



Mexico's New Energy Model

Initial Results from the Mexico Electricity Reform, 2013-18

A Working Paper

By Peter Nance



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Introduction

This chapter will discuss recent changes in the Mexican energy sector over the past five years, including the new auction design and the role and results of the energy auctions. First, it will go over the background of the reforms, and provide a perspective on the current system and key grid changes. Next, it will offer some insights on finance and key market participants. Following this, it will discuss some of the human capital obstacles and new programs. Last but not least, it will summarize the major successes and challenges of the restructuring process.

Background

Mexico is currently the second-largest power market in Latin America and appears poised for continued growth. During the lead-up to the creation of the North American Free Trade Agreement (NAFTA) in the early 1990s, Mexico began a restructuring process to spur greater international investment in electricity infrastructure. Although more than 6,000 megawatts (MW) of capacity was installed under these programs, the investments relied largely on long-term contracts with the state-owned Federal Electricity Commission (Comisión Federal de Electricidad; CFE). Even following the reforms of early 2013, CFE remained the manager of the generation, transmission, and distribution functions.

During this period, inefficiencies in the electric sector persisted largely because of underinvestment in capital stock. At least in part, this was a result of an ineffective pricing and regulatory policy regimen, coupled with heavily subsidized retail rates and high overall system costs. As part of this system, the government reimbursed CFE by subsidizing retail prices through tax and dividend discounts. By 2002, however, the subsidy had become greater than the discount provided, eroding CFE's capital base and ability to fund capital investment. Further, industrial customers faced relatively high retail electric costs and rates that varied from month to month, creating obstacles to planning

and investment. During this period, efforts to address these structural problems were unsuccessful.

Overview of the Restructuring Process

In December 2013, the Mexican Congress passed a constitutional amendment that was designed to greatly restructure the energy sector. The legal status of CFE was modified with a goal of moving the sector from a single vertically integrated utility to include a generation subsector that would expand opportunities for private companies. Transmission investments were also to be opened to international investment under private sector contracts with the Government. Responsibility for distribution activities remained with CFE.¹

In August 2014, Congress passed a series of secondary laws. In parallel, restructuring was undertaken in the natural gas sector with important implications for the electricity sector. These power and gas sectoral changes included nine laws, among them the Electric Industry Law (Ley de la Industria Eléctrica, LIE), and 12 amended laws passed with the following objectives:

- Promoting open access to facilitate consumer choice for certain classes of customers.
- Ending the CFE's monopoly on retail supply, at least to industrial or high-volume consumers, to encourage new entrants to consider developing new services and supplies.
- Encouraging the development of additional energy supplies to meet anticipated demand growth.
- Establishing capacity and ancillary service power markets to more effectively compensate generators for their contributions to grid reliability.
- Establishing an effective independent service operator (ISO) to give all participants confidence that dispatch and commitment would be nondiscriminatory.
- Separating the CFE itself into separate companies and subsidiaries for transmission, distribution, retail, and six individual generation portfolios to

encourage international participation and alleviate concerns of new entrants regarding horizontal market power.

- Restructuring the regulatory and operational frameworks to provide better information and spur private investment across generation, transmission, distribution, and supply.

The keystone legislations that underpin the structure of the electric sector today are the LIE, laws addressing the structure of CFE (CFE Law), and the Energy Transition Law (Ley de Transición Energética, LTE). The LIE and the CFE Law provide for the separation of the CFE into multiple competitive enterprises and forms the legal basis for the competitive and open-access electric market (Mercado Eléctrico Mayorista, MEM). The LTE establishes mechanisms and targets for achieving Mexico's climate goals (in cooperation with previous legislation) as well as Mexico's commitments made in Paris for the Paris Climate Agreement.² The LIE outlines responsibilities for the following key entities:

- The National Energy Control Center (Centro Nacional de Control de Energía; CENACE) is established as an ISO and charged with operation of the national electric system (Sistema Eléctrico Nacional, SEN).
- The Energy Regulatory Commission (Comisión Reguladora de Energía; CRE) organized under the Energy Secretariat (Secretaría de Energía; SENER) is the primary federal regulator, charged with implementing the LIE generally, and oversees specific operational items such as issuing generation and interconnection agreements.
- SENER is the part of the federal government charged with coordinating the initial implementation of market rules. Additionally, SENER coordinates policy-related matters such as establishing specific targets for renewable energy, overseeing the development of strategic natural gas storage, and encouraging third-party development activities in areas such as strategic transmission investments to support renewable development.

Perhaps the most important change involved the opening of the market for competitive supply. This resulted in the creation of energy and capacity markets. Under the new rules, residential supply remains regulated. Although private companies are able to apply for a basic supply permit, many believe that CFE is likely to remain the primary (perhaps sole) basic supplier. Qualified users with peak demand more than 1.0 MW have the ability to select alternate competitive suppliers. Aggregation of multiple meters is permitted to reach this threshold. Consumers with demand greater than 5 MW and 20 GWh/year can participate in the MEM and buy and sell energy directly.

The Role of Clean Energy in the Reform

Beginning in 2008, Mexico made its first efforts with respect to clean energy by setting national targets for nonfossil generation. In general, this effort was largely considered aspirational and lacked well-formed structures to encourage investment. The government provided important carbon management guidance in 2012.

From the outset of power sector restructuring, clean energy has been an integral part, incorporating aspirational goals and objectives into the design of the electricity market in the form of quota obligations for clean energy certificates (Certificados de Energía Limpia or CELs). When fully implemented, the market design is expected to provide investors with information about price, timing, and location of these sources.³ The CEL program was included in Mexico’s National Determined Contributions (NDC) submitted as part of the 2016 Paris Climate Agreement. The 35 percent target for 2024 was reaffirmed by the Senate in January 2016.⁴ Table 6.1 presents the long-term targets.

Table 6.1 Mexico Qualifying Generation Target by year

Year	Qualifying Clean Generation Target (percentage)
By 2024	35
By 2035	40
By 2050	50

Source: SENER, [https://sites.hks.harvard.edu/m-](https://sites.hks.harvard.edu/m-rcbg/cepr/Jeff%20Pavlovic%20Harvard%2021%20Mar.pdf)

[rcbg/cepr/Jeff%20Pavlovic%20Harvard%2021%20Mar.pdf](https://sites.hks.harvard.edu/m-rcbg/cepr/Jeff%20Pavlovic%20Harvard%2021%20Mar.pdf) accessed on 8 April 2018.

Although these targets are official, there are no national or international mechanisms binding the country to them. In Mexico, clean energy is defined to include renewable sources such as geothermal, hydro, solar, and wind; fuel free generation from efficient combined with heat and power plants, carbon capture and storage (with CO₂ emissions less than 100 kg/MWh); and, nuclear energy. Unlike renewable portfolio standards in the United States, the CEL program includes all non- or low-carbon-emitting sources as opposed to specific technologies such as wind or solar. Suppliers are required to source CELs for a specified portion of their annual supply. For 2024, the total requirement is less than 35 percent for existing and new renewable and non-carbon resources. Thus, CEL Target Levels are also set by SENER and intended to incentivize new supply. For 2018, the minimum level of consumption from clean technologies to be demonstrated is set at five (5) percent for all Load Serving Entities, including CFE. These targets are expected to increase as shown in table 6.2.

Table 6.2 CEL Targets

Year	CEL Target (percentage)
2018	5.0
2019	5.8
2020	7.4
2021	10.9
2022	13.9

Source: SENER, <https://sites.hks.harvard.edu/m-rcbg/cepr/Jeff%20Pavlovic%20Harvard%202021%20Mar.pdf> accessed on 8 April 2018.

Beyond 2022, *specific* annual targets are not yet defined.

Significantly, the CEL mechanism represents the first binding program for Mexico, and can be expected to target and accelerate clean energy (largely renewable) development. Retailers of energy are required to purchase or contract for CELs according to the percentage of load served for each listed year. Failure to acquire CELs results in fines per CEL that can vary. CENACE is the manager of the CEL program.

In addition to the CEL program, Mexico allows accelerated depreciation for renewables of up to 100 percent in the first year, or up to 5 years depending on the owner's needs.

Revised Roles for SENER, the CRE, and the CFE

The ministry of energy, commonly referred to as SENER, is in charge of conducting the country's energy policy. SENER has been responsible for implementing the transition to a market-based system establishing the terms for the unbundling of CFE and issuing the initial electricity market. SENER also monitors the clean energy (CEL) program.

The CRE was created in 1994 concurrent with the partial opening of the electricity sector. Since 1995, it has been responsible for the electricity and gas sectors, and obtained additional powers with respect to hydrocarbons and renewable energy generation in 2008. In the 2013 energy reform, the CRE was given budget autonomy. Additionally, the president now proposes the commissioners, and the Senate elects them. Currently, the CRE exists to:

- Promote sectoral competition while preserving minimum service levels nationally.
- Protect the interests of users.
- Ensure the reliability, stability, and security of supply.

Other responsibilities include regulating electricity generation, overseeing interconnection contracts, developing tariffs for basic electricity service, and preserving the efficiency and quality of the power grid. The CRE also oversees the wholesale power market promulgating appropriate rules and regulations, and certain verification aspects of the CEL market.

Geographic Scope of the Electricity System

Prior to the restructuring, the national grid consisted of nine regions. These regions included a handful of DC and synchronous border ties. Postrestructuring, SENER established a nodal pricing system. Mexico currently has four separate synchronous grids.⁵

- Sistema Interconnectada (SIN), the primary national grid.
- The Southern Baja California peninsula (BCS), which is isolated.
- A small isolated region in the middle of the Baja Peninsula (Mulegé).
- The Northern Baja California region (BCN), which is synchronously interconnected with CAISO in the United States.

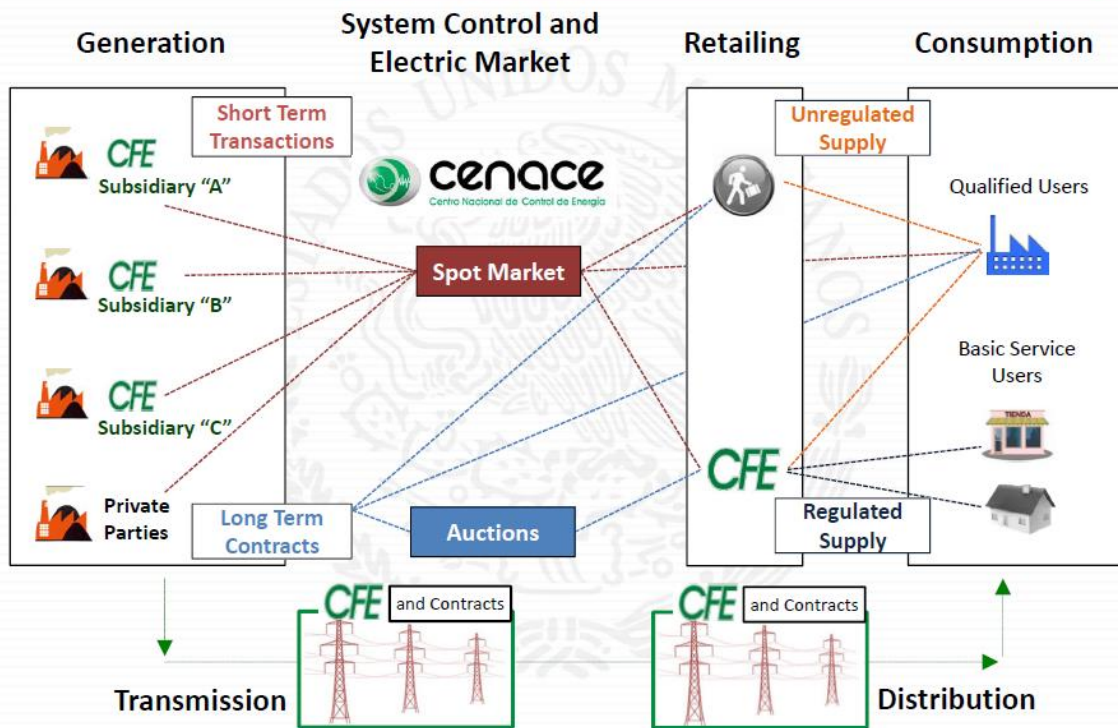
Subsequent sections present a greater discussion of supply resources, demand, and transmission.

Overview of the New Market Structure

The new market structure is characterized by the functional unbundling of CFE; the separation of the sector into generation, transmission, and distribution activities; and the introduction of market-based auction processes to establish prices for various activities. New market participants include qualified users and qualified suppliers, while certain activities such as basic service provision remain on a regulated rate-of-return basis.

Changes in the energy markets required a redefined set of activities. Chief among these is the role of CENACE. CENACE was created contemporaneously with the passage of the secondary laws in August 2014 as a public entity to operate the national electricity system. Beginning in 2016, CENACE initiated operation of the wholesale electricity market. The responsibilities of CENACE include guaranteeing nondiscriminatory access to the transmission and distribution grids, preparing expansion and modernization programs for the transmission network for approval by SENER, and planning and developing the National Electric System (PRODESEN). Schematically, the revised market structure can be visualized as shown in figure 6.1.

Figure 6.1 New Market Structure



Source: SENER, <https://sites.hks.harvard.edu/m-rcbg/cepr/Jeff%20Pavlovic%20Harvard%202021%20Mar.pdf> accessed on 8 April 2018

Revised Role for the CFE

From its formation in 1937, the CFE served as a strategic state enterprise functioning effectively as a monopoly. Following the 2013 restructuring, the CFE was transformed into a productive state enterprise with budget autonomy and a new board of directors. After the restructuring, it was split into subsidiaries for transmission, distribution, and power generation, each focused on profit generation for its owner, the Mexican state. The CFE retained exclusive rights over electricity transmission and distribution.

To constrain horizontal and vertical market power, attention was focused on the CFE and its ownership and control of many of the power assets in Mexico. Over 2016 and 2017, a set of separate companies was created, and management of activities began to be separated. Table 6.3 lists the primary entities created from CFE.

Table 6.3 List of Primary CFE Entities

Entity	Role
CFE Transmission	Administer and maintain the SEN transmission system
CFE Distribution	Administer and maintain the distribution network
CFE Basic Supply	Retail to regulated customers (residential)
CFE Calificados	Competitive retail to qualified users (>0.5 MW of demand)
CFE International	Competes in international and import/export fuel and electricity
CFE Energy	Commercializes gas, diesel and fuel oil
CFE Generation Entities 1–4 and 6	Five separate competitive generation portfolios
CFE Generador de Intermediación	Represents legacy contracts (self-supply and small producer) and plants in the market

Source: SENER.

Additionally, CFE’s nuclear Laguna Verde plant is held by the CFE Corporate company.

Timeline of Market Institutions Implemented During 2016-18

With the legislated changes to the existing sector participants underway, the process of implementing the desired market design was done in stages beginning in 2016. The first market design element to be implemented was the day-ahead wholesale market in the first quarter of 2016. This was followed by the first and second long-term auctions, with a contract term of fifteen (15) years for energy and capacity, and twenty (20) years for CELs. Credit support was bilateral between the parties, with the CFE as the monopoly purchaser. Pricing has been competitive, perhaps reflecting the original design idea of primarily facilitating recovery of costs of developers.

For a variety of reasons, the envisioned real-time wholesale market implementation was delayed and was established in the first quarter of 2017. A more fully featured implementation is envisioned. In mid-2017, CENAGAS, as the operator of a major portion of the Mexican natural gas transportation system, held the first auction to allow third-party contracting for firm gas transportation capacity. This was an important element for fuel supply and correspondingly long-term power pricing in other organized markets. A basic clearinghouse to provide credit support for buyers and sellers was formed in time for the

third long-term auction concluded in the fourth quarter of 2017. The first medium-term auction was held in the first quarter of 2018, with bilateral credit support between buyers and sellers. Participation was low and resulted in a single completed contract for capacity.

Timeline for Market Developments Envisioned During 2018-20

Over the next year, the following major market developments are currently contemplated.⁶

- Between 2018 and 2019, expanded clearinghouse functions are anticipated to support Long-Term and Medium-Term Auction transactions.
- Consistent and transparent spot-market-based gas pricing indices are expected to mature during 2018 in three to four hub locations. This can be expected to improve the day-ahead and real-time price formation processes in the wholesale power market.
- In July 2018, a national presidential election is to be held. Depending on the successful candidate and resulting policies, electricity market developments could be substantively altered.
- During 2018, the values of current and future CELs are expected to be established through the introduction of a market-based mechanism.
- During 2018, two bidding processes are expected for the addition of strategic high-voltage transmission projects to be held in Mexico. In one, it is envisioned that a selected developer will connect renewable generation to be located in Oaxaca, with demand located generally in the center region of Mexico under a BOT (build, operate, transfer) contract with CFE Transmission. The second transmission project, under tender by SENER with a DFBOT (design, finance, build, operate, transfer) contract is expected to connect the Baja California system with the National Interconnected System. The commercial on-line date for each project can be expected to require several years for development and construction.
- Before the end of 2018, a market in financial transmission rights is anticipated to be introduced. This market is expected to be designed to provide products that mitigate congestion costs, reducing price risk and uncertainty for consumers and

generators. The design parameters are public; uncertainty remains regarding the implementation model.

