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Cost Assessment of Clean Generation Incentives in Mexico for Utility Scale Solar Photovoltaic Projects

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Cost Assessment of Clean Generation Incentives in Mexico for Utility Scale Solar Photovoltaic Projects

by

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Thesis

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Dedication

To Carlos, for being the trigger of this amazing and rewarding adventure. I can't wait to see where we go next.

To my parents, whom unconditional love has been the fuel of my every success.

To my mom, for being such an example of bravery, empathy, and generosity.

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Abstract

Cost Assessment of Clean Generation Incentives in Mexico for Utility Scale Solar Photovoltaic Projects

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Mexico recently opened the electric generation sector to competition. In addition, regulations to reach clean generation goals were implemented. These regulations include Clean Energy Certificates (CELs) obligations (similar to the Renewable Portfolio Standards in the United States), and the obligation of electricity suppliers to go into long term contracts with generators to guarantee the required electric energy and CELs supply. These contracts are procured through an auction mechanism. The purpose of this research is to i) estimate the cost of reaching the goals through the implemented policy, and ii) evaluate if the projects could be economically feasible by selling electricity in the short term market, without the incentives. This research looked at three different utility scale solar photovoltaic projects that will operate under long term contracts for the provision of electric energy and CELs. The revenues of the projects under the contract terms were modeled and contrasted with projected Locational Marginal Prices (LMPs). In addition, a discounted cash flow analysis was done for the three projects, both under long term contract conditions and short term market conditions.

Two projects were found to be financially feasible under short term market conditions. For these projects, the LMP was between \$1.34 and \$4.03 USD/MWh higher than the long term contract price. One project was not feasible under short term market conditions. For this project to be feasible in the short term market, the LMPs needed to be over \$1.49 USD/MWh higher than the projections, while the price paid in the contract for this project was approximately \$1.29 USD/MWh higher than the projected LMPs. These results show that the policy implemented is efficient, provides benefits to customers, and in some cases to investors. In the cases where the projects were feasible without the incentive, they would have sold their energy for a higher price without the long term contract mechanism. In addition, the project that was not financially feasible under short term market conditions would have needed a higher premium over the LMP price, than the premium achieved through the long term contract.

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Chapter 1: Introduction

1.1 Overview

In December 2013 Mexico passed a comprehensive energy reform that includes the restructuring of the electricity sector. As a result, Mexico implemented a new wholesale electricity market on 2016, and opened utility scale electricity generation to competition from private generators. Under the restructured market, Transmission and Distribution activities (T&D) remain under federal control through the National Center of Energy Control (CENACE). CENACE has the obligation to guarantee open and non-discriminatory access to all market participants (LIE, 2014). As part of the reform, the Federal Electricity Commission (CFE), a vertically integrated federal government company in charge of all electricity supply, will undergo a vertical and horizontal unbundling process.

One very important feature of this reform is a serious commitment to climate change mitigation. The Electric Industry Law (LIE) enacted on august 2014 defines Clean Energy as those processes and sources of electricity whose emissions or residues do not exceed the limits established by the corresponding regulation. The Clean Energy forms considered in the law include: i) wind, ii) solar radiation, iii) oceanic energy, iv) geothermal energy, v) biofuels, vi) methane from waste, vii) hydro power, viii) nuclear, and ix) efficient cogeneration that meets the corresponding regulation criteria (LIE, 2014). The Energy Transition Law, passed by congress and published in December 2015, mandates that Mexico's Department of Energy (SENER) sets the goal of 35% participation of clean technologies in total electricity generation by 2024 (LTE, 2015).

The main mechanism to reach the goals will be the Clean Energy Certificates (CEL), which will replace previous renewable incentives such as the energy bank, and open season fixed low-cost wheeling charges for wind projects (Watson, et al., 2015). Even though the CELs are said to be the only remaining renewable energy incentive, it is important to consider that the Income Tax Law (ISR law) still allows the tax payer to deduct 100% of renewable energy generation or efficient cogeneration machinery and equipment investments on the first year (ISR DOF, 2016). The CEL requirement implemented in Mexico works in a similar way to the Renewable Energy Certificates under the Required Portfolio Standards implemented in the US creating demand for these generation technologies.

