safety, Energy and Environment |
| CEL | Clean Energy Certificates |
| CENACE | National Centre for Control of Energy |
| CENEGAS | National Centre for Control of Natural Gas |
| CEPAL | Economic Commission for Latin America |
| CFE | Federal Electricity Commission |
| CNH | National Hydrocarbons Commission |
| CONUE | National Commission for Efficient Use of Energy |
| COP22 | Conference of the Parties |
| CRE | Energy Regulatory Commission |
| DGISOS | Directorate of Social Impact and Surface Occupation |
| ER | Energy Reform |
| GHG | Greenhouse Gases |
| IIE | Institute of Electrical Research |
| IPCC | Intergovernmental Panel on Climate Change |
| LAERFTE | Law for the Use of Renewable Energies and Financing of the Energy Transition |
| LIE | Electrical Industry Law |
| LSPEE | Public Electricity Service Law |
| LTE | Energy Transition Law |
| MBP | Power Balance Market |
| MEM | Wholesale Electric Market |
| OLADE | Latin America Energy Organization |
| PEMEX | Mexican Petroleum |
| PRODESEN | National Electricity System Development Program |
| RE | Renewable Energy |
| SC | Structural Changes |
| SEN | National Electric System |
| SENER | Ministry of Energy |

## 1. Introduction

The energy sector is characterized by its dynamism and its strategic nature for every country in the world. Different policies are continuously implemented to promote economic development along with the generation of energy projects. In the last two decades, the dimensions of environmental protection and national security have acquired relevance for

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the energy sector. The phenomenology of energy markets has evolved; some of the causes are associated with technological advances, the constant search for minimizing production costs, continued innovation in designing strategies to connect supply and demand and taking advantage of information technologies and new market schemes. In addition to these phenomena, the integration of renewable energy applications has been carried out. Based on such a dynamic landscape, the countries' energy policy is in continuous reform to adapt to this multidimensional dynamic.

Some studies around the world discuss about different energy nexus and their contribution. Dai et al. [1] mentions that studies of energy-water nexus are increasing, however, there are very few approaches that offer support to governments and implement technical solutions. Marinelli et al. [2] found that energy savings and emission reductions can be achieved by reconfiguring a water treatment plant to obtain and reuse water instead of wastewater discharge. Usman et al. [3] analyze a causal connection between economic growth, foreign direct investment, energy use (conventional and renewable), with trade openness and ecological footprint. In addition, they suggest associating economic growth with clean energy and environmentally friendly technologies, expanding the share of renewable energy in America. Stringer et al. [4] propose a methodology for resilience trajectories from a multidisciplinary perspective. On the part of the photovoltaic nexus, Karasmanaki et al. [5] found that most studies or methodological frameworks do not explicitly place social justice at the center of the discussion. Also analyzes the economic and environmental factors that affect the decision to invest in photovoltaic installations.

A process of Energy Reform (ER) implies Structural Changes (SC) in a country, modifying the role of the state, either with changes in the mission of its institutions or the creation of new ones. Therefore, energy reforms impact regulatory frameworks, and the way markets operate, as well as the orientation of public policies. When a country decides to design and implement a Reform, it involves a set of SC. Structural changes analyzed by CEPAL and OLADE in Latin America and the Caribbean have reported a trend of energy markets liberalization since the early 1980's [6,7]. On the other hand, the planet's challenges are related to the fight against global warming. According to the Intergovernmental Panel on Climate Change (IPCC), this phenomenon leading cause is the increase in the concentrations of Greenhouse Gases (GHG) in the atmosphere, which has an anthropogenic origin associated with fossil fuel burning [8]. Therefore, the actions involve reforming the energy sectors to trigger an energy transition [9]. One of the steps that were taken at the global level is remarked in the Conference of the Parties (COP22) where various countries committed to achieving 100% electricity generation through renewable energy sources. Throughout 2016, 117 countries submitted their first contributions at the national level under the Paris Agreement [10], and 55 of these countries presented renewable energy targets, including Mexico.

The Mexican electricity system has undergone a series of changes since its nationalization in 1960 [11], one of the most relevant being the opening of the energy generation echelon to private entities through generation contracts specified in the 1991 legal system [12]. However, these changes in Mexican legislation were not considered as a reform. It was not until 2008 that a reform to the Mexican energy sector was promoted that mainly included SC in the hydrocarbon sector, but it was ultimately rejected [13]. Lajous A. [14] pointed out the speed with which the Mexican ER was approved in December 2013 and concluded that a stabilization and consensus time was necessary for adequate regulation due to the lack of trained human resources to serve the new public regulatory institutions, considering the government's need for specialized external consultancy. Moreover, Alpizar-Castro [15] highlights that with the approval of the reform, two opposing views arose, defenders and opponents, according to specialist consultants in the field. Further, González-López & Giampietro [16] consider that the effects of the reform need time to mature for the new institutional arrangements and point out the trade-off between improving the autarky of gasoline and associated with its consumption, the consequent increase in GHG emissions.

At a socio-economic level, Moshiri & Martinez Santillan [17], through an econometric model, found that the energy demand in Mexico is elastic concerning income. Therefore, the impact of energy prices in low-income households is more significant than those with middle and high income, concluding that this justifies that a compensation package for the reform would be socially acceptable. In addition to this socio-economic dimension, the ER and its consecutive SC open debates related to concepts like energy democracy, which are of great relevance for international academic discussions that revolve around transitions and energy justice [18,19]. Although the specific definition of this concept is still at the center of intense academic debate, there is a consensus about its importance in expressing the need for more inclusive, equitable, and low-carbon energy systems [20]. The relevance of this energy democracy principle can be traced to the sub-national level in Mexico through its incorporation into climate change laws at the state level. Such is the case of the general climate change law of the state of Querétaro, where it is recognized that "the principle of energy democracy, which represents the shared responsibility of citizens, institutions, productive sectors and public authorities, regarding the use of renewable energy as a common good, in the way that best guarantees fair, equitable, collective and sustainable development" [21]. Nevertheless, it still seems complicated to describe how this principle can be implemented practically through SC after the ER at the national and sub-national levels. Contrasting with principles of energy democracy, Zárate et al [22] argue that the social problems of indigenous communities, a product of the mega-projects of renewable energy on the Isthmus of Tehuantepec, Oaxaca are related to the absence of land use planning norms, the lack of resolution mechanisms for the conflicts of property rights issued for communal and social control, besides, there is a lack of institutional interest in guaranteeing local participation in project planning and in correcting existing top-down political and operational practices.

In this context, in Mexico ER is in a transition stage, where challenges that were not contemplated at the time of its operational implementation have been visible. Therefore, a new multidisciplinary research field is emerging. This case study was focused on five axes that involve economic, organizational, environmental, socio-cultural, planning and water aspects. In order to address the different energy links, a methodological framework was presented that consists of clarifying the energy context and the changes that the reform seeks, and then qualitatively exploring the challenges that arise from it. In energy nexus studies, methodological frameworks are generally proposed that aspire to explore energy relationships with different dimensions of analysis. The study analyzes the trajectory of the ER process that seeks the liberalization of energy markets and draws essential conclusions that undoubtedly serve as a reference and orientation in this new global energy transition dynamic. In a first stance, this paper aims to present a general and summarized historical review of Mexico's experience before and after the 2013 energy reform, considering two crucial axes related to energy policy: the legislative and the organizational structure. Additionally, this paper classifies some of the main challenges faced by this new reform for the first time, based on observations, readings, and analysis of recently reported local studies. This work's main objective is to provide a currently lacking in-depth understanding of the Mexican ER case study in academic literature, potentially leading to the formulation of better solutions by achieving a transition that contributes to the criteria of sustainable development.

The present work is organized into three sections. The first presents a historical overview of the Mexican energy system, from establishing the foundations of the country's energy infrastructure to the liberalization of the energy sector. Section 2 presents the structural and regulatory changes derived from the 2013 energy reform. Section 3 presents the capacity of the national electric system, Finally, the last section classifies and discusses the challenges generated as a result of this reform.

## 2. Historical review of the legislation of the Mexican energy system

Chronologically, the history of electrical energy policy legislation in Mexico is divided into three main periods. The following section provides a brief historical overview of these periods, which are: 1) foundation of the bases for the development of the country's electrical infrastructure (1880-1959); 2) nationalization and consolidation of the electricity sector (1960-1990): and 3) transition and liberalization of the sector (1991-2013).