- During 2018, the CFE is expected to release more detailed information about the status of and plans for its distribution system. Depending on the nature of the disclosures, this may provide a foundation and framework for additional deployment of distributed energy resources.
- By 2021, CENAGAS (Centro Nacional de Control de Gas Natural) expects to add strategic gas storage to the system to increase gas system reliability and increase operational flexibility. This has potential to offset liquid natural gas (LNG) consumption with a corresponding reduction in the level of wholesale power market pricing as well as reducing price volatility.

Growth in Consumer Demand

Over the past 20 years, Mexico has had substantive demand growth. Using a rolling average between 1993 and 2016, annual peak demand growth has averaged 3.5 percent, and overall peak demand has almost doubled.⁷ Like other North American markets, demand growth has slowed in recent years. Between 2006 and 2016, a similar rolling average calculation returns a more modest value of 2.4 percent.⁸ By way of comparison, U.S. peak demand growth has averaged less than 1 percent in recent years.

Compared to overall consumption, industrial load is substantial in Mexico. In recent years, growth has been driven by the hydrocarbon, textile, and automotive manufacturing sectors. Today, industrial consumption accounts for over half of total demand, comparable to that of the U.S. Gulf Coast. Nationwide, however, industrial load only accounts for 25 to 30 percent of U.S. demand.⁹

Mexico's residential electrification is substantive; more than 99 percent of houses have service. However, average household demand is relatively low thanks in large part to the temperate, consistent climate in many large population areas that holds down air conditioning demand. Table 6.4 describes regional noncoincident peak load.

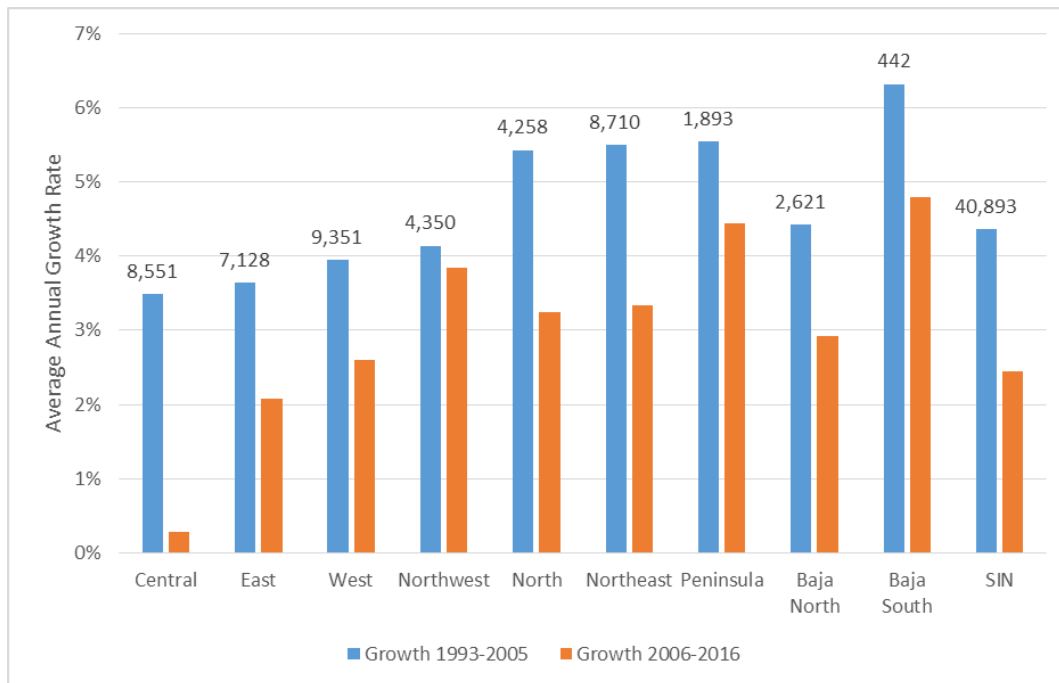
Table 6.4 Regional Noncoincident Peak Load

Region	Peak Month
BCN	August
BCS	July
Central	December
East	May
North	June
Northeast	August
Northwest	July
Peninsula	May
West	May

Source: SENER, “Programa de desarrollo del sistema eléctrico nacional” [National electricity system development program], August 30, 2017, <https://www.gob.mx/sener/acciones-y-programas/programa-de-desarrollo-del-sistema-electrico-nacional-33462>.

Regional peaks typically do not occur in the mid-afternoon (3 to 6 p.m.). In some cases, these can occur as late as 11 p.m. The lack of a summer residential air conditioning peak coupled with high industrial demand and regional peak variation contribute to a very high 83 percent annual average load factor in 2016.¹⁰ A more typical value across North America is 55 to 65 percent (figure 6.2).

Figure 6.2 Regional Peak Demand Growth



Source: “Programa de desarrollo del sistema eléctrico nacional.”

Demand growth has been highly regionalized. The North and Peninsula regions show strong demand growth over the past 10 years, while the growth in the Central region has remained static. Much of the traditional demand in this region has shifted to adjacent regions such as the West.

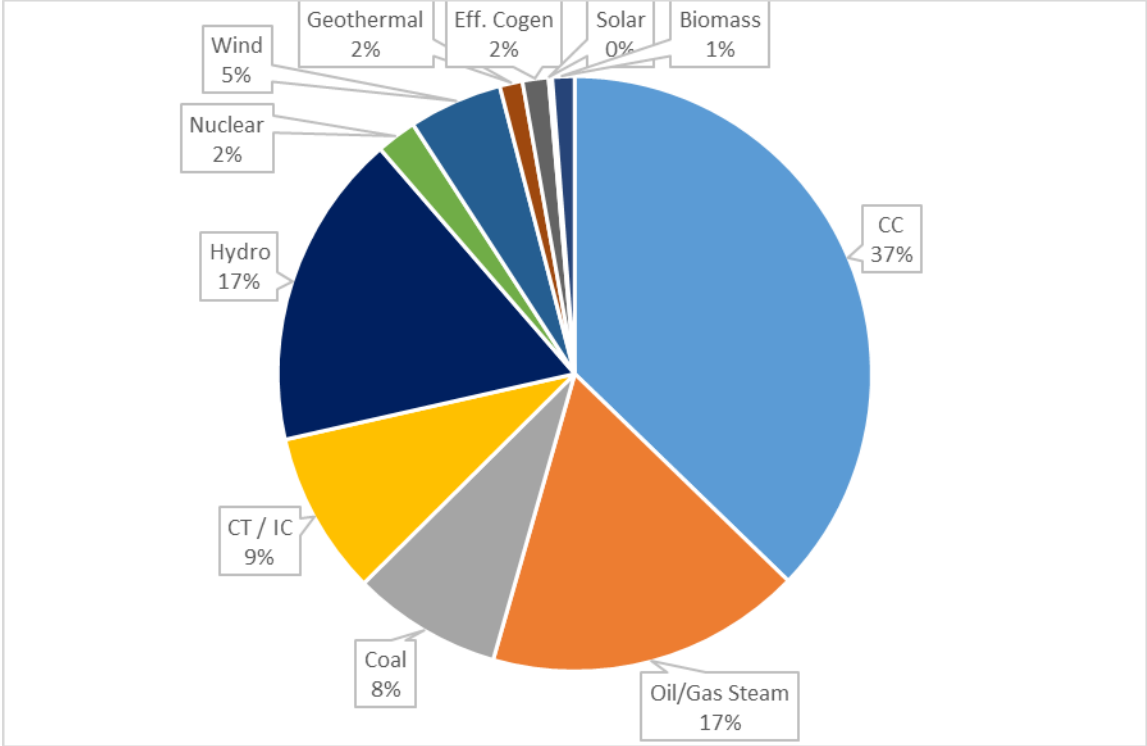
The Peninsula and Baja South are experiencing stronger demand growth as general infrastructure improves. Industrial and population-driven growth continues in the North and Northeast regions.

Existing Generation System

Historically, Mexico’s capacity mix has been a function of local fuel sources, largely oil and gas (figure 6.3). Many oil-burning steam units date from the 1980s and 1990s. Today, many of these are dual-fuel natural-gas capable. Beginning at the turn of the century, a buildout of more fuel-efficient combined cycle units took place in Mexico and North America.

Mexico has significant and large hydro resources, mainly in the south and west. Three major coal plants are in place with coal from international markets, especially Colombia. Laguna Verde, a nuclear plant, operates in Veracruz.

Figure 6.3 2016 Capacity (73,510 MW) by Fuel Source



Source: "Programa de desarrollo del sistema eléctrico nacional."

Beginning in the early 1990s, international companies were encouraged to build generation in Mexico (table 6.4). Largely gas-fired, these new units were offered a long term purchased power agreement from the CFE. By 2016, these companies had grown substantively in size.

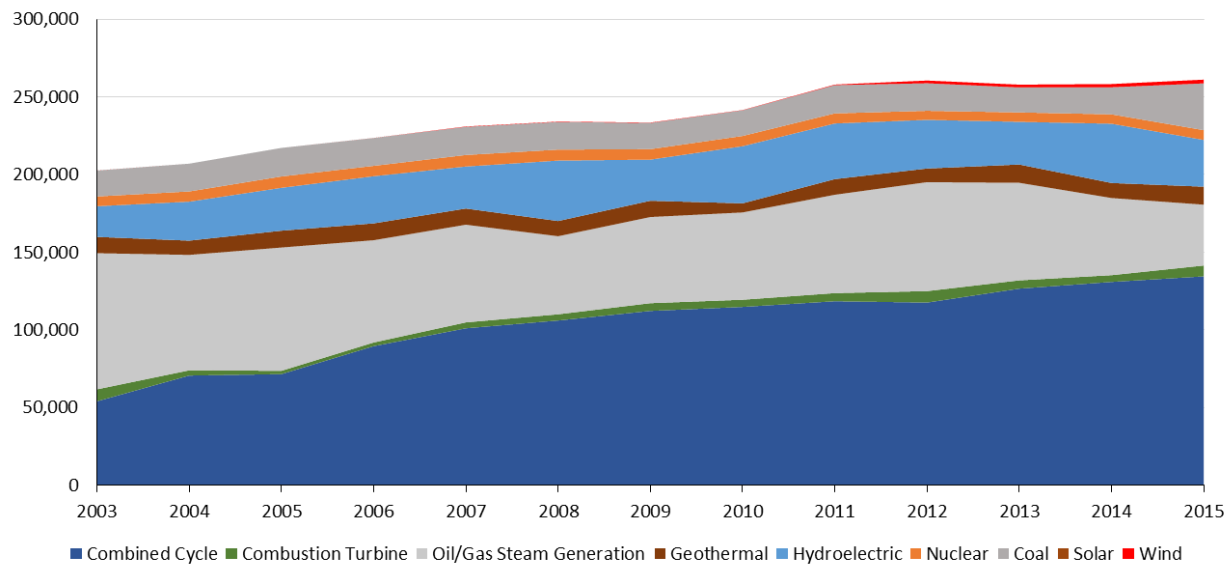
Table 6.4 2017 Existing Capacity by Company and Type

Operator	CC	ST	GT	Hydro	Nuc	Geo	Wind	IC
CFE	6,609	15,587	5,490	11,855	1,365	911	268	418
Iberdrola	5,253	–	–	–	–	–	–	–
Intergen	2,260	–	–	–	–	–	–	–
Mitsui	2,146	–	–	–	–	–	–	–
Fuerza y de Energia de Tuxpan	1,120	–	–	–	–	–	–	–
Techgen	1,025	–	–	–	–	–	–	–
Termoelectrica de Mexicali	625	–	–	–	–	–	–	–
Acciona	–	–	–	–	–	–	588	–

Source: “Programa de desarrollo del sistema eléctrico nacional.”

The Northeast and East control areas have the largest amount of installed capacity, followed by the West. Gulf Coast natural gas production and gas pipelines facilitated the building of a number of combined cycle units in the Northeast region. Oil-burning capacity is concentrated in the Central, West, and Northwest regions. Much of the clean energy renewable production has been in the East and West regions with large hydro plants; however, current developments favor solar and wind expansion (figure 6.4).

Figure 6.4 Generation Mix by Technology

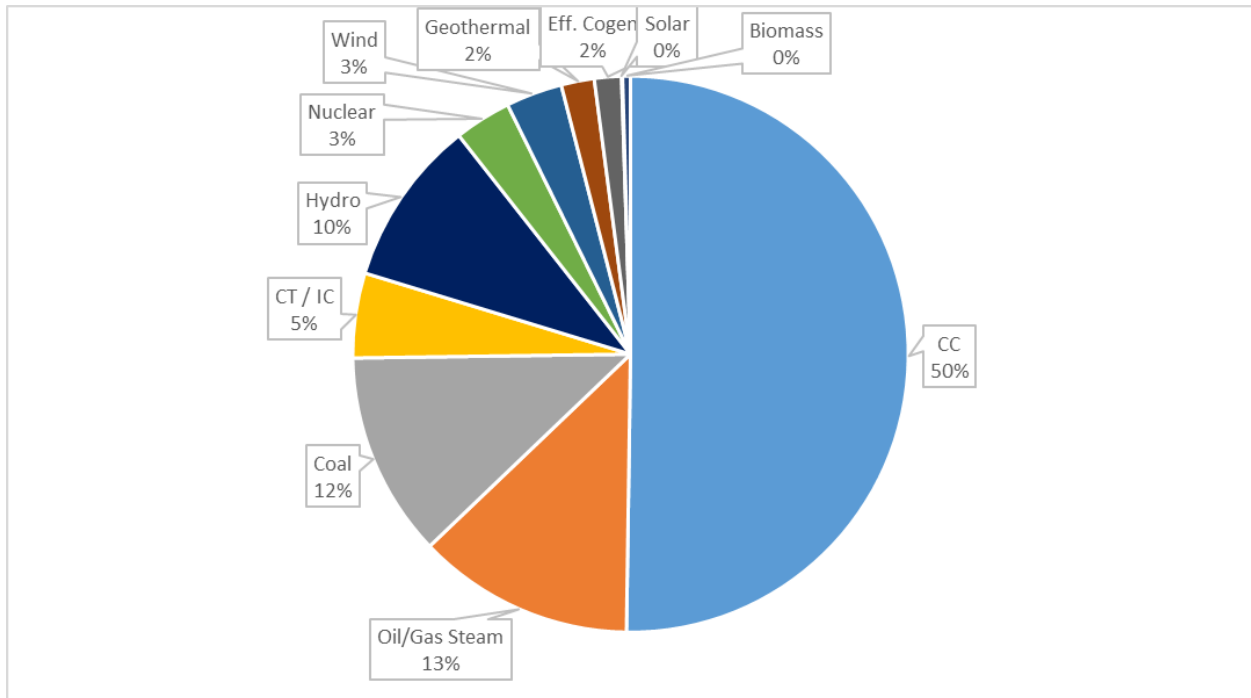


Source: SENER, *Prospectiva del sector eléctrico, 2017–2031* [Electricity sector prospects, 2017–2031], https://www.gob.mx/cms/uploads/attachment/file/284345/Prospectiva_del_Sector_El_ctrico_2017.pdf.

Due to falling costs for gas, more attractive conversion efficiencies, and environmental considerations, the fuel mix has shifted from oil-fired to gas-fired generation. Between 2012 and 2017, CFE has had a goal of reducing oil consumption by more than 80 percent. Although reaching this goal has proven elusive for fuel reliability reasons, progress has been made and can be expected to continue as gas pipeline expansions currently in progress are completed.

Overall, combined cycles generated fully half of the country’s electricity in 2016 (figure 6.5). Baseload units typically with a capacity factor (CF) of 80 percent include coal and gas units. Combined cycle (CC) units typically average 65 to 70 percent CF, while the CF for oil/gas units has averaged 35 to 40 percent. Hydro averages a 30 percent CF.

Figure 6.5 2016 Generation Energy Production by Fuel Source (Total: 319,364 gigawatt-hours [GWh])



Source: "Programa de desarrollo del sistema eléctrico nacional."

The Restructured Wholesale Market and Participants

The electricity sector restructuring provided for the creation of a wholesale electricity market (Mercado Eléctrico Mayorista; MEM). Under this program, licensed private companies are allowed to produce and sell electricity in competition with the CFE and each other.