In 2015, clean generation technologies in Mexico accounted for around 20% of overall electricity generation (PRODESEN, 2016). The CELs requirements will start on the year 2018 at 5% of electricity consumption (DOF, 2015). This percentage is to be increased in future years to reach the goal of 35% clean electricity consumption by 2024. Since then, two long term auctions have taken place in the Mexican electricity market where Mexico's Federal Electricity Commission (CFE), as electricity supplier, has made offers to purchase power, energy, and certificates through long term contracts. The two main reasons for these auctions are i) to procure the desired market products at competitive prices, and ii) to avoid the risks of price fluctuations (PRODESEN, 2016).

The winners from the First Long Term Auction 2015 placed bids that total 5.4 million megawatts hour (MWh) of energy per year from solar and wind projects. The bids of the winners from the First Long Term Auction 2016 add up to an additional 9.2 million MWh of energy per year from a mix of solar, wind, geothermal, and hydropower project (CENACE SLP, undated).

The increase of renewable and Clean Energy generation has some well-known benefits. Among these benefits are i) diversifying energy sources by moving away from a high exposure to hydrocarbon prices fluctuation, ii) access to local, cheap, and vast renewable sources of energy, iii) improvement of public health, and iv) reduction of green-house-gas emissions. Even though benefits are readily apparent, it is imperative to estimate how much will the newly introduced policy cost. Getting the targeted quantity of Clean Energy within the desired timeline entails forcing the market to provide it at an additional cost.

While there is historical data available to estimate capital requirement for installing these technologies, estimating how this investment costs will impact energy prices is a different story. Having no historic data on CELs, all analysts can do is to come up with estimates from models. But given the way energy policy and CEL requirements are being implemented in Mexico, there is some concrete information readily available to estimate the incremental cost of reaching the Clean Energy goals before they are realized in the market. This information consists of the results of the Long Term Auctions published by CENACE (CENACE SLP, undated), and the projected Locational Marginal Prices (LMPs) published in the Development Program of the National Electrical System (PRODESEN) by Mexico's Department of Energy (PRODESEN, 2016).

1.2 Objectives

The present work intends to understand and evaluate the following research objectives:

i) Estimate the cost of reaching the Clean Energy goals through the implemented energy policy

ii) Evaluate if the projects could be economically feasible by competing in the market without the aiding regulation.

iii) Compare the impact that the CEL regulation and long term contract obligations have on the economic value of the clean projects in different geographic locations.

This research will focus on the analysis of three utility scale photovoltaic (PV) solar power plants that are included in Mexico's Program for the Installation and Retirement of Electric Generation Facilities (PIIRCE), and were winner offers in the First 2015 Long Term Auction. Each power plant is to be located in a different transmission region, and therefore corresponds to a different price zone.

To obtain the cost of reaching Clean Energy goals, the revenues of the projects under the contract terms were modeled and contrasted with projected Locational Marginal Prices (LMPs). Further, a discounted cash flow analysis was made for the projects, both under long term contract conditions and short term market conditions. Based on these discounted cash flow analysis, the economic feasibility of the projects and the impact of the incentives on their value were evaluated.

Chapter 2: Background

2.1 Overview of Mexico's Electricity Infrastructure

The National Electric System (SEN) in Mexico is integrated by: i) the National Transmission Grid, ii) the General Distribution Grids, iii) the Electric Generation Facilities that deliver power to the National Transmission Grid or the General Distribution Grids, and iv) other equipment and infrastructure of the CENACE used for the operational control of the SEN (LIE, 2014).

<u>National Transmission Grid and General Distribution Grids</u>

The National Transmission Grid is the system composed of all the electrical networks that transport electricity to the General Distribution Grids and to the general public, as well as the interconnections to the foreign electric systems. The National Transmission Grid is divided into 53 transmission regions, 45 of which are interconnected with each other, making up a total of 62 links in the National Interconnected System. The remaining 8 transmission regions belong to the isolated systems of the Peninsula of Baja California. The 52 transmission regions are illustrated in Figure1. The National Transmission Grid is integrated by lines with voltages greater than or equal to 69 kilovolts (kV). In 2015, the length of the transmission lines with voltage of 230 and 400 kV was 53,216 kilometers (km). In addition, the total length of transmission lines with voltage from 69 kV to 161 kV was 51,178 km (PRODESEN, 2016).

The General Distribution Grids are used to distribute electricity to the general public. These distribution grids are integrated by medium voltage networks with supply at levels greater than 1 kV and less than or equal to 35 kV, as well as low voltage networks with supply at levels equal to or less than 1 kV. In 2015, the total length of the distribution lines was 775,483 km. There are also 79,413 km of distribution lines with voltage level of 34.5kV and 311,857 km with voltage level of 13.8 kV (PRODESEN, 2016).