### *2.1. Foundations and legal bases of the legislation in electrical energy (1880-1959)*

The Mexican electricity sector had its emergence in the last quarter of the 19th century as a product of the rising industrialization of the country. Derived from the early linkages of the electrical system with private industry in the country: textile and mining, coming from countries such as England and Canada. During its early years, the Mexican energy sector was characterized by the lack of government regulations, as well as the implementation of an economic policy that favored the hegemony of foreign private capital companies, allowing them to concentrate control over transmission, distribution and commercialization of electricity in the country [23]. The foregoing brought the emergence of various problems in the sector, such as inequity and abuse in the collection of electricity rates and the inability to interconnect between systems with different characteristics [24]. Therefore, the development of the electrical system in its early stages was not connected with providing energy services to the population, but to supplying a nascent private industry. Less than 50% of the population was supplied with electricity, focusing the supply on large cities and ignoring rural areas as it did not represent economic benefits for electricity companies. In response to this scenario, the Mexican government created in 1920 the National Commission of Motive Force whose main objective was to curb the excessive profit of the electricity monopolies and to obtain governmental control over the operations of the sector. These measures were complemented with establishing the National Electrical Code in 1926, which defined the technical specifications for the generation and distribution of electricity in the country, declaring electricity as a public service and granting Congress powers for its legislation [25].

During the 1930s, the Mexican government carried out two fundamental actions to ensure the growth of the national electricity infrastructure and give rise to its legislation. The first of these was the creation of the Federal Electricity Commission (CFE) in 1937, which was established as a public owned company whose main functions included establishing the country's electrification program, as well as organizing and directing generation, transmission, and distribution of electrical energy [26]. The second relevant action was the declaration of the Electricity Industry Law (LIE) in 1939, designed to regulate all aspects of the nascent Mexican electricity sector and promote its development, representing the main legislation of the national electricity sector until 1960. It was in effect the recognition of electricity as a service of inherent social interest for the national economy that put the electricity system in the federal government's hands to oversee electricity services to most of the Mexican population. Due to the change from private to public companies between 1945 and 1960, around 2,300 MW of electric capacity were installed compared to 100 MW of generation installed from 1935 to 1945 by private companies [27].

### *2.2. Nationalization and consolidation of the national electricity sector (1960-1990)*

From 1960 the Mexican government was characterized by implementing a policy focused on the nationalization of the electricity sector, the objective of which was to ensure the expansion of the electricity infrastructure and the integration of electricity generation systems [28]. The nationalization process was concluded in 1972 with the acquisition and control of 95% of the country's energy segments. As a result, in 1976, the Electricity Public Services Law (LSPEE) was enacted, declaring CFE and LyFC as the exclusive electricity generators, operators and providers [29]. At the end of this stage, the Mexican electricity system was consolidated through the establishment of a new electricity tariff scheme subsidized by the government (1973) and the unification of the electricity distribution frequency at 60 Hz (1976), which allowed reaching a population coverage of 95% [30,31].

During this period, the development of multiple engineering projects, financed by federal funds and international loans, focused on generating electricity through various energy sources such as coal, oil, turbo-gas, hydroelectric, and geothermal [32]. In addition, to promote the electricity sector's technological development, in 1975 the government created the Institute of Electrical Research (IIE) [30]. Since 1980, the country's energy policy has been to increase productivity, save energy, and diversify electricity production. Thus, to establish the guidelines and strategies for the reduction in the use of electricity, the National Commission for the Efficient Use of Energy (CONUEE) and the Electric Power Savings Trust Fund (FIDE) were created in 1985 and 1990 respectively [33,34].

### *2.3. Transition and liberation of the energy sector (1992-2018)*

The main events that mark the historical transition in energy matters in this period are shown in Fig. 1. In the late 1980s, Mexico experienced financial difficulties due to the fall in oil prices on the world market. The increase in interest rates forced the renegotiation of the foreign debt and the operating costs of public policies that were not adjusted for inflation. This scenario generated a radical change in the ideology of the government, reducing state intervention and favoring the free market. In terms of electricity, this represented the gradual reduction of government subsidies and the opening of private investment to the electricity sector. In December 1992, the proposal to reform the LSPEE was presented to the Senate, representing the first legislative amendment on electricity in the country after 55 years. This modification published in 1993 allowed the production and sale of electricity by the private sector to the CFE. In this way, the CFE remained as a state monopoly focusing mainly on the distribution and final sale of electricity in the country [29,33].

Since 1993, the Mexican electricity sector experienced a period in which private investors increased importance while the role of government diminished. Investment by foreign companies in the electricity sector was encouraged, emphasizing the diversification of energy sources such as natural gas and hydroelectric plants. As a result of this, in 1995, the Energy Regulatory Commission (CRE) was created to act as a new actor in charge of establishing the link between the public sector (CFE) and private investment (power generators) through regulation of the electricity price [35]. Between 1998 and 2008, various proposals for a restructuring of the energy sector focused on privatizing the distribution and generation of electricity and the implementation of renewable energy for electricity production were put forward without approval by the legislators [36]. Nevertheless, due to the enactment of the Climate Change Law [37], During this period, small modifications to the law were made by the Mexican Congress, allowing the establishment of interconnection contracts of renewable energies in 2006 - 2007. These modifications culminated in implementing the second legislative amendment on energy, the Law for the Use of Renewable Energy, and the Financing of the Energy Transition (LAERFTE) in 2008. Based on this law, Mexico raises renewable energy sources and natural gas as a fundamental piece of the country's energy development [38]. At the end of this transition period, the independent power production accounted for 35% of the installed capacity and 45% generated by the CFE.

Since the beginning of 2000, Mexico was already considering integrating renewable energy sources in the energy sector. In particular, the state of Oaxaca organized with the support of the IIE, an international colloquium focused on transnational wind companies to take advantage