Background

In 2015, SENER published the Bases del Mercado Eléctrico (Electricity Market Bases) establishing the electricity market design. The document also described operating principles to be implemented in two phases.¹¹ The MEM has the following major components:

- Short-term markets (day-ahead, hour-ahead, real-time, and ancillary services).
- Medium-term auctions for three-year energy and capacity contracts.

- Long-term energy auctions with a 15-year minimum.
- A capacity-balancing market calculated after-the fact for the previous year.

At the time of writing, the following components are currently in development.

- Enhancements to the real-time (hour-ahead) and ancillary service markets.
- Financial Transmission Rights auctions (annual first, quarterly and monthly in a later phase).
- CEL markets (at least once per year beginning in 2018).

Market Participants and Basic Service

Currently, the CFE is currently the only provider of electricity for “basic” service. This is largely targeted at residential, small commercial users, and medium-sized commercial users under regulated tariffs. However, the new market structure allows large energy consumers to satisfy their electricity needs in a variety of ways (table 6.5). Qualified users might conclude a bilateral contract directly with power generators, or rely on the services of qualified suppliers. A consumer may register as a qualified user if it has an expected annual peak demand of 5 MW or more, and consumption of 20 GWh over the year. A qualified user may bid in the auctions to purchase energy, capacity, and CELs.¹² As of January 31, 2018, total of 80 market participants were licensed to operate in the MEM.

Table 6.5 Roles of Market Participants

Market Participant	Number of Suppliers	Description
Basic Service Supplier	1	Represents load centers corresponding to Basic Service Users.
Basic Service User		End User receiving service from a Basic Service Supplier.
Broker/Marketer (Nonsupplier)	11	Trades energy without representing physical assets.
Last Resort Supplier		Represents Qualified Users for a fixed period of time usually under emergency grid conditions.
Power Generator	38	Represents one or more generating plants.
Qualified Supplier	27 (6 in operation)	Represents load centers of Qualified Users that do not participate directly in the MEM.
Qualified User		End User with estimated demand of over 1 MW who buys energy from a Qualified Supplier.
Qualified User (Market Participant)		Represents load center for own consumption, procures electricity directly in the MEM or bilaterally.

Source: SENER, CENACE as of January 2018, <https://sites.hks.harvard.edu/m-cbg/cepr/Jeff%20Pavlovic%20Harvard%2021%20Mar.pdf> accessed on 8 April 2018.

Day-Ahead Market

The day-ahead market began operation in January 2016. Approximately 2,360 locational marginal prices have been established with nodal price calculations including energy, congestion, and loss components. In addition, CENACE reports 101 “distributed nodes” representing average off-taker pricing in a given area. Day-ahead offers are capped to variable costs.

In August 2016, CENACE undertook to recalculate prices back to the beginning of the market as bids were exceeding allowable costs, inflating reported prices. The restated prices were approximately 18 percent lower. CENACE is now implementing tools to disqualify excessive bids in real time. To date, the day-ahead market has been the primary platform for price discovery. It provides the baseline for auction and contract pricing.

Real-Time Market

The real-time market began reporting prices in January 2017 with prices calculated ex-post and reported the following day. Price components are the same as in the day-ahead market. Convergence issues between the real-time and day-ahead markets existed during much of 2017 with real-time prices up to 20 percent higher than day-ahead prices. The market is expected to move to real-time price formation.

Hour-Ahead Market

The hour-ahead market is intended to facilitate arbitrage between the day-ahead and real-time markets. It is expected to be established in the future.

Capacity-Balancing Market

To ensure resource adequacy, CENACE has adopted a unique structure that establishes annual capacity requirements for all load-serving entities. A priori, the protocol establishes capacity procurement requirements. Throughout the performance year, system capacity shortage or excess is measured. Ex-poste, the balancing capacity market compares actual conditions with initial requirements for the preceding year. The resulting system levels drive prices for the longer-term capacity transactions in the same way that real-time energy price expectations drive forward energy contracting.¹³

The balancing capacity market focuses on calculations of load and delivered capacity during 100 “critical hours” of the year. The critical hours are estimated a priori and calculated ex post. Initially, the 100 critical hours were considered to be the highest load hours. In the future, however, critical hours will be those with lowest operating reserves. The ex post market clears in February for the preceding year. Considerations include the establishment of a vertical supply curve based on availability and a demand curve that considers a minimum planning reserve for reliability, economic planning reserves from modeling results, reference technology costs, and energy revenues.

The minimum reserve margin target is established by a loss-of-load expectation of 0.2178 percent, or approximately 1 day in 1.5 years. With an established value of lost-

load of \$2,600 per megawatt-hour (MWh), the economically efficient loss-of-load expectation is calculated at 0.0315 percent, or near the 1-day-in-10-year standard commonly used in U.S. markets.

As of this writing, the SIN has cleared as a single zone with the BCN and BCS grids clearing separately. Subzones may emerge in the future.

Long-Term Auctions

To encourage the development of new capacity, CENACE has held three long-term auctions. The auctions are neutral between qualifying technologies. All transactions are completed under standardized contracts of 15 years for electricity and capacity, and 20 years for CELs. The awarded contracts support the construction of solar and wind power plants. SENER indicates that they expect that the auctions will facilitate a total investment of around US\$9 billion.¹⁴

The first auction concluded in March 2016, the second in September 2016, and the third in November 2017. In these first two auctions, the CFE was the only buyer. However, in the third auction, CENACE established a clearinghouse (Cámara de Compensación; CdeC) through which all buyers and sellers operated with a single contract and centralized credit support. In the first two auctions, the CFE provided performance guarantees for the awarded contracts under a single buyer model. This role has now been passed to the CdeC, which will collect and hold specific guarantees. The level of these guarantees will be set in the auction guidelines. With the introduction of CdeC, the credit risk associated with a power purchase agreement will not be with a specific company but with the market as a whole. CdeC will also have a reserve fund that all parties will pay into giving it liquidity, and will manages the performance guarantees from each party.

To participate in the long-term auction, participants follow formal guidelines submitting bids. First, participants are prequalified by CENACE and make guarantee payments to demonstrate that the offers will be serious ones. The traded products include energy (as a firm delivery schedule), capacity (representing coverage in the balancing capacity market), and CELs from qualifying plants. Energy and capacity contracts are for 15 years;

CEL contracts are for 20 years. Bids must be submitted as descending offer curves for each product, though prices for energy can be shaped according to the delivery schedule. Bids are then aggregated for each product and an offer curve published. Projects may submit offers for one or more products. Projects can also require all or part of the bid to clear in order to be accepted. CENACE clears the three products together, taking the least-cost combination of projects to meet the three offer curves. Offers are either accepted and paid face value or rejected. As a result, the auction does not result in a single price to be paid.

Prior to clearing, CENACE modifies the bids in two ways. First, based on SENER projections of locational pricing, CENACE can set energy price adjustments based on the location of the project. The actual payment made to the plant is unaffected. Projects bidding in a region with high price adjustments effectively can have a bid reduced in the competitive stack, making it more likely to clear even with a higher submitted price. The second element that can modify a bid is a project's interconnection status. If a project has already secured interconnection rights, it is referred to as a "priority" project. A "nonpriority" project has not gained these rights. In the second and third auctions, valuation parameters became more stringent for nonpriority projects. Additionally, for nonpriority projects, interconnection areas and export zones are identified and quantity limits set for each product in each subzone. These nonpriority projects typically must be the cheapest bidder in the subzone to be considered for clearance in the grid-wide offer curve. Thus, these additional details effectively create multiple levels of competition.

The first three long-term auctions have resulted in stiff competition. It is interesting to note, however, that the structure more closely resembles a utility request-for-proposal process than the capacity auctions in selected U.S. markets. In these markets, contract lengths are shorter and have no energy or renewable energy certificate components.

Once accepted, all contracts begin on January 1 of the year beginning three years after the auction. For instance, the 2018 auction had a contract start date of January 1, 2021. If the plant is not in commercial operation by the deadline, a fine of 5 percent of the

monthly value of the contracted products is assessed. Additionally, increased payment guarantees to CENACE may be required. If the project is delayed more than two years or cancelled, these events can result in further fines or the forfeiture of bidding guarantees.

Medium-Term Auctions

Although the long-term auctions are open to new or repowered capacity, the medium-term auctions are designed to support existing capacity. The medium-term auction market closed in February 2018; however, only a single contract was cleared. The products available are capacity and energy, in contract lengths of one to three years. Specifically, offers are defined by the following characteristics:

- Energy offers are defined by total energy as a fraction of load per year, for given load blocks (peak, intermediate, and base), for a given load zone (of which there are eight roughly corresponding to control areas), at a given offer price.
- Capacity offers are defined by quantity, price, year, and capacity zone (now BCN, BCS, and SIN).

The intent of the medium-term auction is to minimize merchant exposure, in both energy and capacity, for both generators and suppliers. The initial view was that the long-term auctions were designed to recover a developer's cost, whereas the medium-term auctions were an opportunity to better match the level of fixed price risk with a participant's view of underlying supply and demand conditions. As a result, the health of the medium-term market ultimately may prove critical.

Viewed from this perspective, the initial 2018 results were not encouraging. In other markets, fixed price contracts of three years or less result have typically resulted in substantively higher transaction volumes as aggregators and consumers (qualified users) seek to obtain competitive prices in advance with certainty and merchant generators (qualified suppliers) seek stable revenues to provide consistent returns to investors.

Financial Transmission Rights

Financial transmission rights cover the difference in cost between two nodes on the transmission system due to congestion and are a feature of many markets in North America. Compared to the end-use price that a consumer might pay, these costs can be substantive.

As of February 2018, the market mechanisms have not been implemented. Some market participants have argued that success requires a market maker structure where a market participant is paid by the market operator to make a two-way (buy and sell) market. Others have expressed concerns that the product features are not clear and could lead to lower liquidity depending on the decisions that CENACE ultimately makes. Still others have argued that the credit support that CENACE will offer is not clear, and could slow down acceptance. Since the price differentials can be large, these participants generally favor a clearinghouse for credit support to reduce the probability of default risk. For the legacy transmission system (the SIN), financial transmission rights are expected to be assigned to generators and suppliers according to their historical system usage between August 2012 and August 2014. Thereafter, rights will be auctioned or traded in the established market.

The current lack of a financial transmission rights market is cited as a factor holding back the growth of the retail market. Until these products are established, qualified suppliers and qualified users are unable to hedge transmission risks across the system. While this is a concern, other developments may also play a role.

Bilateral Contracts

Whereas the long-term auctions currently result in bilateral contracts with a central clearinghouse, and medium-term contracts are expected to duplicate this in 2019, contracting outside of the MEM is also allowed directly between market participants. CENACE describes three types of allowed contracts (table 6.6).

CFE Basic Supply cannot sign bilateral contracts outside of the medium- or long-term auctions. However, qualified suppliers are allowed to sign bilaterally outside of the formal mechanisms. To date, only a handful of bilateral contracts have been signed. Most commonly mentioned are Blackstone through its Ektria market intermediary and its Frontera combined cycle plant, and CFE Qualified Supply.

Table 6.6 Types of Bilateral Contracts

	TBPot	TBFin Fijos	TBFin Referencidas
Type	Capacity Contract	Fixed Energy Delivery Schedule	Percentage of Unit Generation or Supplier Demand
Settlement	Determined by Parties	Financially Settled	Financially Settled
Fund Flow	Directly Between Parties	Through CENACE Accounts	Through CENACE Accounts
Units	MW per Hour	Fixed MWh	% of Unit or Load
Market	Balancing Capacity	DA or RT	RT Only
Location	Zone (SIN)	Node	Node

Source:

<http://www.cenace.gob.mx/Docs/MarcoRegulatorio/Manuales/Manual%20de%20Transac%20Bilaterales%20y%20Registro%20Contratos%20Cobert%20Elec%20DOF%202017%2001%2020.pdf> accessed on 8 April 2018.

Some market participants hope that contracting will increase as more qualified users enter the market and qualified suppliers attempt to increase market shares in the coming years.

Market Implications

Why was participation in the first medium-term auction so low? It is hard to be certain, but some reasons have been cited frequently.

First, the restructuring established the notion of a Basic Service Rate Structure. The Basic Service Rate Structure effectively is designed to provide a user with an understanding of the rate that the CFE would offer under the new market conditions. In other North

American markets, this is somewhat analogous to the “price to beat,” or as economists sometimes call it, an “avoided cost.” Based on the outlook for this rate, as well as the user’s size, and other factors, the user could decide how to approach the new market. The user might retain Basic Service from CFE or (if qualified) become a qualified user or a qualified user (direct market participant). However, prior to December 2017, there was little clarity as to what the new rate methodology for Basic Service would be. In this information vacuum, consumers were understandably not motivated to purchase new or replacement supplies since there were few transparent price benchmarks for decision making. The CRE completed and published the Basic Service structure in December 2017, but there was little lead time for consumers to decide to become qualified users if they had not already done so. Further, for those who had obtained qualified user status, there was little time to make decisions and submit bids for the medium-term auction, which closed in February 2018.

Additionally, there was substantive confusion about the methodology used to establish the Basic Service rate. Chief among these was the inclusion of a transition mechanism (weighting factor) that effectively “phased in” the impact of the new rate—generally an increase—over a period of months during the first year. The Basic Supply structure also established a higher capacity value for certain cities and zones than it did for others, which further differentiated regional prices. This two-part structure added complexity as a consumer sought to understand the costs it would face and what value a qualified user/qualified supplier might bring in the future. Qualified user perspectives initially had been that prices were going to be lower as a result of competition, and this biased them to wait to understand more about future costs. With the possibility that prices might be more volatile (as opposed to simply lower or higher), some were not prepared to make effective decisions in time for qualified users to support the first medium-term auction. Some broker/marketers, qualified suppliers, and qualified users suggest that the lack of a market in firm transmission rights means that consumers cannot fix or hedge the costs of congestion that they accept. This means that any alternative to the Basic Rate cannot be fully guaranteed (or fixed), reducing the attractiveness of the medium-term auctions.

In subsequent medium-term auctions, price discovery can be expected to provide some visibility into forward retail price trends. Further, the transition period and monthly weighting phasing in the new rate structure will end. Thus, some of the key elements to watch and measure the success of the reforms include the following:

- How will qualified users respond to the Basic Service rate structure
- How will the pricing history of the Basic Service tariff develop?
- Will qualified suppliers accept the medium-term auction process? Will they need to stabilize their revenues to meet profit and rate of return objectives promised to their investors? Will they need to augment their revenues under the long-term auction contracts given how low prices have been in the second and third auctions, or will additional revenues from the capacity balancing markets, and the day-ahead/real-time markets prove to be sufficient?

Long-Term Auction Market Results

As of this writing, CENACE has organized three long term auctions. This section reviews the results of the auctions and the contracted generation additions. During the first auction, 5.4 TWh was contracted. In the second auction 8.9 terawatt-hour (TWh) projects won contracts. In the third LTA contracted for 5.5 TWh of clean electricity. Table 6.7 demonstrates that the three auctions have been of substantive interest to the investment community. Prices are competitive compared with the existing system as well as reported installed prices in other jurisdictions.

Table 6.7 Auction Results by Technology Type

	First Auction	Second Auction	Third Auction
Gas (MW)			550
Geothermal (MW)		25	
Solar (MW)	1691	1853	1323
Wind (MW)	394	1038	689
Average Price (USD/MWh)	\$41.80	\$33.47	\$20.57

Source: SENER and CENACE, <http://zumma.com.mx/insights.html>.

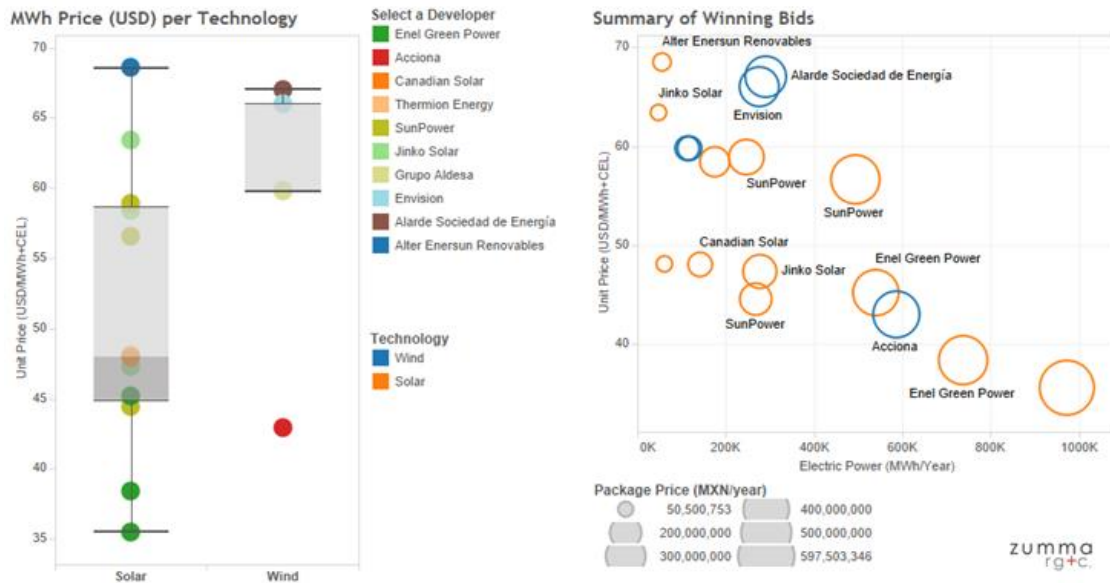
For the third auction, the average price per MWh of \$20.57 (including a value for CELs) fell to a level substantively below what many believe is a levelized cost of energy for new natural gas generation. Market sources believe that the value of a CEL might be \$13–\$14/MWh, although these vary widely as the results of Auction 2 show. If correct, this implies a technology-specific levelized cost of energy of US\$20.57/MWh + US\$13.50/MWh or perhaps US\$34/MWh if CO₂ emissions have a value of zero.