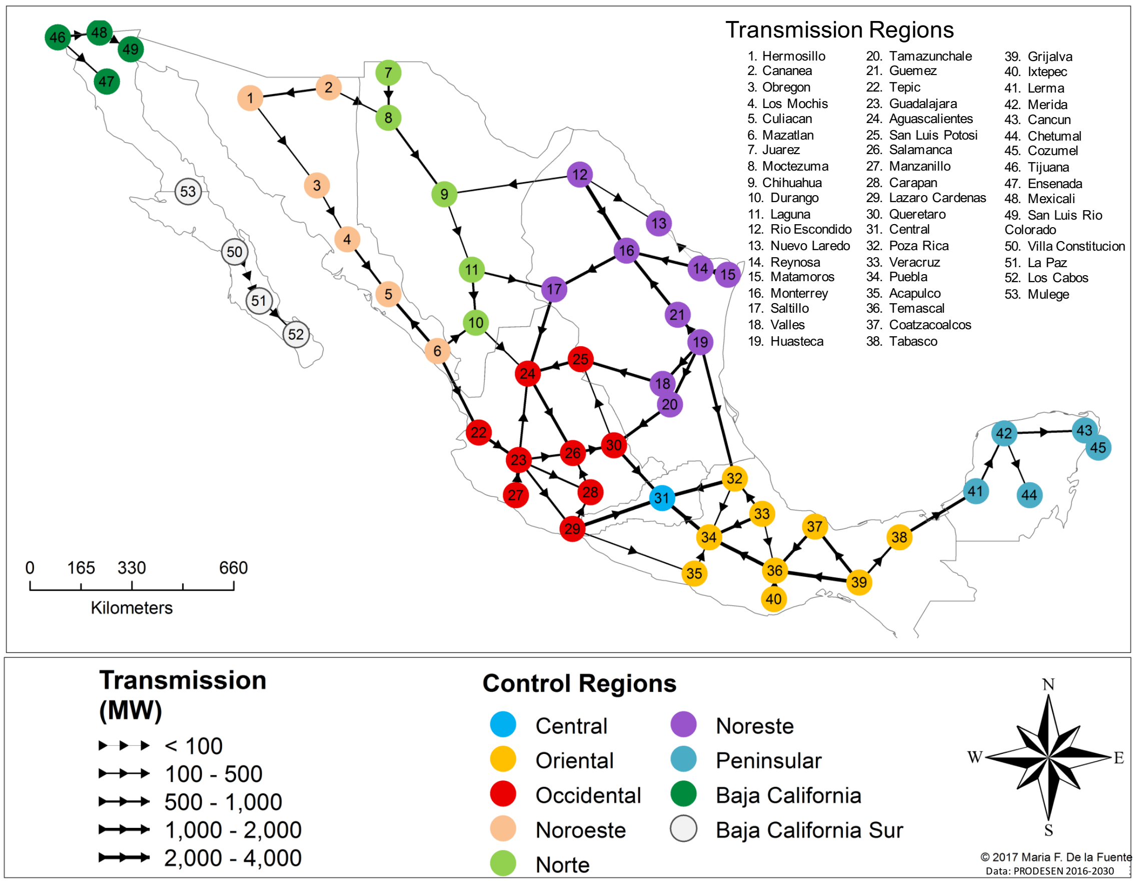

Figure 1: Transmission Regions and Capacity of Transmission Lines of the National Electric System (SEN)

Data Source: PRODESEN 2016-2030. (PRODESEN, 2016)

The SEN is divided into 9 regions for planning purposes. Traditionally these regions were under the responsibility of 7 control centers located in different states coordinated by the CENACE, (CFE, 2007). These 9 regions are called control regions, of which 7 are interconnected forming the National Interconnected System. The interconnection of the control regions in Baja California to the National Interconnected System is expected to start in 2021.

shows the electricity consumption in each control region in 2016. The Occidental region has the first place in electricity consumption with 23%, while The Central region, being the by far the smallest in area, comes in second place with 19% of electricity consumption. Mexico's Department of Energy (SENER) planning scenario considers a mean annual growth of electricity consumption in the SEN of 3.4% for the 2016-2030 period (PRODESEN, 2016).