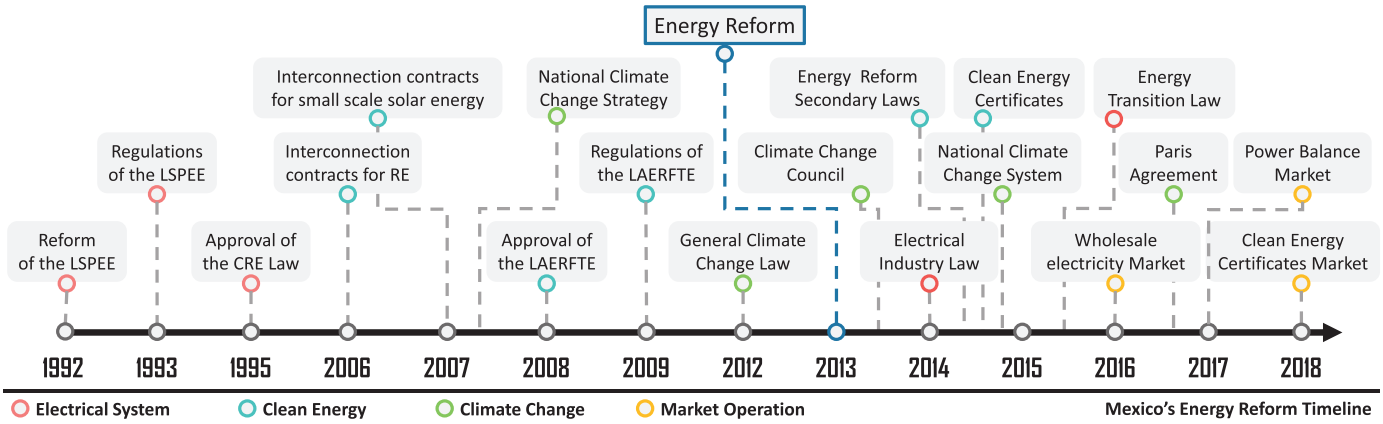


**Fig. 1.** Main historical events of the energy transition in Mexico from 1992 to 2018.

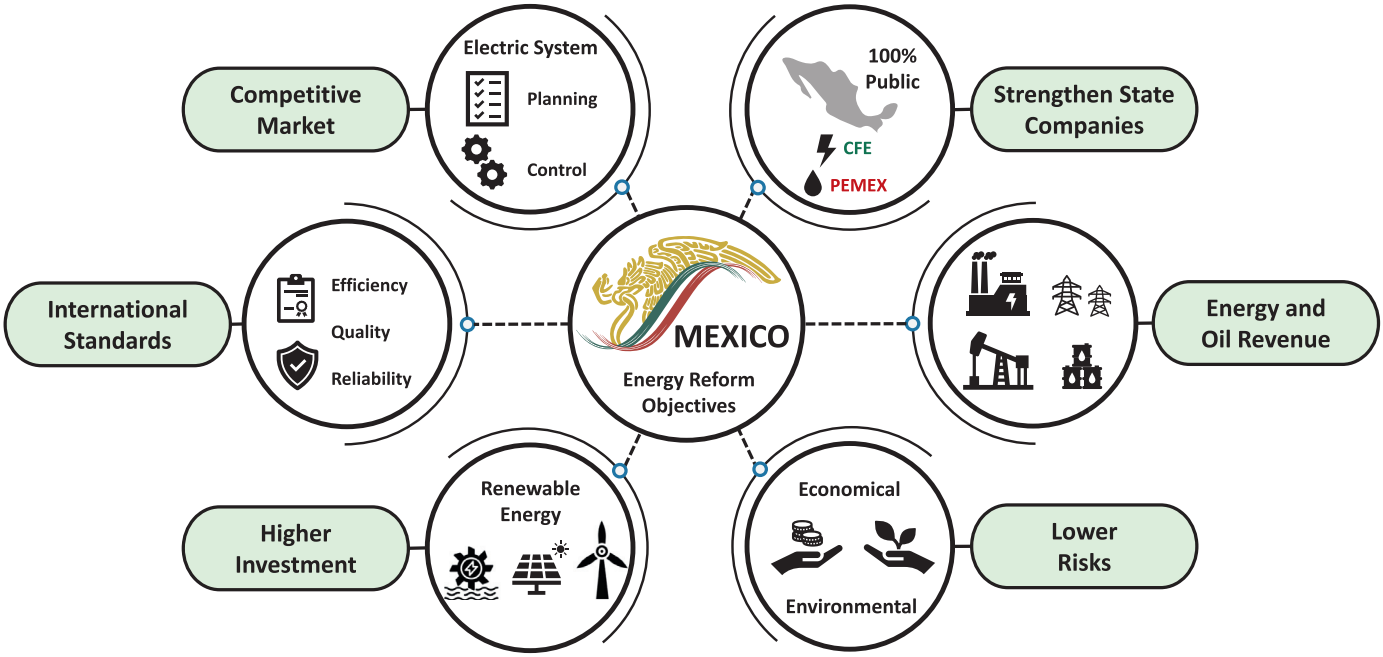


**Fig. 2.** Objectives of the 2013 energy reform in Mexico.

of investment opportunities in wind energy in that entity. Discussions were subsequently held in 2001, 2002, and 2004 under the name of "International Colloquium on Opportunities for Wind Power Development of the Isthmus of Tehuantepec Wind Corridor". In 2006, the resolution of interconnection contracts for renewable energy sources was approved, followed by the implementation of the LAERFTE in 2008. However, it was not until 2013, with the implementation of the energy reform, whose objectives are shown in Fig. 2, where qualified users of the electricity industry were established their obligations in terms of clean energy and the reduction of contaminating emissions [39].

## 3. Structural organization of the Mexican energy sector

### 3.1. Main organizations in the energy sector

Management and decision-making in the Mexican energy sector changed from a central control coordination with vertically organized state companies to a liberalized one. Some responsibilities exclusive to the primary electricity generation company have been transferred to other government agencies [40]. Fig. 3 presents the different levels of the current organizational structure of the energy sector in Mexico.

Level 1 - Coordination. SENER is the main body of the energy system, in charge of conducting and coordinating the country's energy policy in electrical energy; it must draw up sector programs and the National Electricity System Development Program (PRODESEN). It is also responsible for reviewing and authorizing the operation rules of the wholesale electricity market, establishing the energy requirements for electricity generation, as well as the mandatory coverage of electricity supply in rural communities.

Level 2 - Regulatory agencies. CRE is the institution in charge of regulating and promoting efficient development of electricity generation, public and non-public electricity transmission and distribution services, and electricity commercialization. Additionally, the Electricity Industry Law (LIE) declares that the CRE is in charge of establishing general rules for the provision of the Electric Power Transmission and Distribution Public Service. The issuance and application of the rate regulation to the different types of generators, suppliers, users, and services; monitoring compliance with the law in question, its regulations, and other applicable administrative provisions. The CNH is an autonomous body

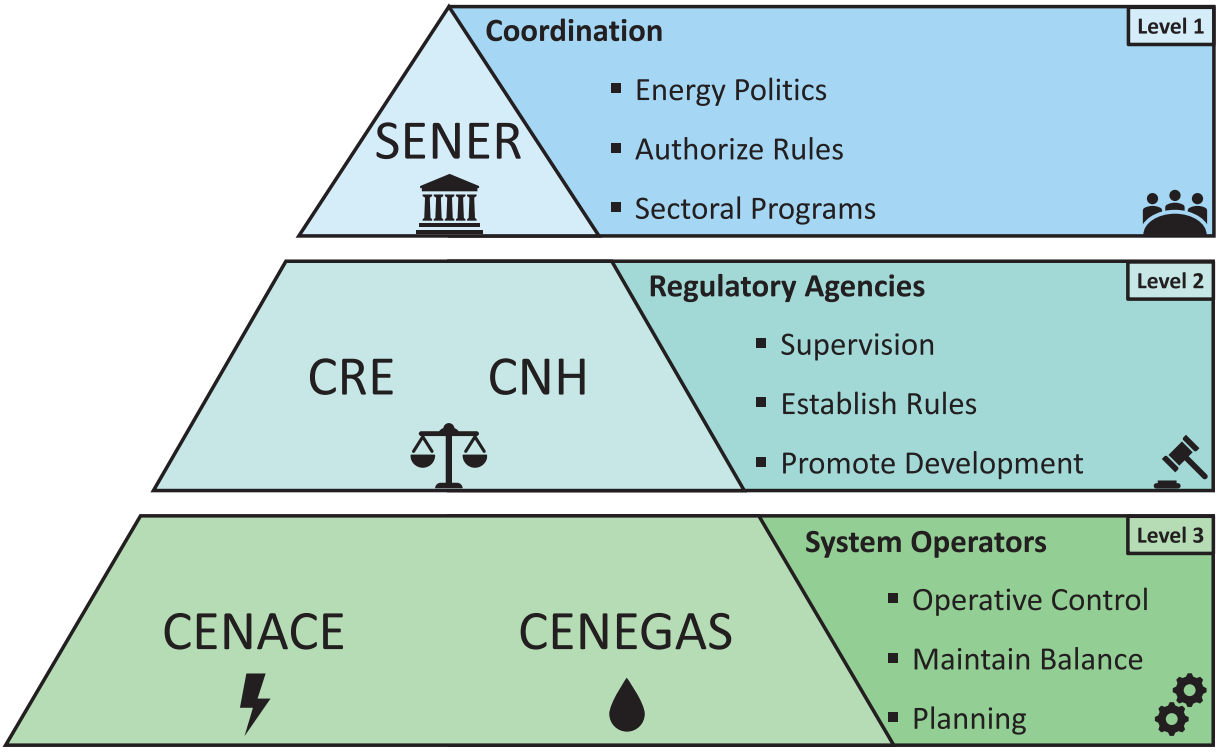


**Fig. 3.** Current structural framework of the energy sector with its different levels and functions.

in charge of supervising the exploration and extraction of hydrocarbons in Mexico. Among its functions are regulating the exploration and extraction of hydrocarbons, administering and supervising activities in assignments and contracts.

Level 3 - System operators. CENACE is a decentralized public body of the federal public administration with legal and patrimonial personality. Under the LIE, it exercises operational control of the National Electric System (SEN), the Wholesale Electricity Market (MEM) operation, and open access to the national transmission network and general distribution networks. Likewise, it is responsible for carrying out expansion and modernization programs of the national transmission network and general distribution networks. CENEGAS oversees managing the federal gas pipeline systems operational capacity and arises from the 2013 energy reform. Its functions are to administer and operate the national transportation and storage system.

### *3.2. Structural transformation of the electrical industry*

Before the reform, there was a vertical model where private companies could develop electricity generation projects (Fig. 4(a)); however, their participation was limited to self-supply schemes or independent producers. In the new model of the electricity market (Fig. 4(b)), private companies can generate electricity independently of the CFE's planning, assuming costs and risks. Private companies can sell electricity through short-term contracts or in the spot market to qualified users through bilateral contracts and to the basic service provider through auctions [41].