Gas generation, likely the next lowest cost conventional alternative, has additional value compared to renewables. These additional values include contributing to dispatch reliability and ancillary services, which solar and wind generally do not; market sources estimate current U.S. costs (in Texas) for gas-fired technology to be around US\$45/MWh, assuming that the penalty assigned to this technology's CO₂ emissions are zero. Many observers assume that gas prices in Mexico for the near to medium term will remain linked to market prices for gas in Texas. Further, assuming that market sources are correct in suggesting an average cost in Texas (ERCOT) of US\$9/MWh for shaping and firming services to be relevant for Mexico, this means that prices bid by solar and wind projects in the third auction are believable and reasonable since US\$34/MWh + US\$9/MWh = \$44/MWh. Finally, it is also clear that these renewable resources are at “grid parity” from a cost perspective.

Auction 1 Review

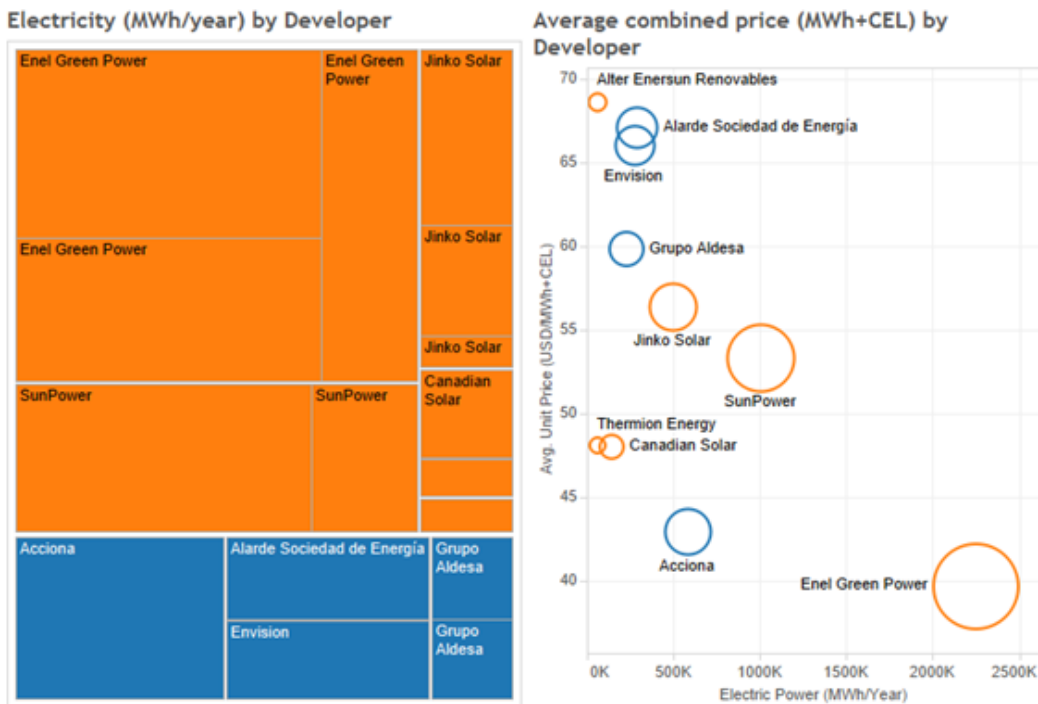
The first long-term auction started in November 2015 and ended in March 2016 (figure 6.6). Eleven companies secured contracts with 18 winning bids. They were selected out of 69 participants that submitted 227 offers (figure 6.7).

Figure 6.6 Auction 1 Price Results



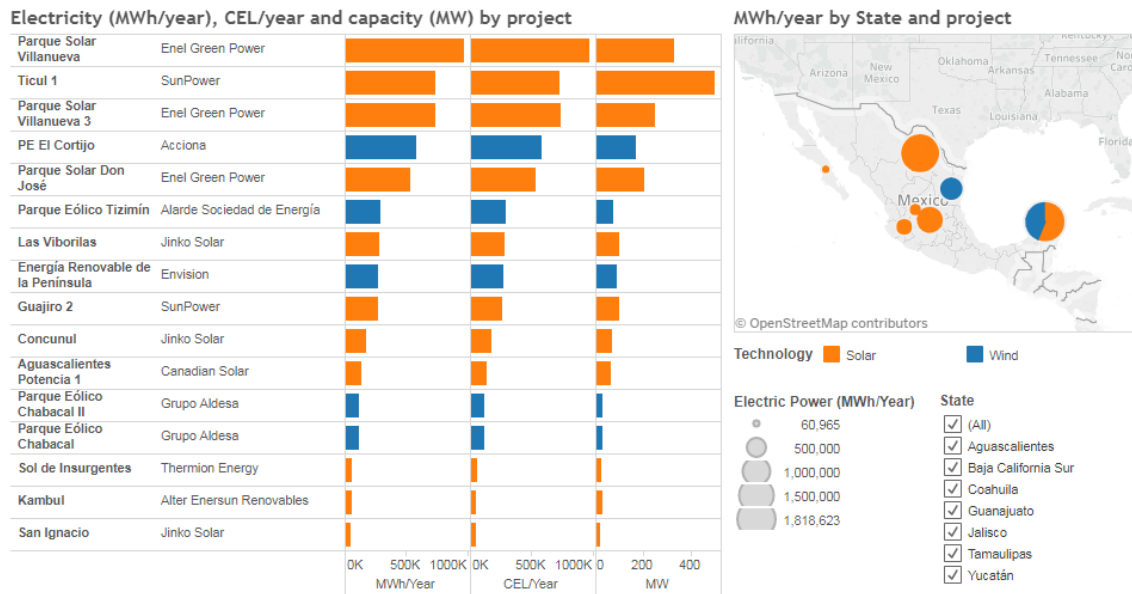
Source: zumma rg+c, <http://zumma.com.mx/insights.html>.

Figure 6.7 Auction 1 Price and Volume Assessment



Source: zumma rg+c.

Figure 6.8 Auction 1 Volume and Location Assessment



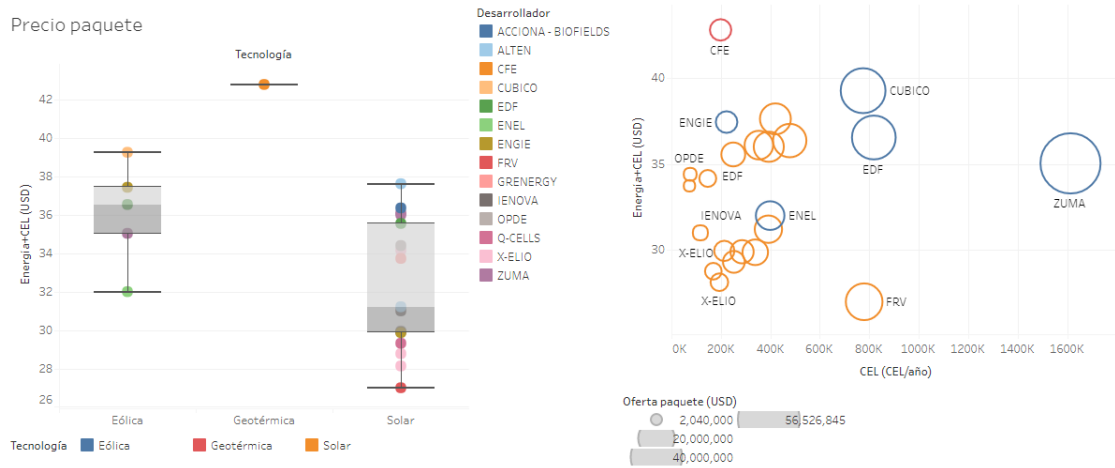
Source: zumma rg+c.

The winning projects are expected to supply 5,402,881 MWh of electricity per year. Solar represented 74 percent of the total, wind 26 percent. There was no interest in the firm capacity component as the price suggested under the auction rules was too low.

Auction 2 Review

The second auction was launched in April 2016, with results announced in September 2016 (figure 6.9).

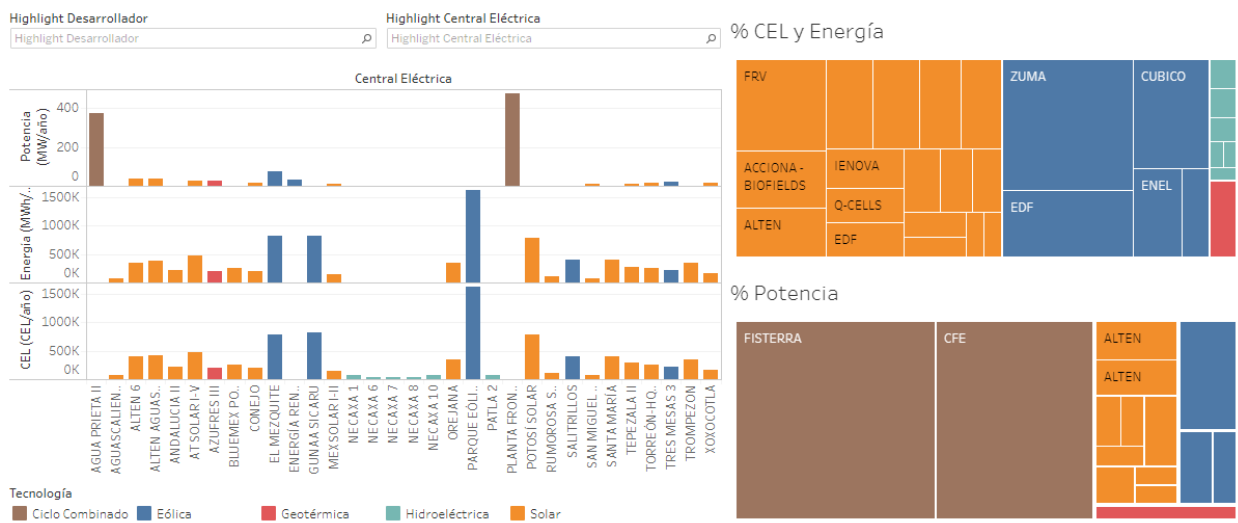
Figure 6.9 Auction 2 Price Results



Source: zumma rg+c.

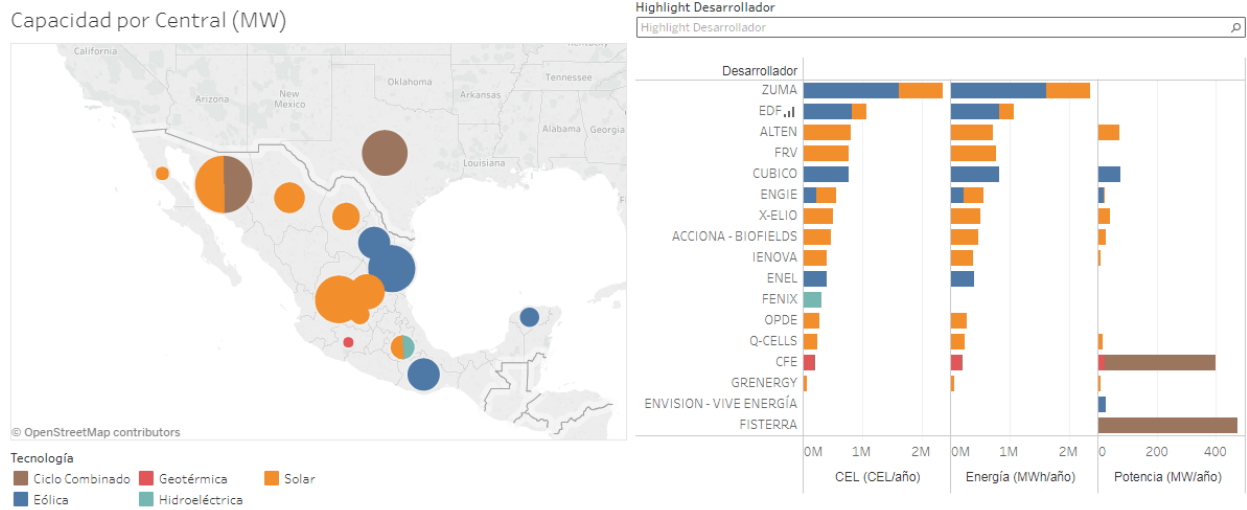
A total of 57 companies submitted economic offers in the competition, out of which 23 entities secured contracts (table 6.8). Successful projects included 1,853 MW of solar, 1,038 MW of wind, and a 25-MW geothermal project. Interestingly, 68 MW of hydropower secured CELs and a 90-MW wind project as a firm capacity contract (figure 6.10, 6.11, and 6.12).

Figure 6.10 Auction 2 Capacity and CEL Assessment



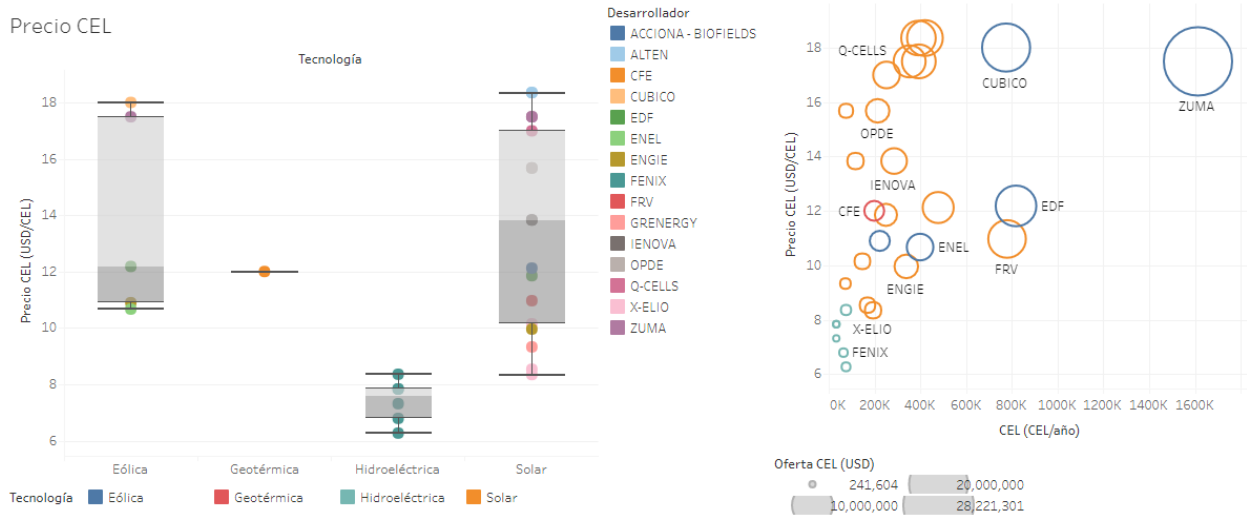
Source: zumma rg+c.

Figure 6.11 Auction 2 Volume and Location Assessment



Source: zumma rg+c.

Figure 6.12 Auction 2 CEL Price and Volume Assessment



Source: zumma rg+c.