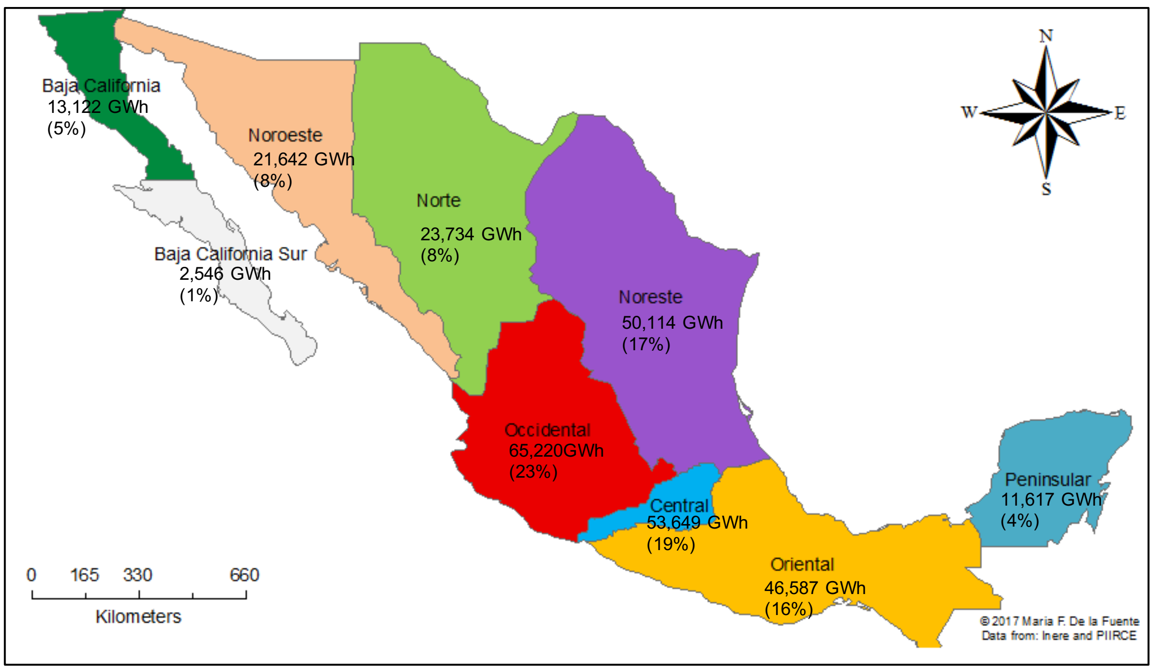

Figure 2: Electricity Consumption by Control Region
Data Source: SENER, 2016. (PRODESEN, 2016)

<u>Installed Capacity and Generation</u>

In 2015, the installed capacity of the SEN was 68,044 megawatts (MW). Of the overall installed capacity, 71.7% corresponds to conventional technologies and 28.3% to what is defined by Mexico's law as clean technologies. As evident in Figure 3 and 4, Natural Gas Combined Cycle (NGCC) had the largest installed capacity in 2015, providing more than half of Mexico's electricity. The 2015 installed capacity increased 4% from 2014. In terms of ownership, in 2015 CFE owned 61.6% of all installed capacity, independent power producers owned 19%, and private individuals contributed the remaining 19.4% via self-supply, cogeneration, small production, export, own continuous uses, generators, distributed generation, and not-interconnected rural systems (PRODESEN, 2016).