In the new electricity market structure, there are participants with various functions. There are two types of generators: those authorized to generate electricity through power plants and those who act as representatives of power plants or as resellers. The generators can sell their electricity in the market or to a qualified user. Qualified end-users are those with consumption equal to or greater than three Mega Watts or those who operate under the previous scheme. For the provider, there are three types: basic services, qualified services, and last resort. The first case, which only includes the CFE, may sell through purchase and sale contracts. In the second case, they will be able to sell their electricity to qualified users and act as representatives of the exempt generators. Those of third may only provide their services to qualified users, under a maximum price and for a specified period. The Energy Reform has established that the transmission and distribution areas remain strategic and exclusive to the state, but there are opportunities to contract with privates. Private sector will be able to participate in the transmission and distribution networks' maintenance and modernization. CENACE will be responsible for proposing, for the Ministry of Energy's approval, the networks' expansion in a non-discriminatory manner so that new energy generators, especially from renewable sources, can achieve their interconnection to the system. A fundamental tool for promoting clean energies is the Clean Energy Certificates (CELs). Generators and distributors of electricity that do not reach the minimum percentage of generation through clean energy, set periodically by the state, must buy these certificates from those who comply; otherwise, they will be creditors of the corresponding sanction. CELs represent a competitive advantage and an additional source of income for clean energy generators. Although the Energy Reform preserves the control of the Nation in the planning and control of the national electricity system, as in the transmission and distribution of electricity, it allows competition to generation and commercialization activities. It also foresees that the state may enter contracts with individuals to enable the expansion and improvement of transmission and distribution networks. The previous seeks to reduce production costs, a more significant share of clean energy, and use of more efficient technologies. Table 1 summarizes the Mexican electricity sector's main characteristics before and after the implementation of the 2013 ER, considering different axes of the sector.

## 4. National electricity system capacity

Mexico has great potential for electricity generation from renewable resources. With the implementation of the Energy Reform and the objectives established in the Energy Transition Law, public policies have been developed that allow the implementation of more clean energy projects. Clean energies are those energy sources and electricity generation pro-

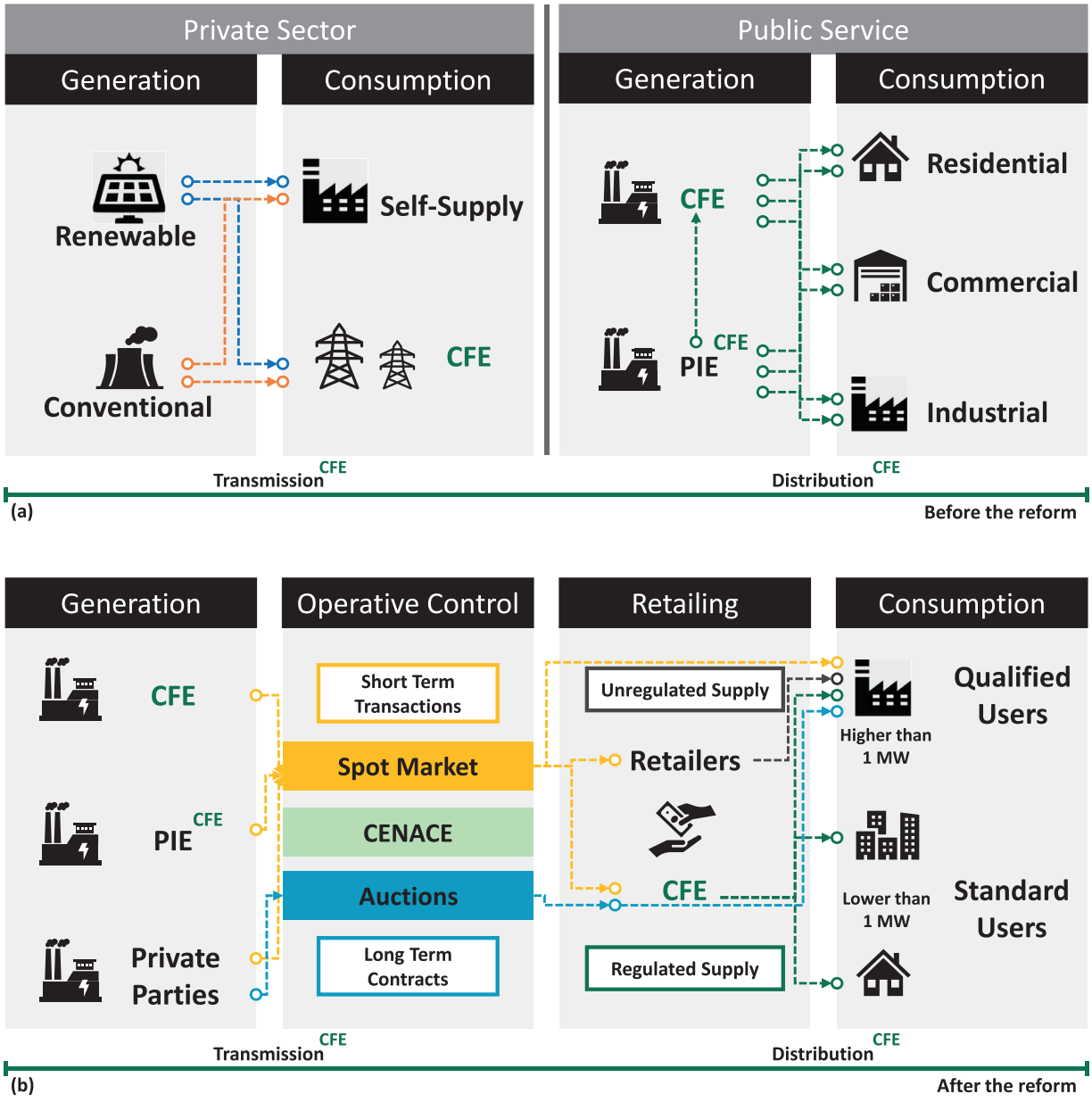


**Fig. 4.** Structure of the electricity market before and after the Energy Reform of 2013.

cesses whose missions or waste, when any, do not exceed the thresholds established in the regulatory provisions. On the other hand, renewable energies are those whose source resides in phenomena of nature, processes or materials that can be transformed into energy usable by human beings, which regenerate naturally, so they are available continuously or periodically. Mexico has competitive operating and electricity production capacity with world electricity markets (Fig. 5). According to the 2021 national development plan [42], which has as the strategic purpose of the government, to guarantee the basic supply of electricity for the entire population, at affordable prices, it is necessary to contemplate the recovery of the CFE generation and transmission capacity, in order for the State company to generate and support the SEN. Therefore, strategic infrastructure projects are contemplated to strengthen the national energy policy, promote the development and efficient operation of the electricity industry, and ensure the reliability of the SEN. Under this premise with the energy policy of the Mexican government, the reactivation of the development of power plants of the CFE was proposed, for which the incorporation of combined cycle plants is proposed, but mainly the rehabilitation and modernization of some hydroelectric plants in operation, as well as the equipment of other existing hydraulic installations.

At the end of 2020 [43], the country had a total installed capacity of 83,122 MW of which 25,594 come from renewable energy representing 30.79% and 3,913 MW from clean energy representing 4.71%. In this period, solar energy was the one that had the highest growth as capacity increased 1,503 MW, becoming the third most important renewable technology in Mexico. Total electricity generation during the 2020 period was 312,347 GWh, of which 74.36% corresponds to conventional sources with 232,259 GWh, 20.88% to renewable energy sources and 4.76% to clean sources. Regarding generation from renewable energy sources presented in Fig. 6, water was the one with the highest generation with 26,817 GWh, followed by wind with 19,702 GWh and solar with 13,528 GWh. On the other hand, among the energies known as clean (nuclear and efficient cogeneration), nuclear energy had a total generation of 10,864 GWh corresponding to 3.48% while that of efficient cogeneration was 4,002 GWh with 1.28%.