Table 6.8 Auction 2 Company Participation and Technology Assessment

Participación por Desarrollador						Porcentaje por Tecnología			
Desarrollador	Energía (MWh/año)		Certificados (CEL/año)		Potencia (MW/año)	Tecnología	Energía (MWh/año)	Certificados (CEL/año)	Potencia (MW/año)
ZUMA	18.11%	8.38%	17.39%	8.05%	0.00%	Solar	54.28%	53.19%	15.49%
EDF	9.18%	2.81%	8.82%	2.70%	0.00%	Eólica	43.49%	41.28%	10.81%
CUBICO	9.21%		8.35%		6.46%	Geotérmica	2.23%	2.14%	2.11%
FRV	8.74%		8.40%		0.00%	Hidroeléctrica	0.00%	3.39%	0.00%
ALTEN	8.10%		8.76%		6.28%	Ciclo Combinado	0.00%	0.00%	71.59%
ENGIE	2.50%	3.85%	2.40%	3.65%	1.82%	Grand Total	100.00%	100.00%	100.00%
X-ELIO	5.73%		5.50%		3.54%				
ACCIONA - BIOFIELDS	5.37%		5.16%		2.44%	Tecnología	Energía (MWh/año)	CEL (CEL/año)	Potencia (MW/año)
ENEL	4.48%		4.30%		0.00%	Solar	4,836,597	4,933,382	184
IENOVA	4.40%		4.34%		0.84%	Eólica	3,874,457	3,828,757	128
OPDE	3.25%		3.12%		0.00%	Geotérmica	198,764	198,764	25
Q-CELLS	2.83%		2.72%		1.54%	Hidroeléctrica	0	314,631	0
CFE	0.00%	2.23%	0.00%	2.14%	31.59%	Ciclo Combinado	0	0	850
GREENERGY	0.82%		0.79%		0.84%	Grand Total	8,909,819	9,275,534	1,187
FISTERRA	0.00%		0.00%		40.01%				
FENIX	0.00%		3.39%		0.00%				
ENVISION - VIVE ENER..	0.00%		0.00%		2.53%				

Source: zumma rg+c.

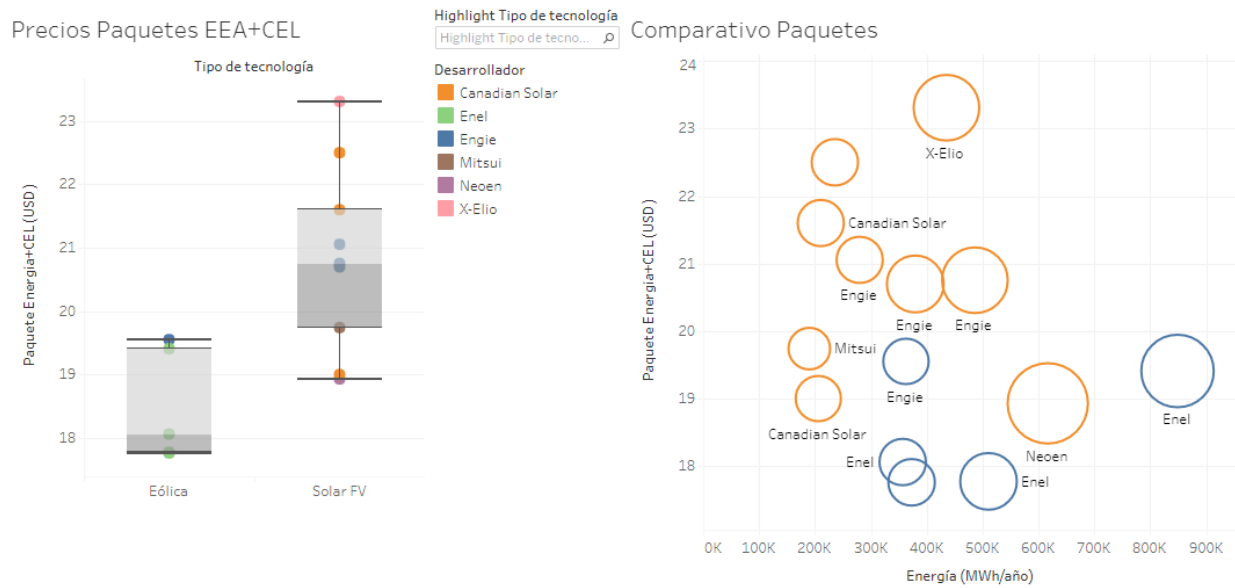
During the second auction, CFE had offered to buy a larger volume of electricity and more than 8.9 million MWh of supply was procured, which represented 83.4 percent of the proposed amount. Further, this was an increase of 65 percent from the first tender.

Zuma Energia, backed by Actis and Mesoamerica, received 725 MW. Cubico Sustainable Investments, in partnership with Alten Energias Renovables, won 540 MW. Solar developer Fotowatio Renewable Ventures won a 300-MW solar project, while EDF Energies Nouvelles won 252 MW of wind and 90 MW of solar.

Auction 3 Review

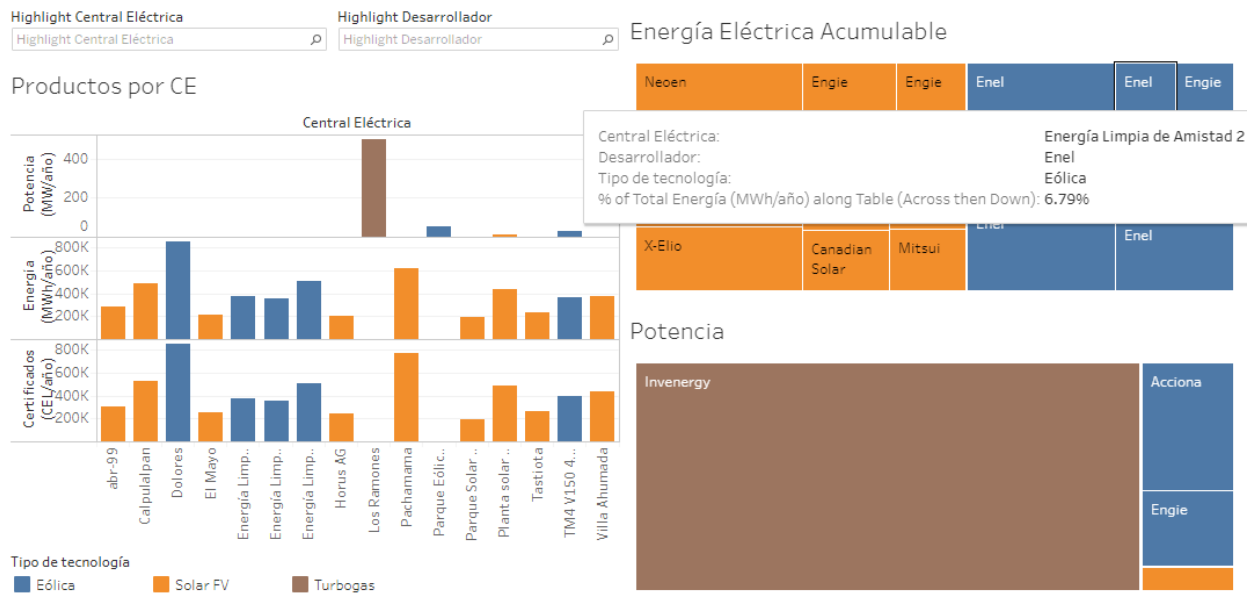
The third process began in April 2017 and concluded in November 2017 (figures 6.13, 6.14, 6.15, and 6.16).

Figure 6.13 Auction 3 Price Results



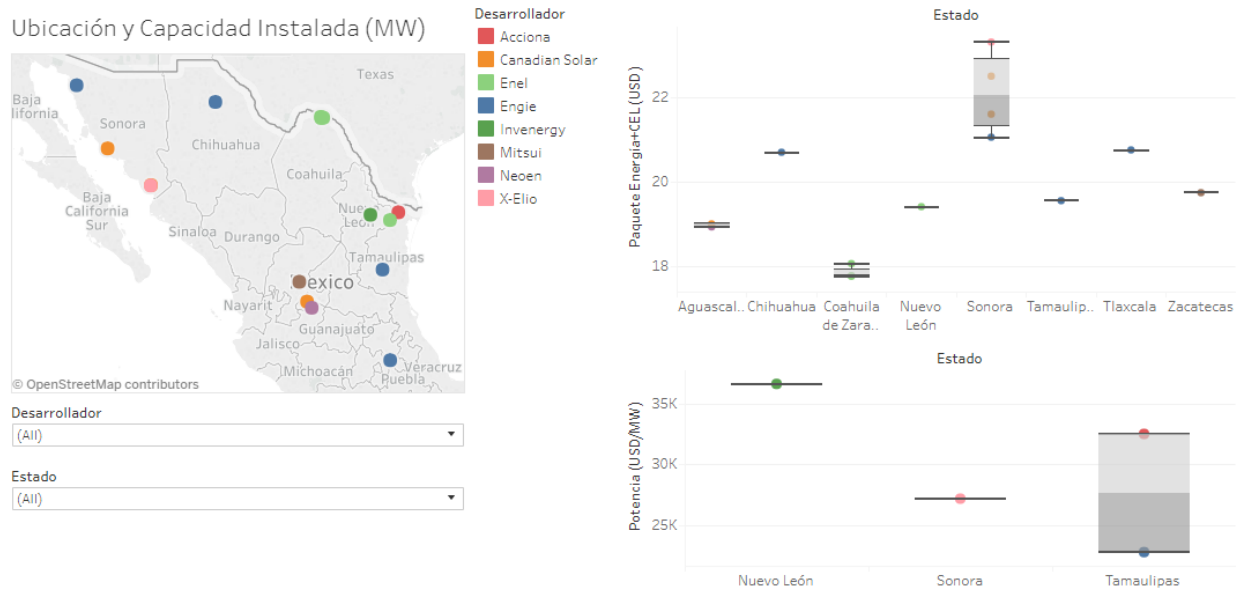
Source: zumma rg+c.

Figure 6.14 Auction 3 Capacity and CEL Assessment



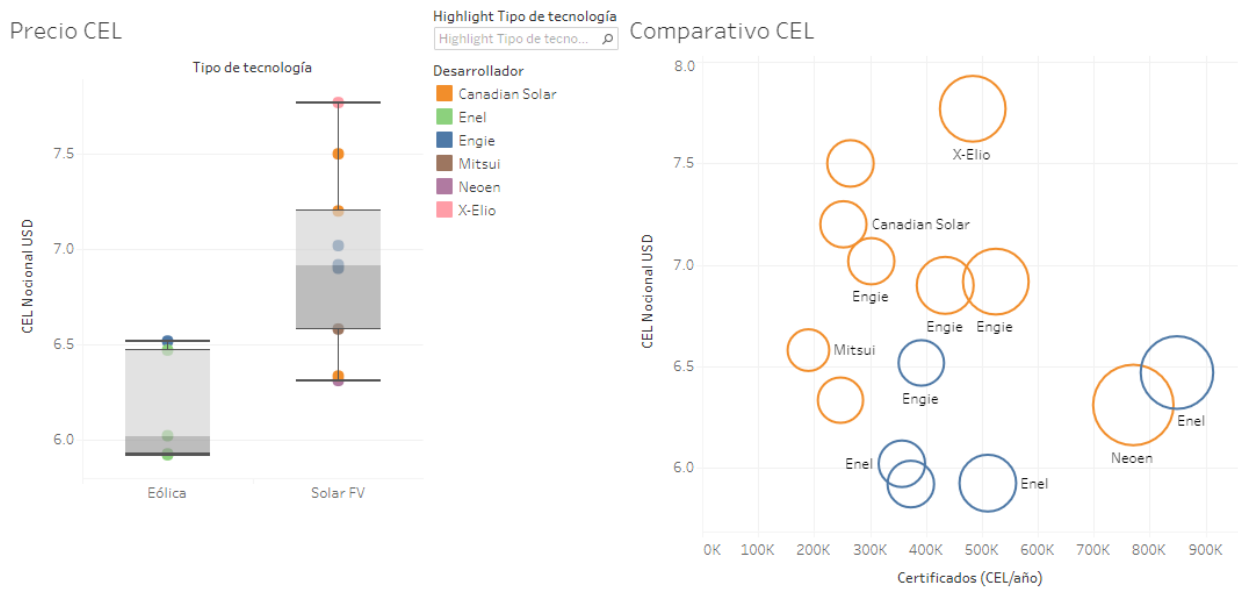
Source: zumma rg+c.

Figure 6.15 Auction 3 Volume and Location Assessment



Source: zumma rg+c.

Figure 6.16 Auction 3 CEL Price and Volume Assessment



Source: zumma rg+c.

Table 6.9 Auction 3 Company Participation and Technology Assessment

Participación por Desarrollador				Participación por Tecnología				
Desarrollador	% de total Energía (MWh/año)		% de total CEL	% de total Potencia (MW/año)	Tipo de tecnología	% de total Energía (MWh/año)		% de total Potencia (MW/año)
						% de total CEL		
Acciona	0.00%	0.00%	8.78%	Eólica	44.65%	41.69%	13.95%	
Canadian Solar	11.87%	12.85%	0.00%	Solar FV	55.35%	58.31%	1.69%	
Enel	38.04%	35.10%	0.00%	Turbogas	0.00%	0.00%	84.36%	
Engie	6.61%	20.86%	6.58%	21.20%	5.17%	0.00%		
Invenergy	0.00%	0.00%	84.36%					
Mitsui	3.46%	3.19%	0.00%					
Neoen	11.23%	12.95%	0.00%					
X-Elio	7.93%	8.13%	1.69%					

Tipo de tecnología	Certificados (CEL/año)	Energía (MWh/año)	Potencia (MW/año)
Eólica	2,481,415	2,452,547	83
Solar FV	3,471,160	3,040,029	10
Turbogas	0	0	500
Grand Total	5,952,575	5,492,575	593

Tipo de tecnología

- Eólica
- Solar FV
- Turbogas

Source: zumma rg+c.

Power purchase agreements were awarded for 5,492,575 MWh per year. The third auction saw the rise of additional buyers that entered into long-term contracts. CFE, Iberdrola, and Cemex, were the three successful purchasers; successful sellers included Engie, Enel, and Neoen (table 6.9).

The Interconnection Process

One of the important considerations for the long term auction process is a project's designation as a "priority project." If the project has obtained an interconnection agreement, bids submitted receive a designation as a priority project with increasing likelihood that its proposal will be accepted in the auction. From 2015 through 2017, the CRE relied on interim rules for interconnection as a new, more permanent interconnection manual was under development. Generally, the interim rules are extensive and mirror rules in other ISO markets.

To obtain an interconnection agreement, a developer can utilize the PRODESEN planning process or make individual requests to the CRE. The two processes present the developer with different cost and timing alternatives. Interconnection agreement terms are linked to the term of the CRE generation permit issued to the plant under the LIE. As

of this writing, a large request backlog exists, delaying approvals beyond the timeframe envisioned in the statutes.

There are numerous advantages to requesting an interconnection agreement on an individual basis. However, for projects that may have substantial network upgrade costs, the PRODESEN process may be preferable since these costs can potentially be socialized to the system. Developers indicate that the interconnection agreement process initially was a source of some frustration as the newness of the process meant that all parties were, to some extent, “learning by doing.” Most of these factors have been overcome. However, the lead time needed to obtain a permit, especially under the individual request process, continues to present obstacles to development with lead times of 18 to 24 months reported. Especially for solar projects, this is a material contribution to the overall development and construction timeline.

Natural Gas Fuel Supply

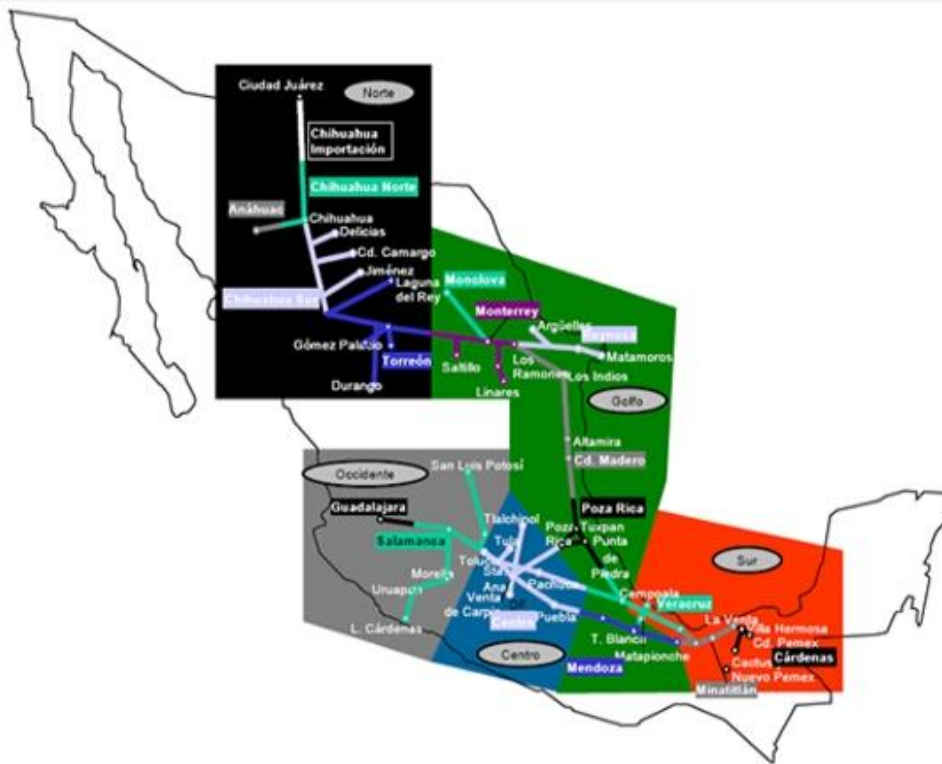
Energy reform in Mexico has been a wide-reaching undertaking. For natural gas and refined products such as diesel, Pemex has historically been the supplier to CFE. In Mexico, Pemex long served as the major natural gas supplier and operator of the gas pipeline system known as the Sistema Nacional de Gasoductos (SNG). Additionally, private pipelines operated off the SNG.