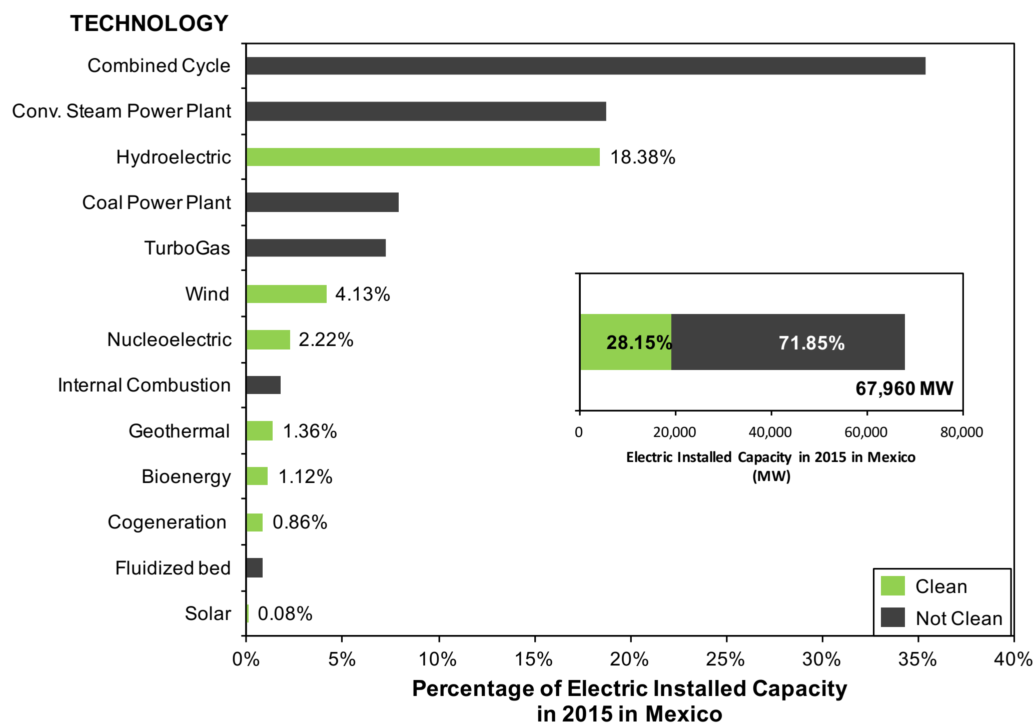

Figure 3: Installed Capacity by Technology on 2015
Data Source: SENER, 2016 (PRODESEN, 2016)

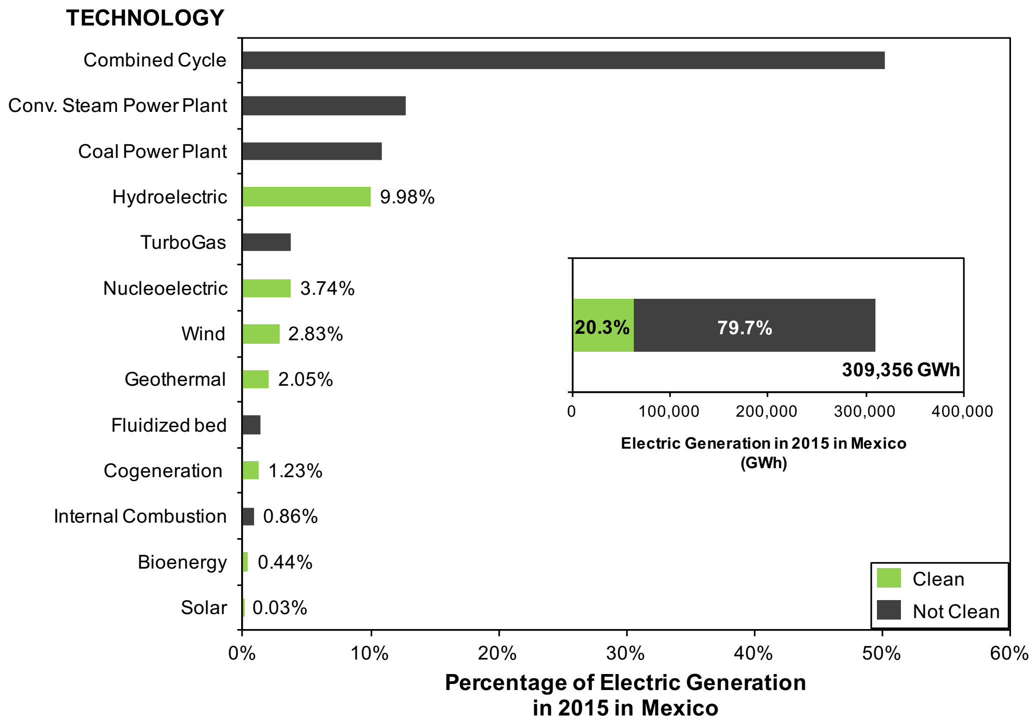

Figure 4: Electricity Generation by technology on 2015
Data Source: SENER, 2016 (PRODESEN, 2016)

Generation is more concentrated in north and east States, as shown in Figure 5. In 2015, 67.6% of the total electricity generated came from the Noreste, Oriental, and Occidental control regions. The Norte, Central, Noroeste and Peninsular control regions accounted for 25.1% of the generation, and the remaining 7.3% was generated in the isolated systems of Baja California and Baja California Sur (PRODESEN, 2016). The highest participant technology by far in the Noreste region is NGCC, while in the Oriental region Nuclear and Hydropower follow natural gas more closely, as can be seen in