**Table 1**
Characteristics of the Mexican electricity sector before and after the 2013 ER.

| | Before the Energy Reform | After the Energy Reform |
|---|---|---|
| Generation | ▪Electricity generation for private companies was limited.<br>▪Independent electricity producers had purchase and sale contracts only with the CFE through tenders.<br>▪Small producers (less than 30 MW) sold energy to the CFE through auctions.<br>▪Generators under the self-supply scheme could generate electricity and sell it to their consumer partners. | ▪The participation of the private sector in activities of the electricity industry increased.<br>▪Private generators can sell their electricity in a Wholesale Electricity Market.<br>▪The CFE company continues as an electricity generator for the sale of basic service (residential, small, and medium industry).<br>▪The CFE participates as a competitor of the Wholesale Electricity Market. |
| Transmission and distribution | ▪The CFE oversaw the transmission and distribution of electricity<br>▪The participation of private companies was limited to transmission and distribution only with their consumer partners under the self-supply scheme. | ▪CENACE oversees coordinating the electricity transmission and distribution networks.<br>▪The state can manage contracts or form associations with individuals to carry out the financing, installation, maintenance, management, operation, and expansion of the infrastructure necessary to provide electricity transmission and distribution services. |
| Market operation | ▪The electricity market was operated solely by the state's productive company.<br>▪Marketing activities for private companies were not allowed.<br>▪The private sector had a minimal presence in self-sufficiency schemes. | ▪The entry of private investment in the commercialization of electrical energy was allowed in two main modalities: providers of basic services and qualified service providers.<br>▪The electricity market is made up of the wholesale electricity market for large users and the retail market for basic service users (residential, small and medium-sized companies).<br>▪The MEM is operated by CENACE and regulated by CRE. |
| Renewable energy | ▪Private investment was allowed in generation activities with renewable energy sources under the self-supply scheme.<br>▪There was no regulatory framework that allowed private investment in generation plants. | ▪Gradual increase of the participation of Renewable Energies in the Electric Industry, to achieve the established goals of clean energy and reduction of CO2 emissions.<br>▪Implementation of long-term auctions for the installation of renewable energy projects in areas with high potential. |

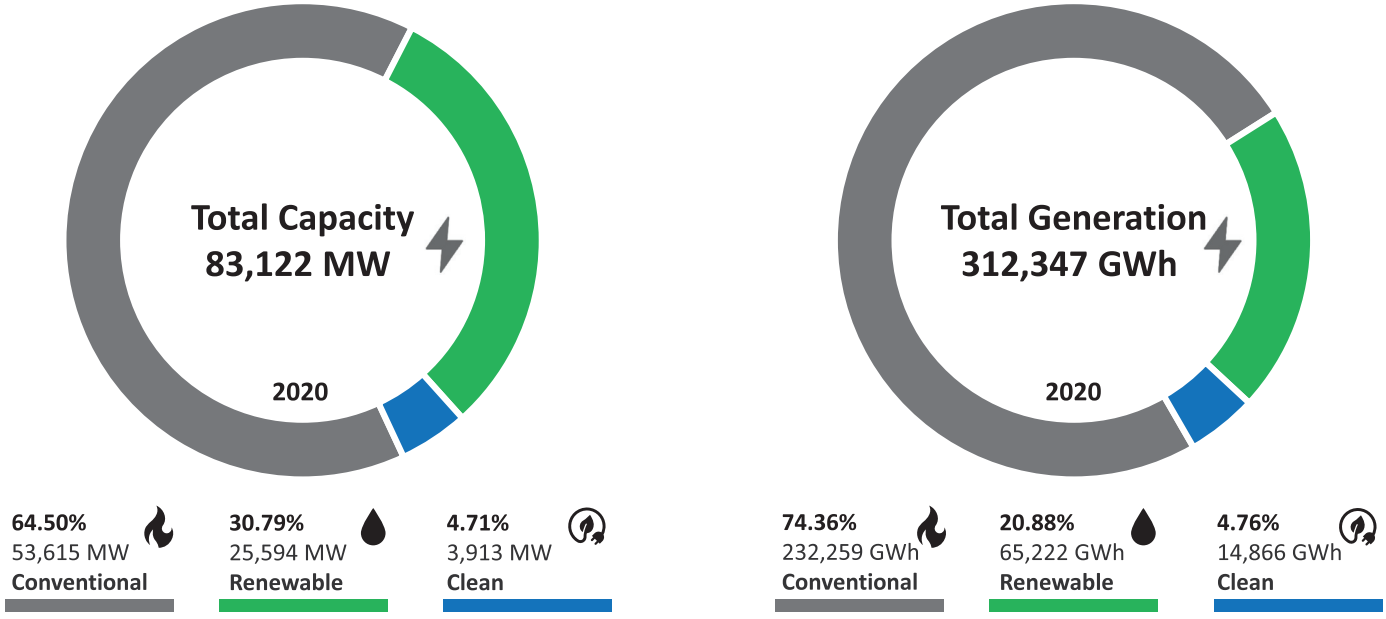


**Fig. 5.** Total operative capacity and electricity generation by technology (2020).

Mexico continues to follow the steps for the liberation of the electricity market, the country has established measures to take the necessary elements for a competitive and modern electricity system. Mexico's ambitions in the energy transition require careful planning and setting of short- and long-term goals. Therefore, generation targets have been established for various energy sources for the next few years. To ensure the success of this transition, investments in the sector's value chain should be maintained.

## 5. Main challenges of the Mexican Energy Reform

The first challenge facing the energy sector comes from the gray areas generated by the vertical disintegration of the CFE, the liberation of the market, and the prevailing integration of renewable energies into the energy matrix, which result in a struggle by private companies to ensure the best places to generate renewable energy. The second challenge is related to possible myopia in the energy infrastructure planning process associated with the modalities of coordination between state bodies and private companies. The third challenge addressed in this article refers to the different environmental, socio-economic, and socio-cultural impacts produced by the new additions of renewable technology, which have shaped Mexico's market and electrical infrastructure. The fourth challenge describes the concept of energy democracy. It outlines the efforts to strengthen it in practice, focusing on balancing the imperative of liberalizing energy markets and community organization forms. The fifth challenge relies on the nexus energy water and the complexity of the implementation of hydroelectric systems as well as the impacts on the population and its social repercussions.

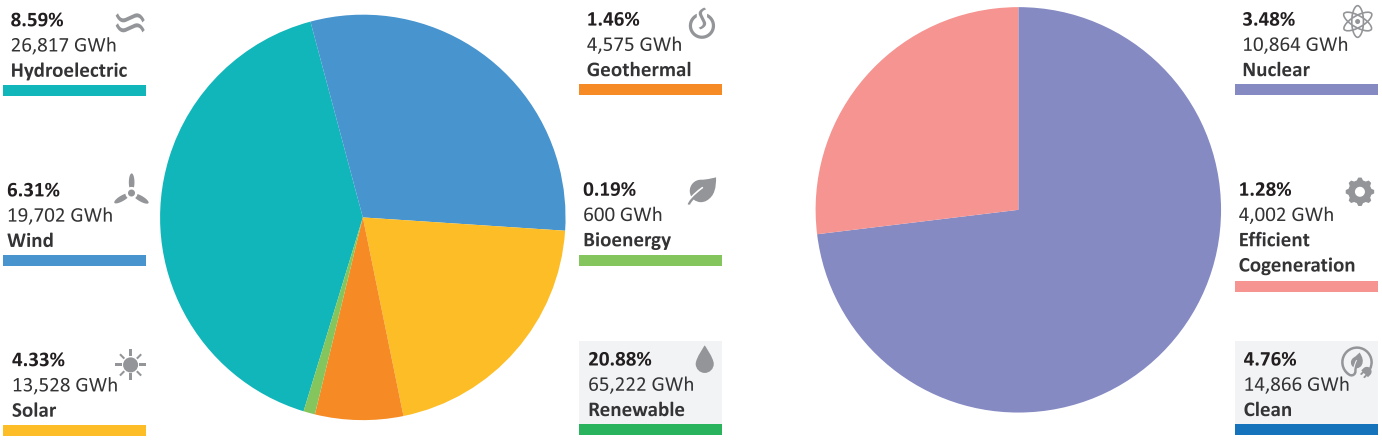


**Fig. 6.** Electricity generation by clean and renewable energy sources (2020).

### 5.1. Energy economic nexus

The vertical disintegration of the CFE was implemented in each echelon of the electrical system, providing the public company with instruments to compete in the new open market. Within this market logic, the criterion for allocating electricity generation permits is based on an auction system, where permits are assigned to the competitor offering the greatest amount of energy at the lowest price. Under the current nodal price scheme, the geographical location of supply and demand, technology, and the moment of the demand curve at which electricity is offered become a key element for the success of projects. Within this context, the integration of renewable energies also responds to a spatial logic, as the quality of renewable resources, such as the sun or wind, serves an inherently geographical nature that determines specific territories of great value for exploitation and renewable energy generation. Therefore, this challenge arises from the struggle to guarantee the best location of the generating plants and ensure the best supply (solar, wind, hydro, geothermal, etc.) that maximizes the investment return from the energy project and the best offer for the electric auction. The complexity of renewable and clean energy projects increases between the value that can be exploited from the geographical location with the aspects that influence local development, especially of indigenous communities and ecological reserve areas. On the one hand, there are compensations for the communities that are in possession of the exploitable location that influence the decision of the project, such as economic income, reduction of electricity costs and taxes, technical and legal training, in general all those aspects that lead to a material improvement. On the other hand, the State must balance the decision between guaranteeing well-being conditions for both the population and the market. And it adds the business purpose that has as a natural objective to maximize the returns on your investments. Additionally, the generation of renewable energy impacts the electricity market due to the generation of Clean Energy Certificates (CELs) and the obligations that users with an electricity demand greater than 1 MW must pay for CELs to cover their clean electricity consumption requirement. In parallel, the struggle to guarantee the best locations for installing power plants that take advantage of renewable energies is intensifying, as scarce installation surface is considered a scarce good. However, in recent years, they have shown how the projects proposed based on the SC described above have faced challenges related to government changes or protected areas. It has been demonstrated that the new federal administration, beginning in 2018, has consistently challenged the SC made by the 2013 energy reform. Specifically, the new administration has harshly criticized and has tried to modify mechanisms such as CELs and temporarily stop the auction processes for renewable energy projects. Regarding the existing challenges to manage protected areas and those with a high potential for renewable energies, as well as the possible conflicts that emerge from these overlaps, tools, and programs such as AZEL (National Atlas of Zones with High Potential of Clean Energies) have been developed. This tool allows, through geographic information systems, to explore the country's territories where the theoretical potentials of renewable energies are high and exclude potential conflicts with protected areas.