Development of CENAGAS and the Relationship to VPM

Beginning in 2015 and 2016, the operation of the SNG was transferred to CENAGAS. Just as CENACE operates as an ISO to facilitate open access, CENAGAS is designed to do the same for the SNG.¹⁵ In the past, natural gas prices in Mexico were linked to natural gas prices in the United States through a Pemex tariff. Known as Venta de Primera Mano (VPM), the formula relied upon U.S. prices in south Texas and linked them to two points: Reynosa and the Ciudad Pemex plant. The VPM took the source commodity price and added transport, distribution, and marketing costs. For Pemex, this proved to be a money-losing endeavor, largely because of costs associated with balancing and operating the system. In June 2017, the VPM program was formally ended (figure 6.17).

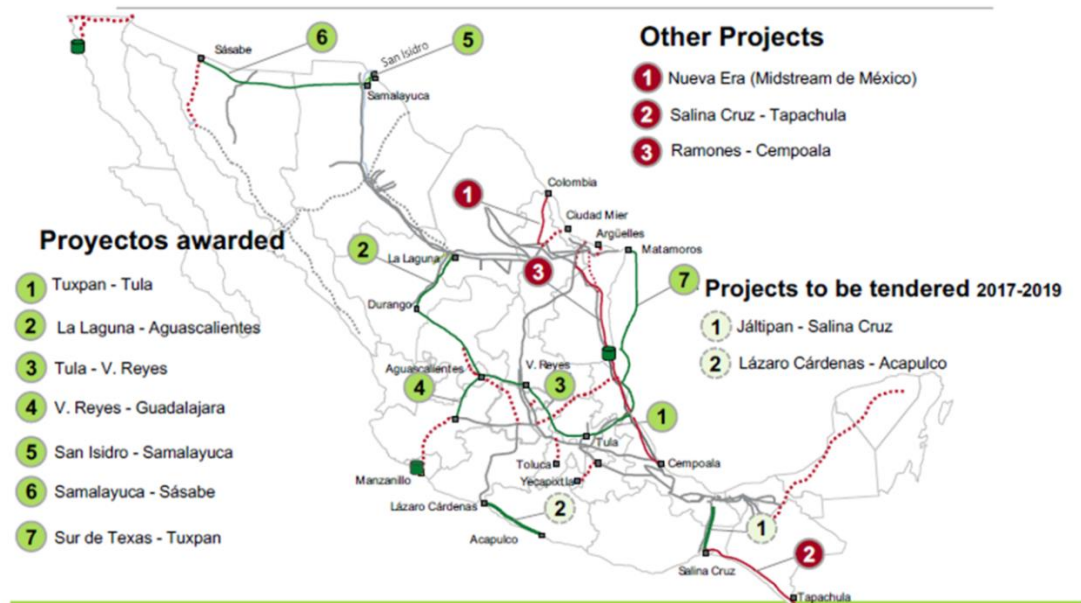
Generally, the energy reform has sought to honor existing contracts. Legacy long-term power purchasing agreements with the CFE typically based gas fuel supply on VPM or arrangements made directly with Pemex with gas costs generally passed through to the buyer, the CFE. Thus, there is little pressure to renegotiate. To transition from oil as a marginal fuel and lower system costs, the CFE substantively expanded new gas pipelines (figure 6.18). Many of these pipes support specific generation plants, especially in the Northwest. Others are expected to relieve gas supply constraints in the Center and South. To satisfy these constraints, fuel switching to imported LNG or fuel oil is typically the solution of choice.

Figure 6.17 VPM Gas Delivery Zones



Source: Pemex.

Figure 6.18 CENAGAS Five-Year Expansion Pipeline Projects



Source: SENER, “Segunda revisión anual, plan quinquenal de expansión del sistema de transporte y almacenamiento nacional integrado de gas natural 2015–2019” [Second annual review, five-year plan to expand the integrated natural gas transport and storage system 2015–2019], March 31, 2017, <https://www.gob.mx/sener/articulos/segunda-revision-anual-del-plan-quinquenal-de-expansion-del-sistema-de-transporte-y-almacenamiento-nacional-integrado-de-gas-natural-2015-2019?idiom=es>.

Delivered Natural Gas Prices

Delivered prices in Mexico have largely tracked commodity prices in the United States. Under the VPM program, delivered prices have been highest in the regions furthest from the injection points at Reynosa and Ciudad Pemex. As a result, the North and Gulf regions often have had the cheapest delivered gas, while the Center and West have experienced higher costs (table 6.10).

Table 6.10 Historical Delivered Industrial Gas Prices by Zone (US \$/MMBtu)

Delivery Zone (gas, \$/MMBtu)	2013	2014	2015	2016	2017
Gulf	\$5.20	\$6.00	\$3.90	\$3.80	
Central	\$7.00	\$7.40	\$5.20	\$5.10	
North	\$6.10	\$6.70	\$4.60	\$4.20	
West	\$6.40	\$6.80	\$4.70	\$4.80	
South	\$6.10	\$6.80	\$4.70	\$4.40	
Mexican Maya Crude (\$/bbl FOB)	\$97.25	\$85.79	\$44.02	\$36.40	\$46.95
Gulf Coast ULSD Diesel Oil No 2 (\$/gal)	\$2.97	\$2.71	\$1.58	\$1.32	\$1.62
Gulf Coast ULSD Diesel Oil No 2 (\$/MMBtu)	\$21.56	\$19.68	\$11.45	\$9.60	\$11.79

Source: CRE, “Precios gas natural a usuarios finales” [Natural gas prices to end users], <https://datos.gob.mx/busca/dataset/precios-de-gas-natural-usuarios-finales>; U.S. Energy Information Administration, (EIA), “U.S. FOB Costs of Mexican Maya Crude Oil,” May 1, 2018, <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=IMX2810004&f=M>; and EIA, “U.S. Gulf Coast Ultra-Low-Sulfur No 2 Diesel Spot Price, Annual,” 2016, https://www.eia.gov/opendata/qb.php?category=241335&sdid=PET.EER_EPD2DXL0_PF4_RGC_DPG.A

Power Market Prices

Short run costs and DA prices by major zone are shown in table 6.11.

Table 6.11 Historical Power Prices by Region (Nom USD/MWh)

Control Area	2013	2014	2015	2016 (DA)	2017 (DA)
Northwest	\$108.30	\$65.90	\$49.20	\$44.28	\$52.63
North	\$99.00	\$58.00	\$44.10	\$43.34	\$61.82
Northeast	\$97.00	\$57.40	\$44.50	\$43.64	\$56.96
West	\$103.40	\$60.50	\$47.10	\$47.32	\$66.38
Central	\$101.90	\$59.90	\$47.10	\$46.21	\$65.69
East	\$101.40	\$59.60	\$48.00	\$46.97	\$67.18
Peninsula	\$108.00	\$73.30	\$68.80	\$53.02	\$83.73
BC North	\$31.60	\$38.40	\$23.40	\$30.32	\$31.35
BC South	\$231.80	\$223.30	\$139.10	\$108.16	\$134.99

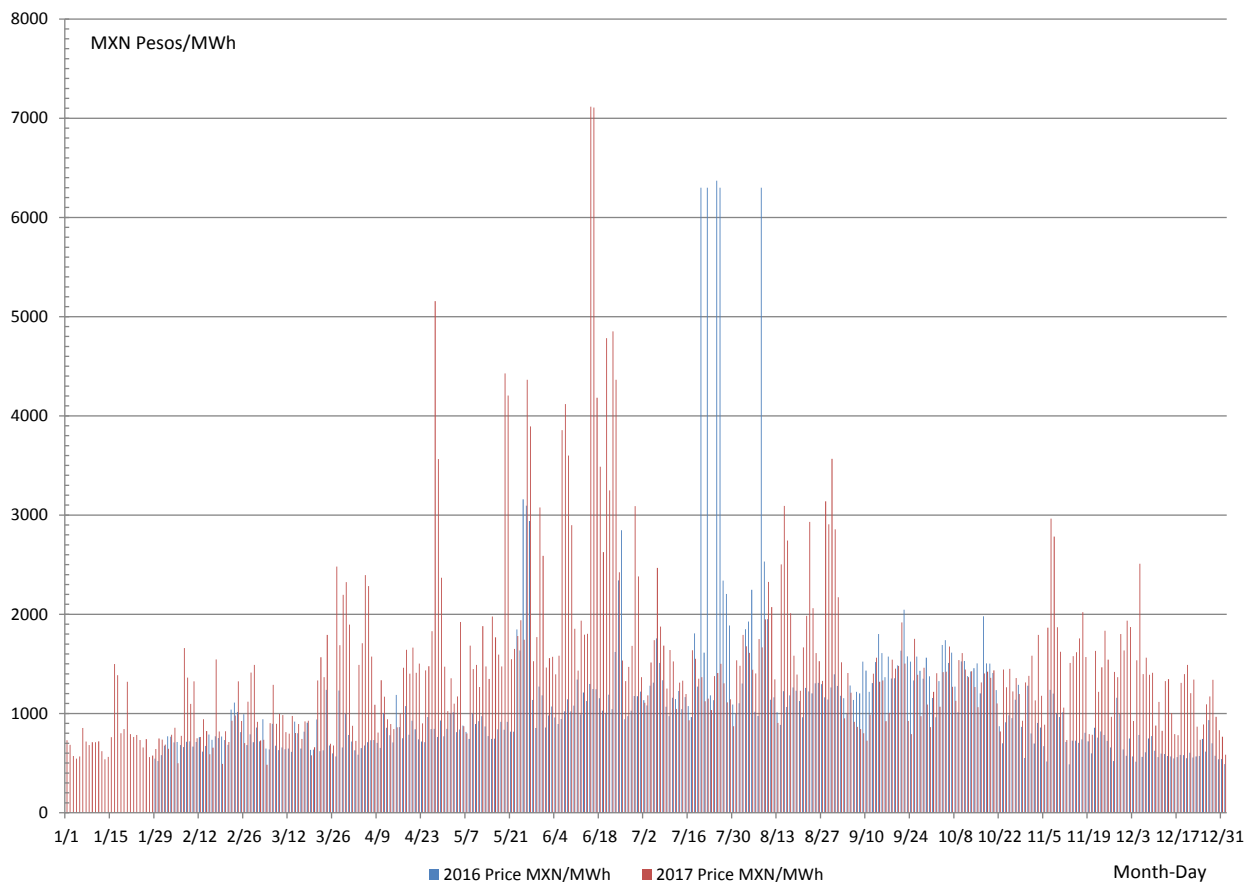
Source: CFE, CENACE, using proxies for zones and exchange rates.

In January 2016, the day-ahead market organized by CENACE began operation. Prior to that, the CFE reported short-run marginal costs. These short run marginal costs did not

include transmission effects (congestion), losses, and bidding effects, however. Power price trends overall are heavily influenced by oil prices and consumption of refined products. BCN is an exception as its grid is synchronous with the CAISO grid (figures 6.19 and 6.20; table 6.12).

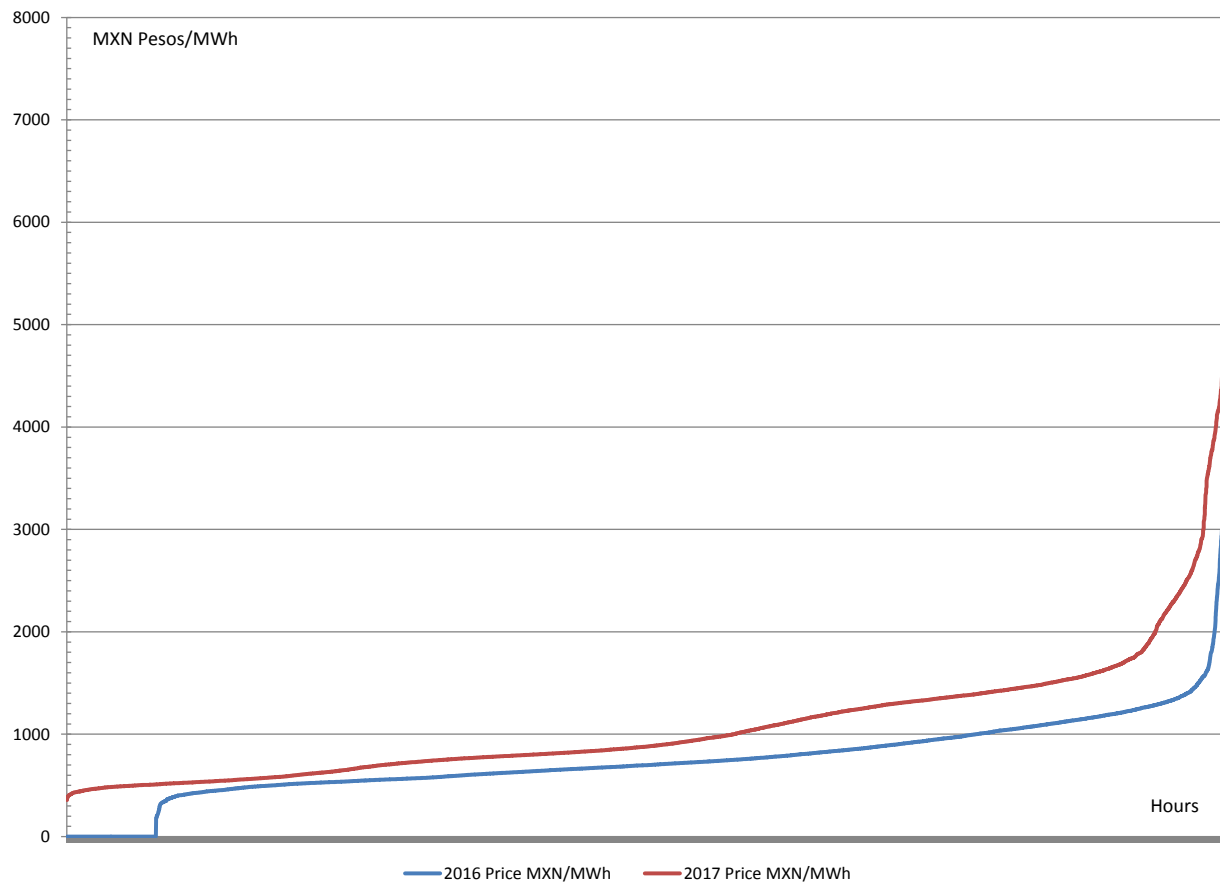
The implied heat rate can be calculated by dividing fuel consumption by generation. Since natural gas is frequently the marginal fuel, the calculation approximates the conversion efficiency of the system in a specified region. Beginning in 2014, national implied heat rates have averaged 10,000 to 12,000 British thermal units per kilowatt-hour (Btu/kWh). Further, total electrical losses (technical and other) have remained in the 13 to 15 percent during the same period. Both are relatively high when compared to other North American markets.

Figure 6.19 2016 vs. 2017 Day-Ahead Power Prices Noreste



Source: CENACE using proxy for Noreste.

Figure 6.20 2016 and 2017 Sorted Hourly Day-Ahead Power Prices Noreste



Source: CENACE using proxy for Noreste..

Table 6.12 2016 and 2017 Sorted Hourly Day-Ahead Power Price Noreste Table

	2016	2017	2016	2017
	MXN/MWh	MXN/MWh	USD/MWh	USD/MWh
Lo	\$0.00	\$357.55	\$0.00	\$18.90
1%	\$0.00	\$438.29	\$0.00	\$23.17
5%	\$0.00	\$493.08	\$0.00	\$26.07
10%	\$406.18	\$525.18	\$21.74	\$27.77
50%	\$697.71	\$878.66	\$37.35	\$46.45
90%	\$1,192.66	\$1,643.93	\$63.84	\$86.91
95%	\$1,317.87	\$2,216.89	\$70.55	\$117.20
99%	\$1,943.28	\$3,878.21	\$104.03	\$205.04
Hi	\$6,369.53	\$7,115.60	\$340.97	\$376.19

Source: CENACE using proxy for Noreste.