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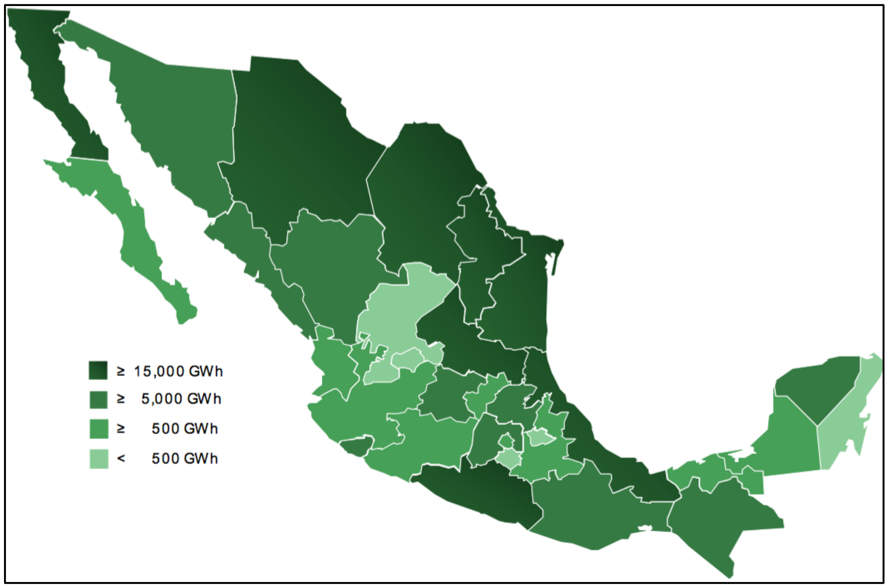


Figure 5: Electricity Generation by State
Figure Source: SENER, PRODESEN 2016-2030, 2016

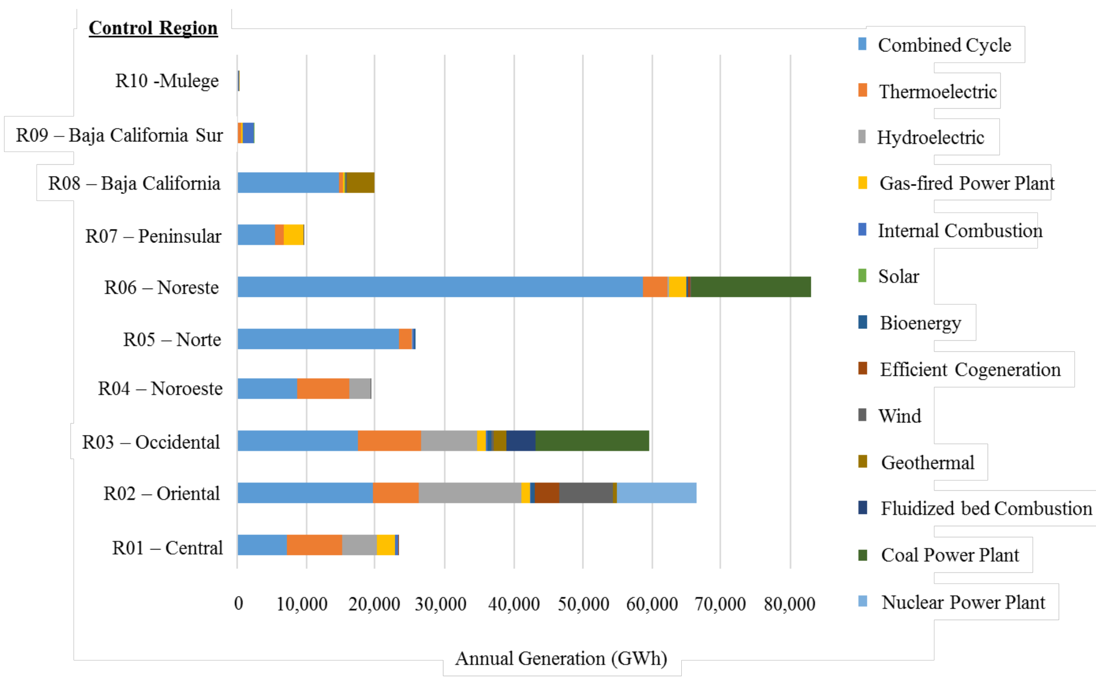


Figure 6: Electricity Generation by Technology and Control Region
Data Source: SENER, (PRODESEN, 2016)