### 5.2. Energy planning nexus

The second challenge refers to potential myopia in the current energy planning system generated by gaps in the coordination processes between regulatory entities and energy companies. For the electric power generation echelon, there are two options: 1) by the CFE, whose decisions are made based on the increase in energy demand in different regions of the country, 2) private sector investments, based on increasing its supply by taking advantage of the opportunities in the electricity market. For the electricity and natural gas transmission echelon, the regulators are CENACE and CENAGAS. As commented in previous sections after the RE, the transmission and generation links remain property of the Mexican state; however, the private sector can participate through permits or install its own transmission systems as long as this is not used to provide public service. Both CENACE and CENAGAS operate using two regulatory principles: 1) free access to the transmission system facilities (electricity and natural gas, respectively) and 2) generate market disputability or competition conditions. However, the type of regulation becomes problematic since it responds to a complex combination of a private business regulation system based on users interacting within a market and a centralized planning system. In hydroelectric projects, the repowering and reconfiguration of existing plants can have multipurpose benefits such as increasing the irrigation capacity of agricultural areas. Even reconfigurations of water treatment plants to include mini hydropower (turbines less than 30 MW) can generate electricity, reduce polluting emissions or the ecological footprint and generate reusable water for irrigation instead of consuming energy in pumping for wastewater discharge. Due to the aforementioned, the challenge for the planning of energy projects focuses on striking a balance between short-term decisions based on market signals and long-term decisions that will allow a resilient energy infrastructure that contributes to the country's development.

### 5.3. Environmental, social, and cultural nexus

The third challenge refers to make visible and solving the environmental and socio-cultural impacts related to energy projects, especially those coming from renewable energy, existing within the different echelons of the energy chains. To make visible and solve such impacts, it becomes necessary to implement mechanisms that guarantee an adequate balance between the benefits and local impacts caused by these projects'

installation and operation. Although there are independent regulatory entities for the operation of the market, there are not enough institutional resources or mechanisms that, comprehensively and effectively, regulate, supervise, and control the effects arising from different renewable and clean technologies.

The iconic case of the failed "Mareña Renovables" wind project in Oaxaca, represents a clear example of how the potential socio-environmental impacts of renewable energy developments generate great concern for local communities that function as guests of such projects [44,45]. The lack of clarity from potential environmental impacts from the wind project to the fragile lagoon ecosystem of the region and the potential social implications to traditional livelihoods of the "Zapoteca" and "Ikoot" fishing village generated sustained and robust resistance to the project, which ended up being canceled [46]. Therefore, the iconic case study of "Mareña Renovables" demonstrates the lack of specific regulation to attend and publicize the potential environmental impacts of renewable energy mega-projects, representing a clear challenge after the ER to promote a fair energy transition.

The current absence of recycling regulations or regulations regarding waste from photovoltaic panels or wind turbines is an example of environmental problems waiting to manifest in the medium and long term for communities hosting renewable energy mega-projects. These examples illustrate the challenges that the energy transition faces in the context of an incomplete ER that failed to include specific and transparent mechanisms to measure, avoid, mitigate, and clarify the environmental impacts of potential projects on rural and indigenous communities. It becomes necessary to generate SC that allow a better evaluation of the potential socio-environmental impacts from projects, through specific environmental impact assessments for each energy technology. Additionally, greater participation and inclusion of state authorities in the supervision of socio-environmental impacts could allow the proper development of restoration strategies. Technology's specialized measures may contribute to improving evaluation mechanisms, translating into more transparent and more direct communication with local communities, and in the generation of more effective mitigation strategies that consider the specific characteristics of the places where energy projects intend to settle. It has been observed that energy projects, especially those of renewable energies, have a common factor, not considering the sustainability criteria in their socio-environmental or socio-cultural dimensions [47]. A clear example of the challenges faced in addressing the socio-cultural dimension can be found in the challenges regarding social impact assessments and indigenous consultation, which were mentioned above. Until now, neither SENER as head of the sector nor its departments, such as DGISOS, have sufficient human resources, regulatory procedures, or technical training to carry out their functions effectively.

In the case of the evaluation of social impacts mechanism, the Mexican legal system has experienced great difficulties integrating its secondary legislation into the Electricity Industry law until 2018 (Oaxaca Economic, 12 years after constructing the first wind farm in Mexico in 2006). Additionally, the secondary provisions of the social impact assessment were integrated relatively recently, in 2018. On the other hand, the indigenous consultations, which seek to *"... identify the traditional authorities, in the definition of the collective subject of law, in the application of intercultural communication strategies for the delivery of information, among others ..."* [48] frequently encounter significant problems to implement these mechanisms in a way that adheres to the principles of due process and transparency, satisfying the demands of local and regional resistance groups [49]. There is a lack of training programs that help the communities submitted to consultation to make informed and rationalized decisions about energy projects requesting permission to settle within their territories. Due to the combination of "energy illiteracy", present in any citizen who does not have studies or professional experience in the area of energy, and the common lack of a clear and transparent language by the companies and government entities that participate in the processes of consultation, large information gaps are created that are perceived by different groups in the communities as an absence of transparency (corruption), or worse still as mechanisms for legitimizing projects [50]. Differential perceptions between community groups can open the way to social conflicts, which attend to arguments of an unfair distribution of the projects' negative environmental and socio-cultural impacts and their socio-economic benefits [51,52]. These conflicts unleash episodes of violence at the intracommunity level between groups with opposing interests, families [53], or affect the Mexican electricity system's materiality by generating uncertainty in private investment.

### 5.4. Organizational energy, normative legal and human rights nexus

Energy has always been a terrain of struggle, in which processes of social and political confrontation determine the practices of use, distribution, and production [54]. Within this struggle, energy democracy aspires to put in the hands of energy users and workers power and an active role in all aspects of the sector, from production to distribution and from supply to financing, technology, and knowledge production. As mentioned before, the concept of energy democracy has been mentioned on some occasions within the ER context to promote greater inclusion and participation of Mexican society in national energy activities and the energy transition process. However, it is currently still difficult to mention examples where this principle of energy democracy is being put into practice, promoting energy projects that involve Mexican citizens in decision-making or as active partners in different energy projects. The concept of energy democracy has been implemented in practice through community generation models, especially in the form of community renewables, by several countries in Europe such as Denmark, the United Kingdom, and Germany [55], as well as some Latin American countries like Chile [56]. These energy generation models have not been debated only in their ability to internalize the potential benefits of energy transitions towards citizens and local communities. Still, they have also been identified as possible means to improve the social acceptance of low-income carbon projects by local communities. However, some authors highlight that the support mechanisms in public policy are a determining factor for the success of these community renewable energy models that pursue the principles of energy democracy [57].

The case of Mexico is an example of how this support from public policies becomes an essential factor for the materialization of such community generation projects. Frequently voices from government and academia that have addressed wind energy in the Isthmus region have highlighted the importance that community generation models could have for contexts of high social resistance and socio-economic inequality such as the Isthmus [58,59]. Since 2008, the Yansa project has proposed creating a community wind generation project with some members of the Ixtepec community as partners of 50% of the project. The model proposed by Yansa attends to an equal distribution of the socio-economic benefits between the company and indigenous communities and establishes governance structures where community members become decision-makers [60]. Authors such as Baker [61] had already highlighted the opportunity that the SC brought by the ER represented for the generation of new regulatory mechanisms that would allow community models for the generation of renewable energy by indigenous and rural communities in Oaxaca. The challenge to integrate the principle of energy democracy in low carbon transitions after ER continues as a significant slope in Mexico.