Historical Capacity Prices

As discussed earlier, the balancing capacity market runs ex post only. Table 6.13 shows the results in the SIN, BC, and BCS zones:

Table 6.13 Capacity Prices by Zone

Year	Zone	Total Fixed Costs (\$/kW-yr)	Energy Revenues (\$/kW-yr)	“Economically Efficient” UCAP (VIRPe-RP)	Net Capacity Price (\$/kW-yr)
2016	SIN	\$109.43	\$77.43	15.3%	\$64.63
2016	BC	\$90.55	\$20.108	16.4%	\$134.23
2016	BC South	\$149.46	\$36.08	32.7%	\$66.39
2017	SIN	\$102.62	\$135.09	15.3%	\$37.52
2017	BC	\$83.72	\$13.46	16.4%	\$31.41
2017	BC South	\$139.04	\$9.95	32.7%	\$145.64

Source: CENACE. Note: Reserve margin defined against the average demand during 100 critical hours. See CENACE, “Resultados del mercado para el balance de potencia” [Results from the balancing capacity market],

<http://www.cenace.gob.mx/Paginas/Publicas/MercadoOperacion/ResultadosMercadoBalancePotencia.aspx>.

“Net Capacity Price” FX is average. Fixed costs and energy revenues reported by CENACE.

Initially, many thought that Mexico would be long on capacity; however, the capacity process demonstrates that there were significant de-rates between the nameplate capacity and the actual measured availability during the critical hours. As a fleet, the SIN averages 77 percent of nameplate capacity, including perhaps 65 percent for major oil/gas units and 87 percent for major combined cycles.

Existing Transmission System and Planned Changes

The Mexican electric transmission grid comprises more than 100,000 kilometers (km) of transmission lines and almost 200,000 megavolt-ampere (MVA) of transformer capacity of 69 kilovolts (kV) to 400 kV (figure 6.21).

Figure 6.21 High Voltage Transmission System

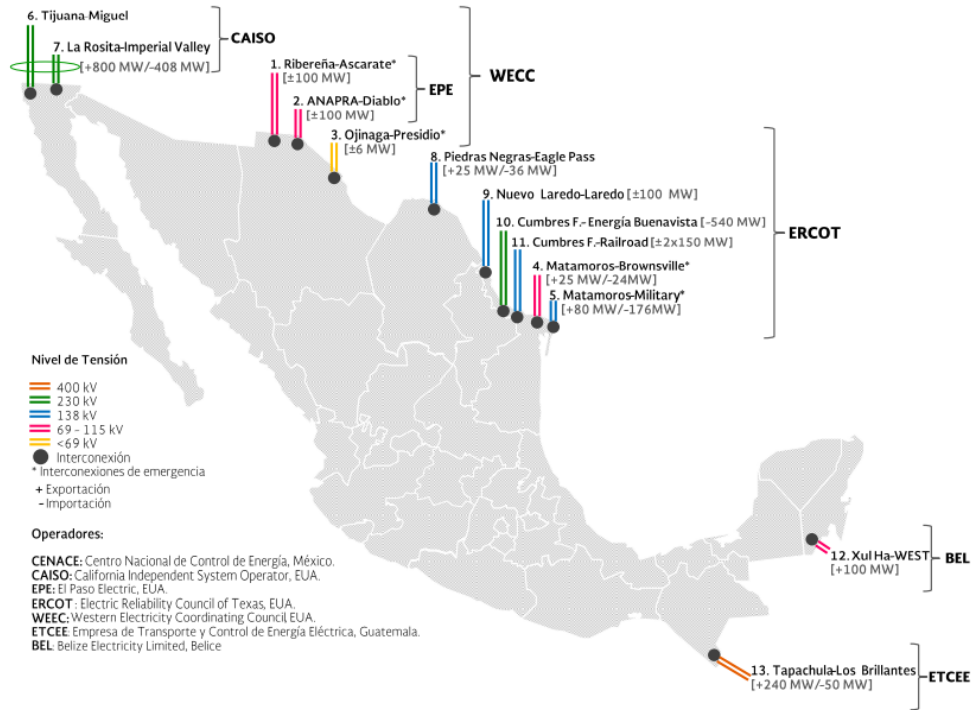


Source: “Programa de desarrollo del sistema eléctrico nacional.”

Interconnections and Internal Transfer Capabilities

The high-voltage system also connects with neighboring countries (figures 6.22 and 6.23). External ties exist with Belize, Guatemala, and the United States. Total transfer capacity with the first two is about 100 MW with Belize and 240 MW with Guatemala. For the United States, 530 MW of export and 636 MW of import is transferred with the Electric Reliability Council of Texas through a series of DC ties. Other transfers include approximately 200 MW with El Paso Electric in WECC, and two synchronous connections between the California ISO (CAISO) and the BCN region at Tijuana and the La Rosita CC plant.

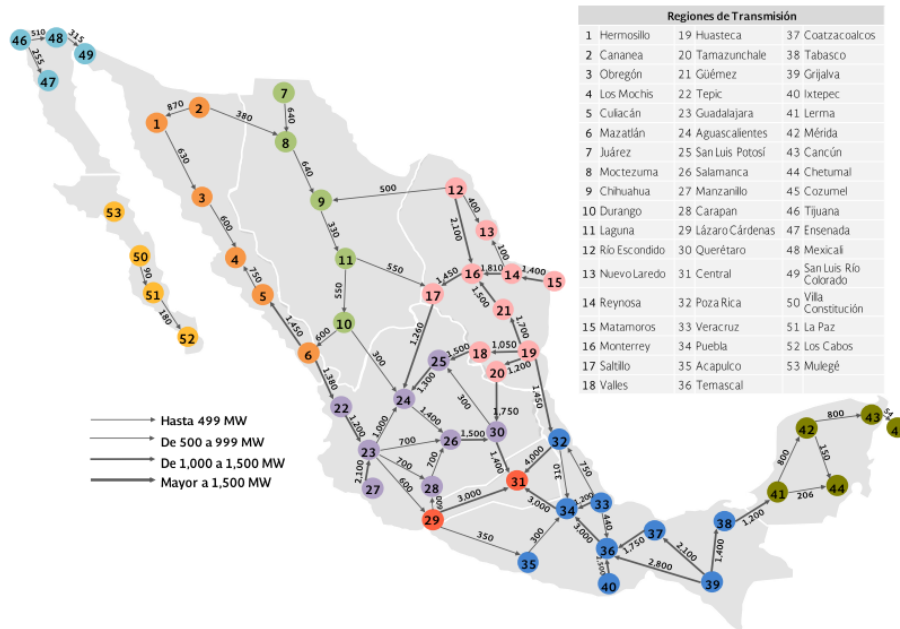
Figure 6.22 Existing Cross-Border Transmission



Source: “Programa de desarrollo del sistema eléctrico nacional.”

Figure 6.23 Internal Transmission Transfer Capabilities

(Megawatt)



Source: “Programa de desarrollo del sistema eléctrico nacional.”

Congestion and Planned Improvements

The PRODESEN planning document identifies existing transmission issues and planned improvements. These include a lack of interconnection between the BC, BCS, and SIN grids; constraints in the North and Northwest regions (which are seeing large capacity buildout); limited transmission to the Yucatan Peninsula, evidenced by higher prices and the June 2017 peninsula-wide blackout due to transmission failure, and import constraints into the capital region.

SENER has prioritized and authorized a number of projects to address these issues. Figure 6.24 illustrates some of the more important changes.

Figure 6.24 Planned Expansion



Fuente: CENACE
 Source: "Programa de desarrollo del sistema eléctrico nacional."

The 2017 PRODESEN offered details as to future power generation capacity and the fuel mix. It also provided information on expected investments in the national electricity system, as well as demand and capacity projections. Overall, 55,840 MW of utility-scale power generation capacity are expected over the next 15 years to meet growing demand, with 63 percent of new deployments expected from wind, solar, and efficient cogeneration. Investments in transmission will include various interconnection projects, 23,772 km of new transmission lines, and 58,099 MVA of additional transformer capacity.

Under the restructuring, private participants are able to finance, operate, maintain, and expand the transmission and distribution network. Smaller, standard transmission upgrades remain the responsibility of the CFE. Additionally, larger, nonstandard “strategic” projects are likely to be awarded under a competitive bidding process. Projects for the Baja California Peninsula and to Cozumel are two identified processes. The Baja California process envisions a 1.5-GW high-voltage direct current transmission line 1,400 km long connecting the California grid at Mexicali to the SIN near Hermosillo, Sonora. Initiated in December 2017, 45 companies have expressed interest. Investment is estimated at US\$1.1 billion.

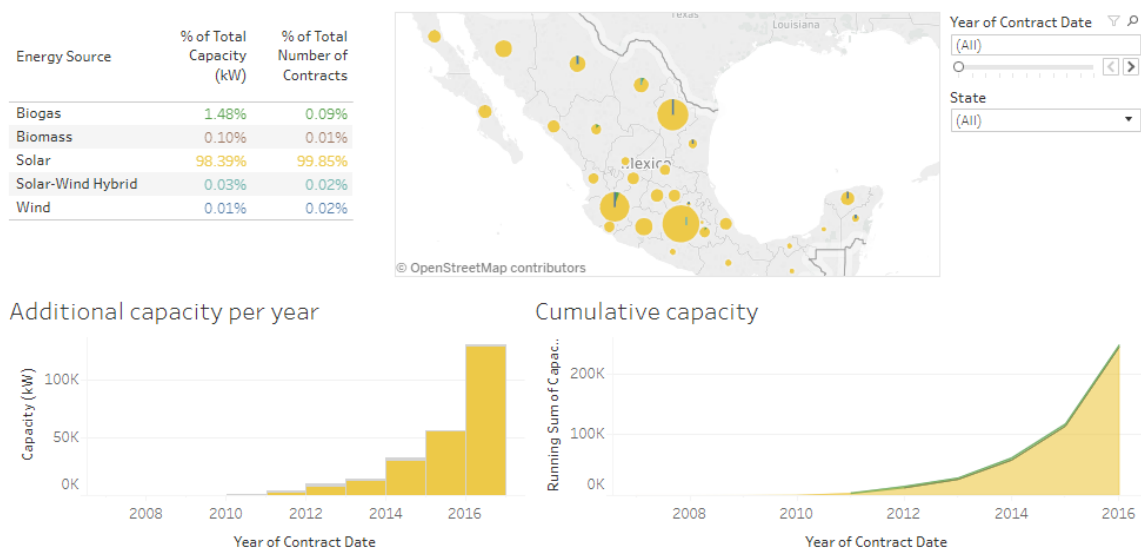
The Distribution System and Distributed Generation

Currently, the Mexican electric distribution grid comprises more than 750,000 km of distribution lines. Under the terms of the LIE, the distribution system remains administered by CFE. The PRODESEN process envisions that transmission and distribution projects will account for about 20 percent of the total US\$107 billion invested over the next 15 years. Transmission investment of US\$12 billion is expected with 89 percent of the spending occurring over the next five years.¹⁶

For distribution, an investment of US\$9.6 billion is anticipated for distribution expansion and modernization projects, including development of smart grids. Between 2017 and 2024, between US\$500 million and US\$650 million is expected to be invested each year. Given technical and economic developments in other markets in North America, this distribution outlook may be subject to some changes.

In some cases, certain types of distributed energy resources can substitute for distribution system wires additions. Additionally, in recent years, distributed generation—one type of distributed energy resource—has grown. Distributed generation can require distribution upgrades or relieve constraints depending on the local conditions. It is defined as an exempt generator that does not require a CRE permit. To achieve this designation, the asset must be less than 0.5 MW in size and connected to a distribution circuit with a high concentration of load centers. A distributed generation provider can participate in the MEM if it is represented by a basic or qualified supplier. The CRE has developed a model contract for the basic supplier, as well as methodologies for net metering, net billing, and energy sales. By the end of 2016, Mexico had distributed generation capacity of 247.6 MW. Solar installations smaller than 30 kW accounted for 50 percent of the total, while 48 percent were solar bigger than 30 kW but smaller than 500 kW (figure 6.25).

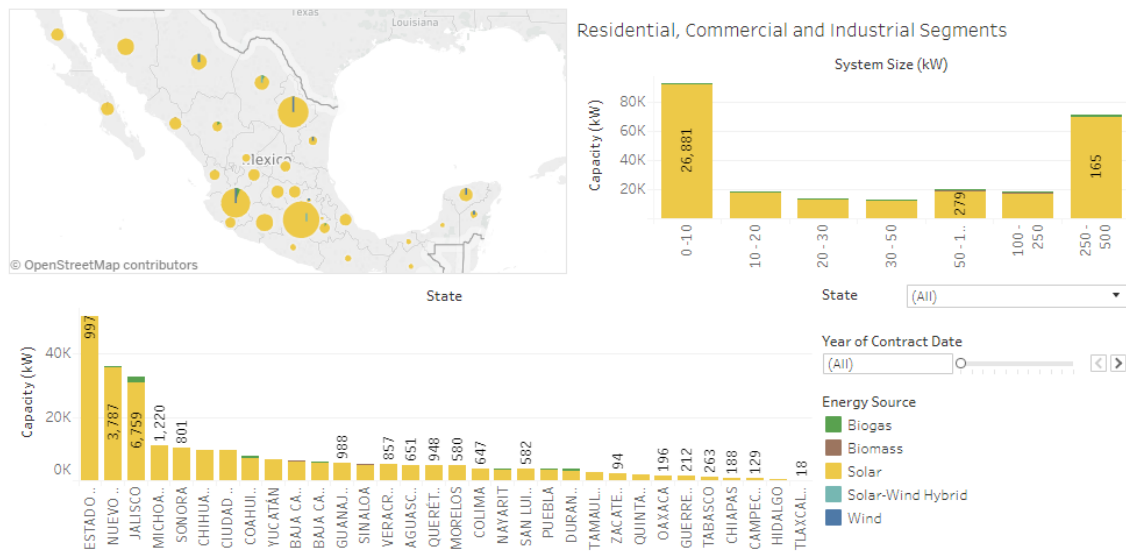
Figure 6.25 Distributed Generation Capacity and Energy Sources



Source: Zumma rg + c.

In December 2017, a roadmap for solar development was published. By 2030, the roadmap envisions 22 GW of installed photovoltaic capacity in 2030, with 9 GW of large-scale plants and 13 GW of distributed generation solar systems. Additionally, the roadmap established an interim goal for 2024 of five GW large-scale and two GW distributed generation solar (figure 6.26).

Figure 6.26 Distributed Generation System Size and Location



Source: Zumma rg + c.

Project Development Status

To date, the most tangible project development successes as a result of the restructuring are concentrated in the long-term auction process for generation. The first three auctions awarded more than 6,500 MW of generation power purchasing agreements. For three processes conducted over a year and a half, the participation has been substantive.

Although the award of offtake agreements from the long-term auctions is a tangible and important sign of success, some renewable projects also have been successful in obtaining offtake agreements outside of the CENACE-sponsored process. This achievement is another important marker of success. Yet converting these commitments into viable projects that have reached financial close has proven to be much more challenging. First, the financial engineering necessary to satisfy debtholders has meant that the traditional project finance structure used elsewhere in North America needed modification. Importantly, the development community, the government, and CENACE have used other intermediaries, such as development banks, to accept some of the risks that private sector capital markets found difficult to hold. Key participants have included the North American Development Bank. Second, the process of bidding itself might have

included more detail that could have streamlined the process to reach financial close, such as the output profile that was bid (e.g., P50, P99) for intermittent renewables. These details lead to a nonstandard process for the capital markets and delays in closing. The process also exposed differences among money center banks in standardizing the debt-equity ratio that might be acceptable to the capital markets. Today a 70 percent/30 percent to 60 percent/40 percent debt/equity ratio predominates thanks to the important role of the development banks in assuming select risks especially with respect to profile and tenor.

Future work could be useful to identify improvements and unlock greater leveraging. Chief among these could be capital market solutions in the area of availability and tenor. The goal here would be to increase the gearing ratio by covering certain risks by third-party “enhancement” contracts that insurance-oriented participants with global capital scale might offer. This type of participation could also be key to enhancing the size of the risk warehouse of the development banks.

In the medium term, further development of market structures in Mexico’s natural gas markets—for instance, greater availability of capacity release programs, or more options for firm gas supply and pricing—could lead third parties to allow wrap products that guarantee fixed prices. This would allow partially variable market-priced bids into the long-term auction market, reducing the need for CENACE participants (i.e., the CFE and other third-party buyers) to accept fixed price risk.

For many observers, one major risk to the overall restructuring remains with the developer process in the long-term auctions. Observers have been discussing several major unresolved questions:

- Are the prices bid (especially in the third auction) sufficient to compensate equity holders and allow for debt service coverage across a reasonable range of outcomes?

- Given how long it has taken for awards in the first two auctions to reach financial close, will all projects be completed and reach commercial operation in a timely fashion?
- Market participants have reported that some projects from the first two auctions are shopped for sale to new third parties for completion. Was the qualification process robust enough? Are the level of guarantees and penalties as well as awarded prices imposed by CENACE sufficient to incentivize developers to successfully complete their projects? What are the consequences to system reliability if certain awarded projects are delayed, or not completed at all?