2.2 THE EVOLUTION OF MEXICO'S ELECTRIC SECTOR

In the early decades of Mexico's electric industry, generation and provision of electricity was predominantly in the hands of few private and vertically integrated companies. As a result, there was a monopolistic pricing tendency that led to customer protests against high rates. In the 1920's the government made the first attempt at regulation of the electric industry, however, these efforts were not very effective (CEE and TEC, 2006). In addition, by the 1930's only 38% of the population was serviced, leaving behind most rural areas (CFE, undated).

In response, generation and distribution of electricity was declared to be a public utility service by decree in 1933. Additionally, the Federal Government created the Federal Electricity Commission (CFE) on 1937, to coordinate a national system for the provision of electric energy, and to provide it without purpose of profit (CFE, undated). A process of nationalization began in 1944 and culminated in 1960 with the amendment of Article 27 of the Mexican Constitution (Carreón-Rodriguez, et al., 2003). The constitution now made it the exclusive responsibility of the Nation to generate, transmit, and supply electricity. In addition, it forbade the granting of concessions to private individuals (DOF, 1960).

Consequently, the electricity sector in Mexico was a pure national monopoly for over 32 years (from 1960 to 1992), with CFE as sole provider of all activities in the electricity supply chain, which includes generation, transmission, and distribution. CFE served all the territory with one exception, Luz y Fuerza del Centro (LFC), another government-owned company that served a few central States in Mexico. This company was originally Mexican Light and Power. The federal government changed its name to LFC after the decree of 1960. The company was to be dissolved and absorbed by CFE, but this did not happen until 2009 because of extreme opposition of unionized workers of the company (CEE and TEC, 2006).

By 1992, CFE had been struggling to keep pace with rising demand. There had been high cross subsidization from industrial customers to residential customers, since residential tariffs were politically risky to increase despite rises in fuel costs. This situation, coupled with financial crises, motivated small reforms to allow limited private participation in electricity generation (CEE and TEC, 2006). The amendment to the Public Utility Electricity Service Law (LSPEE) on December 1992 allowed participation on generation of electricity from private parties for self-supply, to be sold for export, or to be sold to CFE (Decree, 1992). Even under these restricted schemes for private participation, up to 36% of the installed capacity in the national electric sector came from private entities in 2013 (DOF, 2013).

2.3 Mexico's Energy Reform

In December 2013, Mexico passed a comprehensive energy reform that includes the restructure of the electricity sector. Under this new regulatory framework, Mexico implemented the new wholesale electricity market between the months of January and March 2016 (CENACE, undated). The generation sector was opened to competition from private generators, while transmission and distribution remain under federal government control. The key regulatory elements of this energy reform that pertain to the electric industry are the amendments to articles 25, 27 and 28 of the Constitution in December 2013, and derived secondary laws such as the LIE, and the Federal Electricity Commission Law (CFE Law).

Article 27 now states that the planning and control of the National Electric System (SEN), as well as the transmission and distribution of the electricity, is the exclusive responsibility of the Mexican federal government. Therefore, no concessions will be granted for these activities, notwithstanding that Mexico's federal government may still go into contracts with private parties to provide this service under the terms established by the mexican laws (Decree, 2013). Under the light of other amendments made to regulate and penalize monopoly practices, Article 28 paragraph 4 of Mexico's Constitution was amended to state that the strategic activities that are performed by the state in an exclusive way will not be considered monopolies. Among these activities are nuclear energy generation, planning and control of the SEN, and the transmission and distribution of electricity (Decree, 2013). Article 25 was amended to state that the public sector will be exclusively in charge of the strategic areas mentioned in article 28 paragraph 4, and Mexico's federal government will maintain ownership and control over the State productive companies and organizations established to fulfill these activities.

A State productive company is a company owned by the federal government that participates in the market in the same way as private companies do. The new CFE Law makes CFE a State productive company. This Law was enacted by the Mexican Congress on August 2014 and encompasses the rules regarding its organization, administrative structure, salaries, operation, acquisitions and leases, responsibilities, dividends, budget, debt, and reporting obligations (CFE Law, 2014). CFE is given more flexibility to make corporate government and business model decisions, as well as being provided with budgetary autonomy and increased freedom to negotiate and acquire debt (PwC, 2014).