Another geographical enclave where the term of energy democracy is of great relevance is San José Tipceh in Yucatán. In this case, and from ethnography [47] analyzed how they have enacted their power over the rural communities without questioning the local authorities and without their inhabitants having the appropriate tools to effectively defend their interests. In this context, Velasco-Herrejon and Bauwens [62] highlighted the importance of conceptual frameworks such as the "capability approach" to understand the tools and information channels that different indigenous communities use to support a process of resistance

against wind energy in Oaxaca [52]. In parallel, A. El Mekaoui detected that the planning and design processes of energy mega-projects do not consider the community's processes, nor the heterogeneity of the indigenous communities. This lack of recognition and due process fragments communities in different groups of "winners" and "losers", fostering the breakdown of communication channels between society and the private sector. Such is the reality of the populations selected for implementing mega-projects of renewable energies in the state of Yucatan promoted by transnational companies. A. El Mekaoui [47] shows how power is exercised in the implementation of energy projects in the absence of an inclusive and equitable governance system that not only recognizes the principles of energy democracy but also ignores the local socio-cultural contexts of the host communities of energy projects. This exercise of power ignoring socio-cultural contexts results in the generation of new powers and permanent conflicts that remain a heritage for the communities.

### 5.5. Water energy nexus

Hydroelectric projects are highly complex because the infrastructure and location are multipurpose, they are important for their potential to positively impact the population with the supply of electricity and water, to reduce polluting emissions and contribute to the energy transition. In the locations with the largest potentials, there are generating plants that are in the planning stage for repowering or reconfiguration, and the current federal administration is including the potential for mini hydropower. One of the great challenges for the massive exploitation of these technologies is the impact on the cost of water to generate electricity versus the cost of using water for human or animal consumption and irrigation. A regulatory framework is necessary to avoid situations of economic competition between the uses of water for endosomatic purposes. The design and implementation of a regulatory framework that avoids situations of water grabbing and investments in infrastructure is also considered a challenge. In the reconfiguration of large hydroelectric plants, it is necessary to consider the effects of climate change, for example, the over accumulation of water in reservoirs in the rainy seasons, including bioethical rules for in situations of pressure release or deliberate flooding. in populated, growing, livestock or other areas. Some strategies such as the primary use of water for agriculture or strategies of moderate drainage of some hydroelectric plants can serve to minimize the effects of flooding in populations.

## 6. Conclusion and Policy Implications

Since the 2013 energy reform, a series of secondary laws have been implemented focused on strengthening this reform's objectives and establishing a transition of the energy sector path. The Energy Reform was reflected in the culmination of different types of markets. On the other hand, and no less critical, it continued with including climate change to the country energy sector's priorities with implementing the general law of climate change. Although regulations on climate change and the environment have been regularized and approved, there are still no specific mechanisms to address the potential environmental impacts generated by the implementation of renewable energy mega-projects. The impacts range from land use in the areas designated for these projects to the final disposal of the equipment at the end of its useful life.

The challenges in Mexico in energy matters have political, economic, cultural, social, and environmental implications in fulfilling international obligations. Although it is expected that, by attracting investment in the electricity sector with renewable energy projects such as hydroelectric, photovoltaic and wind, plus modifications at the constitutional level and secondary laws, the energy transition will be achieved, from the point of view of decarbonization and legally - administrative. It will undoubtedly be achieved; however, it is necessary to consider finding a solution to the emerging challenges. Challenges have two levels of analysis; the first comes from the effects of the energy transition, applying to the decarbonization of the energy system from the perspective of seeking technological change and the rationalization of both the demand and supply agents' modes production. The second is the energy transition and the migration of institutional arrangements before and after the reform. These two levels are compounded by a challenge related to the fluidity of implementation, given the change of administration in the federal government at the end of 2018, which raises management oriented towards social welfare, suggesting that the government incentive is not only to create and regulate markets. In this sense, market criteria will not necessarily capture profitable socially oriented welfare requirements in their communities. The social challenges are problematic since the government does not have the procedures or the necessary training to establish communication with the communities, manage the problems transparently, or concerning the private sector's interests. Additionally, the government does not have adequate training for the decision-making on energy sector projects with economic potential.

Finally, this study illustrates the various challenges faced by Mexico since 2013 to generate structural changes that properly implement. Within this context, regulatory gaps or implementation problems were identified for the categories of challenges analyzed and discussed in this article, as well as potential remediation strategies. In this way, this research contributes to the study of structural changes and energy reforms in the field of energy transitions from underrepresented geographies in the international academic literature, such as Latin America and other countries.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## References

[1] J Dai, S Wu, G Han, J Weinberg, X Xie, X Wu, et al., Water-energy nexus: a review of methods and tools for macro-assessment, Appl. Energy 210 (2018) 393–408, doi:10.1016/j.apenergy.2017.08.243.
[2] E Marinelli, S Radini, Ç Akyol, M Sgroi, AL Eusebi, GB Bischetti, et al., Water-energy-food-climate nexus in an integrated peri-urban wastewater treatment and reuse system: from theory to practice, Sustainability 13 (2021), doi:10.3390/su131910952.
[3] M Usman, R Kousar, MR Yaseen, MSA. Makhdum, An empirical nexus between economic growth, energy utilization, trade policy, and ecological footprint: a continent-wise comparison in upper-middle-income countries, Environ. Sci. Pollut. Res. 27 (2020) 38995–39018, doi:10.1007/s11356-020-09772-3.
[4] LC Stringer, CH Quinn, HT V Le, F Msuya, J Pezzuti, M Dallimer, et al., A new framework to enable equitable outcomes: resilience and nexus approaches combined, Earth's Futur 6 (2018) 902–918, doi:10.1029/2017EF000694.
[5] E Karasmanaki, D Sfiri, G Tsantopoulos, et al., Factors affecting Landowners' decision to invest in photovoltaics on their farmland: the case of landowners in a Greek rural area, in: JR da Costa Sanches Galvão, PS de Brito, F dos Santos Neves, FG da Silva Craveiro, H de Amorim Almeida, JO Correia Vasco, et al. (Eds.), Proc. 1st Int. Conf. Water Energy Food Sustain, Springer International Publishing, Cham, 2021, pp. 335–343. ICoWEFS2021.
[6] NU. CEPAL, OLADE, Deutsche Gesellschaft für Technische Zusammenarbeit. Energía y desarrollo sustentable en América Latina y el Caribe : guía para la formulación de políticas energéticas, Primera ed. Naciones Unidas (2000) CEPAL.
[7] NU. CEPAL, OLADE, German Agency for Technical Cooperation. Energía y desarrollo sustentable en América Latina y el Caribe: guía para la formulación de políticas energéticas | Publicación | Comisión Económica para América Latina y el Caribe, Segvunda v (2003).
[8] IPCC. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,. 2018.
[9] REN21. Renewables 2017 Global Status Report. 2017.
[10] UNFCCC. Report of the conference of the parties on its twenty-second session. 2016.
[11] J Ovalle Favela, La Nacionalización de las Industrias Petrolera y Eléctrica, Boletín Mex Derecho Comp (2007) 169–191.
[12] Camara de Diputados del H, Congreso de la Union, Ley del Servicio Público de Energía Eléctrica (2014) 1–21.
[13] OS Ángeles Cornejo, Crónica de una muerte anunciada: La reforma energética propuesta por el gobierno de Calderón. Memoria histórica, Rev Digit Inst Investig Económicas 1 (2009) 1–23.
[14] A. Lajous, Mexican Energy Reform, 2014 New York.
[15] I Alpizar-Castro, C. Rodríguez-Monroy, Review of Mexico's energy reform in 2013: Background, analysis of the reform and reactions, Renew. Sustain. Energy Rev. 58 (2016) 725–736, doi:10.1016/j.rser.2015.12.291.