As this is written, the strategic transmission solicitation process is underway and due to be completed in the third quarter of 2018. Many parties have expressed interest in this process. As a result, most observers are confident that a competitive process will ensue. Some developers suggest that the process may be hypercompetitive and are choosing not to participate in these first projects.

Some large international participants who might otherwise participate in the long-term auction process have had similar cautious views. As a result, some developers and private equity backers have turned to the bilateral market outside of the auctions to aid in the margins available to the project. By guaranteeing discounts to the Basic Service rate, these companies hope that their qualified supplier status can enhance project margins by selling directly to qualified users. In the first three years after the restructuring began, these qualified users entering transactions were few and far between. As grandfathered projects initiated under the old rules and protected during the transition began to assume less importance, this type of qualified supplier/qualified user transaction may assume continuing importance. Qualified suppliers are starting to consider that prices may become more volatile under the restructured process and will not fall as many believed earlier in the process. In addition, growth, reliability, and additional load needs suggest that at least some of these qualified users are rethinking their initial strategy.

Additional Issues

In addition to complications in the financing and development process stemming from the restructuring, Mexico faces other project and market development challenges in the areas of human capital and technology transfer.

Historically, the CFE played an important role in developing the Mexican energy sector's human capital. The organization historically has been a long-term employer that provided opportunities for both recent graduates and senior-level executives. Since 2016, the CFE has been split into separate organizations, and the traditional paths for personal development have been shifted. Additionally, new organizations have entered or expanded in the Mexican power sector. These new companies have created demand for staff at all levels. Some of these needs have been met by hiring people away from the CFE; others have been met by international hires. Although international hiring has brought in new talent that could supplant some domestic jobs, it has a benefit of cross-pollinating experience gained internationally into the Mexico context. The new companies that have entered also have brought benefits to the broader economy by adding new projects and plants at lower costs. The awarded prices for wind and solar projects are clearly world-class. These experiences also have the potential benefit of broadening and deepening the acceptance of the restructuring among those beyond the sector.

Numerous observers have wondered, "Does Mexico have sufficient trained and knowledgeable people to continue to build out the sector?" To increase the odds of success, bring about economic development and global competitiveness, some of the country's primary institutions have sought to increase collaboration with international academic and development agencies to support specialized skill development. Recent achievements include the following:

- An agreement with the University of Texas at Austin (UT) and Tecnológico de Monterrey (Monterrey Tech) to develop a reliable, clean, sustainable, and affordable electric power sector for Mexico.¹⁷ The goal is to make it easier to transfer and share knowledge and best practices, leveraging the strengths of both

institutions to meet Mexico's fast-growing demand for electricity. The partnership, managed in the United States by UT's Energy Institute, will link Monterrey Tech with more than 100 faculty members at UT in 20 energy-related research centers. The two universities will conduct joint faculty and student exchanges, conferences and seminars, and research on electric power. Areas of collaboration will include energy security, reliability, sustainability, efficiency, affordability, and good governance for energy markets.

- An agreement with Arizona State University (ASU), the University of California at Berkeley, and Monterrey Tech to enable, by means of power electronics devices, highly reliable and efficient grid implementations.¹⁸ Mexico's National Council for Science and Technology (Consejo Nacional de Ciencia y Tecnología; CONACYT) and SENER are also involved in the project's formation. As a consequence of the recent Mexican energy reform, the high power interconnection between Mexico and the United States has become a pressing issue that will benefit the emerging binational wholesale electricity market. Additionally, Mexico is currently migrating to the development of new technologies such as high-voltage direct current transmission systems. A new research plan that will address the current Mexican grid demands the combination of the experience of Monterrey Tech in electrical engineering and the top qualified experience of Arizona State University in high-voltage transmission. The plan consists in a collaborative supervision of more than 30 outstanding Mexican postgraduate students and the eventual development of a binational medium voltage power electronics laboratory.¹⁹
- Analysis of Improvements in Energy Efficiency and Energy Conservation in the Nonresidential Electricity Sector. The Mexico lead institution is the Center for Research and Teaching of Economics (Centro de Investigación y Docencia Económicas; CIDE) with international partner the University of California at Davis.²⁰
- Demonstration Buildings of Bioclimatic Design in Warm Subhumid Climate. The Mexico lead institution is the Institute for Renewable Energies at the National Autonomous University of Mexico (Universidad Nacional Autónoma de México) with international partner LBL Berkeley Lab.²¹

- Lighting Application Research Center for the Development of Demonstrative Projects of New Lighting Systems to Improve Energy Efficiency. The Mexico lead institution is the Autonomous University of Guadalajara (Universidad Autonoma de Guadalajara) with international partner the University of California at Davis.²²
- Consortium for Energy Efficiency in Nonresidential Buildings. The Mexico lead institution is Monterrey Tech, Nuevo Leon, with international partner the University of California at Davis.²³
- Observatory for Energy Efficiency in Buildings. The Mexico lead institution is the National Institute of Electricity and Clean Energy (Instituto Nacional de Electricidad y Energías Limpias; INEEL) with international partner LBL Berkeley Lab.²⁴

Mexico's CONACYT indicates that in the four years since the enactment of energy reform, "Over \$175 billion USD in funds have been pledged that will create hundreds of thousands of well-paid jobs" across the comprehensive energy sector. It indicates that nearly 60,000 students have received support from the government to take advantage of the new opportunities in the sector. CONACYT expects to launch a new call for applications to award graduate scholarships to specialists in energy matters in 2018.²⁵

Conclusion

During the 2013–18 timeframe, potential investors and industry observers expressed various opinions with respect to key elements of the reform. As discussed, many of the observations and restructuring activities have been received favorably by new and potential market participants. In this sense, then, an interim report card on electricity sector restructuring can indicate that the reforms are regarded as successful.

Some observers have cited the relatively low participation of firms outside of the long-term auctions as a hindrance to the reforms. Generally, their perspective is that power sector participation rates has been more muted compared with participation in the upstream oil and gas rondas? As with many things in life, improvements can be identified and are generally to be expected. In this spirit, critiques can be identified and can generally been clustered around six major concerns.

1. The CFE's preexisting monopoly status remained unresolved for the first three years of the process. Investors and industry observers expressed concerns regarding the CFE's ability to exert vertical and horizontal market power with respect to commitment and dispatch operations, provision of firm gas pipeline capacity, and competition for qualified users (consumers).
2. The Basic Service rate-making process and overall level of these rates was the source of considerable confusion, some of which remains at the time of writing. Many qualified users approached the restructuring process with the belief that wholesale market prices were likely to decrease. This Basic Service process would determine a de-facto "price to beat" for new market entrants who would want sell at retail to consumers to substitute the Basic Service that the CFE provided to larger consumer classes. The CRE released this methodology in December 2017, but confusion over the transition mechanisms and the nature of the phase-in process has persisted. This lack of clarity set back the timing and implementation plans of new market entrants, including aggregators and generators. From conversations with market participants, the confusions likely slowed participation of qualified users in the first medium-term auction held in the first quarter of 2018. Still unclear is the role of subsidies for certain classes of residential and industrial customers. The finance ministry will need to provide guidance for qualified user and qualified supply participants as to timing and changes to better understand how the rate-making process may change in the future.
3. Some of the initial statements and promises made to build political support for the restructuring may have reduced the speed of its progress. One of the primary reasons established to build popular support for the restructuring was the notion that doing so would create construction and ongoing operating jobs. Second, it was promised that the reforms would modernize the sector by increasing operational efficiencies, and prices would fall thanks to the effects of market forces and competition. However, these promises also established an expectation among knowledgeable buyers that it was better to wait for these lower prices. Third, during the process of passing the constitutional amendment and secondary laws, it was

frequently repeated that “not one nut or bolt” of the state-owned enterprises—Pemex and CFE—were to be sold. By removing the possibility of full or partial privatization in the short to medium term, these enterprises were assured of their important role and the political process was concluded successfully. However, early opportunities for international capital participation were reduced. Various observers have speculated that future administrations may be more (or even less) likely to make changes to this commitment. Fourth, there was an expectation that infrastructure investment could be attained on a broader scale and more rapidly by relying more heavily on international capital sources. However, certain market design elements and subsequent market developments exposed weaknesses in the structure and resulting risks that traditional project finance structures were initially expected to take on. This inhibited the utilization of traditional structures and required that other quasi-public institutions, such as development banks, devise new products to take on the risks that commercial banks and private equity would not accept.

4. After an initial wave of enthusiasm, project finance and development uncertainties, largely around timing and land acquisition, led small and medium-sized private equity capital to pull back and slow development activities. After this pull-back, multinational enterprises with core rate-of-return oriented businesses, and a positive view of country risk, exchange risk, capital cost, and the success of the long-term Mexico auction process, stepped in to provide low cost development capital. In doing so, they accepted an expected rate of return lower than that some traditional private equity firms were willing to accept given the risks involved. These multinational enterprises teamed with international infrastructure funds and capital providers looking for stable, long lived returns. This has provided the multinational enterprises with a deep capital source and an exit strategy for their development activities, and they expect to profit over the longer term by continuing to operate the assets they develop. It is clear that financial close has not been reached in a timely fashion for selected projects. In a global interest rate environment rising above historic lows, additional project risks may materialize and threaten completion of a subset of the successfully awarded projects.

5. The desired market design was implemented in stages beginning in 2016. This was understandable as energy officials, regulators, and market participants needed time to understand and assimilate detailed proposals into their plans. However, stretching this process out over several years has slowed the acquisition of retail consumers by qualified suppliers and generators interested in building a business outside of the long-term auction process, owing to regulatory uncertainty associated with what remains to be structured. Staging the implementation also inadvertently contributed the qualified users' belief that retail prices would be likely to fall, which may have contributed to a reduced number of completed transactions with qualified suppliers early in the transition since little transparent pricing and understanding of pricing processes was available. As the regulatory process has taken much longer to become clear, participants are inclined to wait and watch. Infrastructure investors are by nature a conservative bunch, and this view has tended to dominate the notion of a "first-mover advantage" that might be gained by early action.
6. Future implementation of several important market activities is not fully clear. The manner in which these activities are implemented could have substantive implications for future market success.

So, on an interim basis, how can we think about the power sector restructuring? Is it successful? Is it happening in slow motion? Is it a failure compared to the early successes of the rondas?

One's conclusion depends, at least in part, on one's assumptions. Many argue, as a counter to the ronda perspective, that the power sector is simply different. Markets are more immediate—hourly instead of daily—which leads to more complexity. Longer lead times are generally involved in the power sector, perhaps three or more years in project development and construction. Longer-term contracts often are needed; likewise, 12- to 15-year periods are often needed for completing the capital recovery phase, rather than the one to seven years more typical in the hydrocarbon sector (except for deepwater projects). Capital expenditures can also be longer than on-shore field requirements

(again, ignoring deepwater projects). Technical complexity of power projects can be either higher or lower than upstream development. These differences are in no way comprehensive, but they illustrate some of the considerations need to be taken into account in any comparison.

Perhaps a better metric to judge interim success or failure is to compare the Mexican experience in power sector restructuring to that of other North American countries. Using this standard, Mexico is attempting to do in five years for power what has taken more than 15 years in other jurisdictions and markets. By this standard, Mexico is well on its way to a successful transition. When one considers the magnitude of the restructuring across many energy sectors, especially in thinking through interdependence with the natural gas sector and its system changes, the progress is even more notable. Whereas other markets had the luxury of undertaking gas sector restructuring prior to power sector restructuring, the Mexican case relies on reforming both simultaneously. Thus, mechanisms such as the long-term auction processes are understandable steps that ensure reliability through utility-like solicitation and auction process—structurally similar to but materially different from the process used in Brazil and Colombia—while enabling international capital participation as the role of retail choice and greater participation evolves.

In short, things can always be improved. An entire management subdiscipline focuses on continuous improvement. However, the Mexican government deserves substantial recognition for implementing a credible a strong process. The next five years likely will not be an easy and straight path, but they certainly hold a strong chance for additional successes.

¹ <https://sites.hks.harvard.edu/m-rcbg/cepr/Jeff%20Pavlovic%20Harvard%2021%20Mar.pdf> accessed on 8 April 2018

² Gabriel Roldán Alonso, *Reporte anual del mercado eléctrico mayorista 2016* [Annual report of the wholesale electricity market 2016] (Mexico City: Monitor Independiente del Mercado, March 2017), www.cenace.gob.mx/Paginas/Publicas/MercadoOperacion/ReporteAnual.aspx.

³ International Energy Agency (IEA), *World Energy Outlook 2017: A World in Transformation* (Paris: IEA, 2017), www.iea.org/weo2017/.

⁴ Rivelino Rueda, “Senado avala por mayoría Ley de Transición Energética” [Senate majority endorses the Energy Transition Law], *El Financiero*, December 1, 2015, www.elfinanciero.com.mx/nacional/senado-avala-por-mayoria-ley-de-transicion-energetica.html.

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- ⁵ Secretaría de Energía (SENER), *Prospectiva del sector eléctrico, 2017–2031* [Electricity sector prospects, 2017–2031] (Mexico City: SENER, 2017), www.gob.mx/cms/uploads/attachment/file/284345/Prospectiva_del_Sector_Elctrico_2017.pdf.
- ⁶ <https://sites.hks.harvard.edu/m-rcbg/cepr/Jeff%20Pavlovic%20Harvard%2021%20Mar.pdf> accessed on 8 April 2018; additional conversations.
- ⁷ SENER, *Prospectiva del sector eléctrico, 2017–2031*.
- ⁸ *Ibid.*; and “Programa de desarrollo del sistema eléctrico nacional” [National electricity system development program], SENER, August 30, 2017, www.gob.mx/sener/acciones-y-programas/programa-de-desarrollo-del-sistema-electrico-nacional-33462.
- ⁹ International Energy Agency (IEA), *Mexico Energy Outlook*, World Energy Outlook Special Report (Paris: Organization for Economic Cooperation and Development [OECD]/IEA, 2016), www.iea.org/publications/freepublications/publication/mexico-energy-outlook.html; and EIA.
- ¹⁰ Load factor = total energy / (peak load x 8760). This can be thought of as the average load year-round as a fraction of annual peak.
- ¹¹ SENER, “Bases del Mercado Eléctrico Acdo Sener DOF” [Bases of the electricity market Acdo SENER DOF] (Mexico City: SENER, 2015), www.cenace.gob.mx/Paginas/Publicas/MercadoOperacion/BasesMercado.aspx.
- ¹² <https://sites.hks.harvard.edu/m-rcbg/cepr/Jeff%20Pavlovic%20Harvard%2021%20Mar.pdf> accessed on 8 April 2018.
- ¹³ Centro Nacional de Control de Energía (CENACE), *Mercado para el balance de potencia* [Power balance market] (Mexico City: CENACE, 2017) www.cenace.gob.mx/Docs/MercadoOperacion/ResultadosBalancePotencia/2018/Informe%20Ejecutivo%20MBP%202017%20v2018%2002%2028.pdf.
- ¹⁴ <https://www.amdee.org/LiteratureRetrieve.aspx?ID=144215> accessed 8 April 2018.
- ¹⁵ SENER) *Prospectiva de gas natural, 2017–2031* [Natural gas prospects, 2017–2031] (Mexico City: SENER, 2017), www.gob.mx/cms/uploads/attachment/file/284343/Prospectiva_de_Gas_Natural_2017.pdf.
- ¹⁶ “Programa de desarrollo del sistema eléctrico nacional.”
- ¹⁷ “University of Texas and Monterrey Tech Join Forces to Improve Electric Power in Mexico,” University of Texas at Austin, November 17, 2017, <https://news.utexas.edu/2017/11/17/universities-partner-to-improve-electric-power-in-mexico>.
- ¹⁸ “Collaboration on U.S.-Mexico High Voltage Direct Current Links (Monterrey Campus),” Arizona State University, accessed April 8, 2018, <https://mexico.asu.edu/our-mexico-portfolio/collaboration-us-mexico-high-voltage-direct-current-links-tecnol%C3%B3gico-de-monterreys-monterrey-campus>.
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- ²⁰ “Mexico Energy Initiative,” International Energy Studies Group, Lawrence Berkeley National Laboratory, 2018, <https://ies.lbl.gov/region/mexico-energy-initiative>.
- ²¹ *Ibid.*
- ²² *Ibid.*
- ²³ *Ibid.*
- ²⁴ *Ibid.*
- ²⁵ “Electricity Coverage to Reach 100% in 2018,” President of the Republic of Mexico, February 8, 2018, www.gob.mx/presidencia/en/articulos/electricity-coverage-to-reach-100-in-2018?idiom=en.