[16] R González-López, M. Giampietro, Relational analysis of the oil and gas sector of Mexico: Implications for Mexico's energy reform, Energy 154 (2018) 403–414, doi:10.1016/j.energy.2018.04.134.
[17] S Moshiri, MA. Martinez Santillan, The welfare effects of energy price changes due to energy market reform in Mexico, Energy Policy 113 (2018) 663–672, doi:10.1016/j.enpol.2017.11.035.
[18] B Van Veelen, A Pinker, M Tingey, G Taylor Aiken, W Eadson, What can energy research bring to social science? Reflections on 5 years of Energy Research & Social Science and beyond, Energy Res Soc Sci 57 (2019) 101240, doi:10.1016/j.erss.2019.101240.
[19] BP Koirala, E Koliou, J Friege, RA Hakvoort, PM. Herder, Energetic communities for community energy: a review of key issues and trends shaping integrated community energy systems, Renew Sustain Energy Rev 56 (2016) 722–744, doi:10.1016/j.rser.2015.11.080.
[20] B van Veelen, D. van der Horst, What is energy democracy? Connecting social science energy research and political theory, Energy Res. Soc. Sci. 46 (2018) 19–28, doi:10.1016/j.erss.2018.06.010.
[21] Queretaro E deLEY DE CAMBIO CLIMÁTICO PARA EL ESTADO DE QUERÉTARO. Queretaro, Poder Legislativo Estado de Queretaro, 2019.
[22] E Zárate-Toledo, R Patiño, Fraga J. Justice, social exclusion and indigenous opposition: a case study of wind energy development on the Isthmus of Tehuantepec, Mexico, Energy Res. Soc. Sci. 54 (2019) 1–11, doi:10.1016/J.ERSS.2019.03.004.
[23] AM Ramírez-Camperos, V Rodríguez-Padilla, PA. Guido-Aldana, The Mexican electricity sector: Policy analysis and reform (1992-2009), Energy Policy (2013), doi:10.1016/j.enpol.2013.06.063.
[24] C. Lara, La industria electrica de energía eléctrica, 1953 México DF, México: Fondo de Cultura Económica.
[25] L. Campos Aragón, La electricidad en la ciudad de México y área conurbada: historía, problemas y perspectivas. México DF, México, Siglo XXI Editores (2005).
[26] A. El Mekaoui, The energy sector in challenges and social problems: Case of megaprojects in the communities of Yucatan, Mexico. Ing Rev Académica La Fac Ing Univ Autónoma Yucatán 22 (2018) 64–75.
[27] MS. Wionczek, The State and the Electric-Power Industry in Mexico, 1895–1965, Bus. Hist. Rev. 39 (1965) 527–556, doi:10.2307/3112602.
[28] MT Sánchez Salazar, JM Casado Izquierdo, E Saavedra Silva, La inversión privada en el sector eléctrico en México: marco institucional y estructura territorial, Invest. Geográficas 67 (2012), doi:10.14350/rig.30183.
[29] MA Jano-Ito, D. Crawford-Brown, Socio-technical analysis of the electricity sector of Mexico: Its historical evolution and implications for a transition towards low-carbon development, Renew. Sustain. Energy Rev. 55 (2016) 567–590, doi:10.1016/j.rser.2015.10.153.
[30] FJ González Quiñones, Instituto de Investigaciones Eléctricas: Antecedentes y consolidación, Instituto de Investigaciones Eléctricas, Cuernavaca, Mexico, 2015.
[31] J Ramos-Gutiérrez L de, M Montenegro-Fragoso, La generación de energía eléctrica en México, Tecnol y Ciencias Del Agua 4 (2012).
[32] G Aleman-Nava, V Casiano-Flores, D Cárdenas-Chávez, R Díaz-Chavez, N Scarlat, J Mahlknecht, et al., Renewable energy research progress in Mexico: a review, Renew. Sustain. Energy Rev. 32 (2014) 140–153.
[33] R. Vargas, El sector eléctrico mexicano: ¿Nuevos espacios para las coorporaciones transnacionales? Acta Sociológica (2011), doi:10.22201/fcpys.24484938e.2011.54.25674.
[34] FIDEFideicomiso para el Ahorro de Energía Eléctrica, 2019.
[35] CRÉComisión Reguladora de Energía: Evolución histórica, 2011.
[36] M. Breceda, Debate on Reform of the Electricity Sector in Mexico. Report on its Background, Current Status and Outlook, North American Commission for Environmental Cooperation, 2000.
[37] SEGOB. Ley general de cambio climático. 2014.
[38] SEGOB. Ley de Transición Energética. 2015.
[39] SEGOB. Ley de la Industria Electrica 2014. http://www.dof.gob.mx/nota_detalle.php?codigo=5366665&fecha=31/10/2014.
[40] KJ Gasca Lara, Reforma Energética en México, 2015.
[41] Instituto Nacional de Electricidad y Energías LimpiasModelo de la industria eléctrica, 2015 https://www.gob.mx/ineel/prensa/el-papel-del-nuevo-cenace-en-el-modelo-de-la-industria-electrica-post-reforma.
[42] SENER. Programa de Desarrollo del Sistema Electrico Nacional 2021 - 2035. 2021.
[43] CENACEPrograma de Ampliación y Modernización de la Red Nacional de Transmisión y Redes Generales de Distribución del Mercado Eléctrico Mayorista 2021-2035, 2021.
[44] Hurtado-Sandoval A. Wind Energy Development in Mexico A case study of the potential for local socio-economic benefits in Mareña. 2015.
[45] C. Howe, Anthropocenic Ecoauthority: The Winds of Oaxaca, Anthropol Q 87 (2014) 381–404, doi:10.1353/anq.2014.0029.
[46] A. Dunlap, Insurrection for land, sea and dignity: Resistance and autonomy against wind energy in Álvaro Obregón, Mexico, J Polit Ecol 25 (2018) 120–143, doi:10.2458/v25i1.22863.
[47] A El Mekaoui, R Tariq, OB Ramírez, Méndez-Monroy PE. Sustainability, sociocultural challenges, and new power of capitalism for renewable energy megaprojects in an indigenous Mayan Community of Mexico, Sustain 12 (2020), doi:10.3390/SU12187432.
[48] SENERProtocolo para la implementacion del proceso de consulta previa, libre e informada sobre el desarrollo de un proyecto de generacion de energia eolica, de conformidad con estandares del convenio 169 de la organizacion internacional del trabajo sobre pueblo, 2014.
[49] SJ. Anaya, Observaciones del Profesor S. James Anaya sobre la consulta en el contexto del proyecto energia eolica del sur en Juchitan de Zaragoza, Juchitan (2015).
[50] A. Dunlap, A Bureaucratic Trap :" Free, Prior and Informed Consent (FPIC) and Wind Energy Development in Juchitán, Mexico, Capital Nat. Social 29 (2018) 88–108, doi:10.1080/10455752.2017.1334219.
[51] ME Huesca-Pérez, C Sheinbaum-Pardo, J. Köppel, Social implications of siting wind energy in a disadvantaged region – The case of the Isthmus of Tehuantepec, Mexico. Renew Sustain Energy Rev 58 (2016) 952–965, doi:10.1016/j.rser.2015.12.310.
[52] L Alonso-Serna, A. Mejia-Montero, Rentas eólicas y nuevos procesos de diferenciación social en el Istmo de Tehuantepec, Oaxaca, in: C Tornel (Ed.), Altern. para limitar el calentamiento Glob. en 1.5°C Más allá la Econ. verde. 1st ed editor, Ciudad de Mexico: Fundación Heinrich Böll, 2019.
[53] CCCHistorias y aprendizajes sobre el desarrollo de la energia eolica en Mexico, 2015 Ciudad de Mexico.
[54] N Hildyard, L Lohmann, S Sexton, Seguridad energética. Libros en Acción, 2014.
[55] SJW Klein, S. Coffey, Building a sustainable energy future, one community at a time, Renew. Sustain. Energy Rev. 60 (2016) 867–880, doi:10.1016/j.rser.2016.01.129.
[56] F Merino, A Mejia-Montero, C. Dastres, An inclusive and participative model for energy transition in Latin America: the case of Chilean Generación Comunitaria, in: L Noura Guimaraes (Ed.), Regul. Policy Lat. Am. Energy Transitions. 1st ed., Elsevier, Sao Paulo, 2020, pp. 392–412.
[57] G Seyfang, JJJJ Park, A. Smith, A thousand flowers blooming? An examination of community energy in the UK, Energy Policy 36 (2013) 977–989, doi:10.1016/j.enpol.2013.06.030.
[58] S Juárez-Hernández, G. León, Energía eólica en el istmo de tehuantepec: Desarrollo, actores y oposición social, Probl Desarro 45 (2014) 139–162, doi:10.1016/S0301-7036(14)70879-X.
[59] CDPIM, La energía eólica en México-Una perspectiva social sobre el valor de la tierra, 1, 2015, doi:10.1017/CBO9781107415324.004.
[60] S Oceransky, The Yansa Group: Renewable Energy as a Common Resource, in: K Abramsky (Ed.), Sparking a Worldw. Energy Revolut. - Soc. Struggl. Transit. to a Post-Petrol world. 1st ed, AK Press, Oakland, Edinburgh, Baltimore, 2010, p. 670.
[61] SH. Baker, Mexican energy reform, climate change, and energy justice in indigenous communities, Nat. Resour. J. 56 (2016) 369–390.
[62] P Velasco-Herrejon, T. Bauwens, Energy justice from the bottom up: a capability approach to community acceptance of wind energy in Mexico, Energy Res. Soc. Sci. 70 (2020) 101711 https://doi.org/10.1016/j.erss.2020.101711.