The LIE was enacted by the Mexican Congress on August 2014 and establishes the foundation principles of the electricity market. The law aims to regulate the planning and control of the SEN, the electric energy transmission and distribution service, and all other activities of the electric industry. It also looks to promote the sustainable development of the electric industry, and to guarantee its continuous, efficient and safe operation that benefits its customers. The LIE also intends to ensure compliance with universal public service, Clean Energy, and pollutant emission reduction obligations. The LIE gives the

Energy Regulatory Commission (CRE) the responsibility of establishing the market rules, and the CENACE the role of overseeing the market and establishing the market operation rules (LIE, 2014).

2.4 MEXICO'S NEW ELECTRICITY MARKET RULES

The LIE states that the generation, transmission, distribution, marketing of electricity, and supply of primary materials for the electric industry will be carried out in an independent manner, and under conditions of strict legal separation. In the same way, the Basic Services Supply (electricity service supply under a regulated tariff to users with a minimum load of less than 1MW) and other marketing modalities will be separated. It is stipulated that SENER will establish the terms of this legal separation and will oversee compliance with it. In addition, the LIE gives the CRE the faculty to require the functional, accounting, or operative unbundling of the members of the electric industry (LIE, 2014) .

Privately owned generators that existed under the previous schemes (such as Independent Power Producer, cogeneration, self-supply and small generation) can choose between continuing under their old roles, or transition to the new generation scheme defined in the LIE. Transmission and distribution will be controlled by the CENACE. Despite the fact that the law establishes that no concessions will be made regarding transmission and distribution, CENACE will still be able to enter into contracts with private parties for grid expansion, maintenance and operation. The LIE states that CENACE is in charge of "the operational control of the SEN, operating the wholesale electricity market, and the open and non-discriminatory access to the national transmission network and the general distribution networks". Additionally, the CRE is in charge of setting the rules for the calculation of transmission and distribution fees (LIE, 2014).

Electricity generation facilities require a permit if they want to participate in the wholesale electricity market as electricity generators, or if they have a generation capacity larger than 0.5MW. Facilities that do not require a generation permit are referred to as exempt generators. This is the case in two scenarios, i) their capacity is less than 0.5MW, or ii) their capacity is destined only for self-supply, emergencies, or for interruptions of the electricity supply service. Small generators that do not require a generation permit will be able to sell their electricity and controllable demand related products through their electricity service suppliers, who will represent them in the market (LIE, 2014).

Under the new law, Qualified Users are defined as customers with a minimum load of 1 MW. These customers can represent themselves in the wholesale market, or be represented by a Qualifier Service Supplier. Smaller customers with similar interests will be able to aggregate their demand in their load centers to be registered as Qualified Users, but they will need to be represented in the wholesale electricity market by a Qualified Supplier. On the other hand, Basic Supply is the electricity service provided under a regulated tariff to customers that are not Qualified Customers. In the new regulatory framework, individuals and businesses can participate in the wholesale electricity market in the following roles (LIE, 2014):

1. Generator: An entity that owns or represents an electric generation facility in the wholesale electricity market.
2. Basic Service Supplier: A supplier that provides electricity, and other services needed to satisfy electricity demand to Basic Supply users, and that can represent them as exempt generators in the wholesale electricity market.
3. Qualified Service Supplier: A supplier that provides electricity, and other services needed to satisfy electricity demand to Qualified Users under a competition regime, and can represent them in the wholesale electricity market as exempt generators..

4. Last Resource Supplier: A supplier of electric services at maximum prices when a Qualified Supplier fails to deliver such services. The rules for the determination of maximum prices to be charged by the last-resource suppliers will be established by the CRE.
5. Non-supplier Marketer: Is a market participant that has a permit to carry out marketing activities but is not a Supplier.
6. Market Participant Qualified Users: Customers with a minimum 1 MW load that represent themselves in the wholesale electricity market.

CFE and other Generators will be able to sell their electricity in the short-term wholesale market, or enter into bilateral contracts with Suppliers and Qualified Users through competitive, non-regulated tariffs. Basic Service Suppliers, on the other hand, will be able to offer services to Basic Service users under regulated tariffs. The rules for calculation of regulated tariffs will be set by the CRE. Basic Suppliers can only enter into bilateral electric coverage contracts through the auctions to be performed by the CENACE (LIE, 2014). Figure 7 illustrates the structure of the wholesale electricity market.

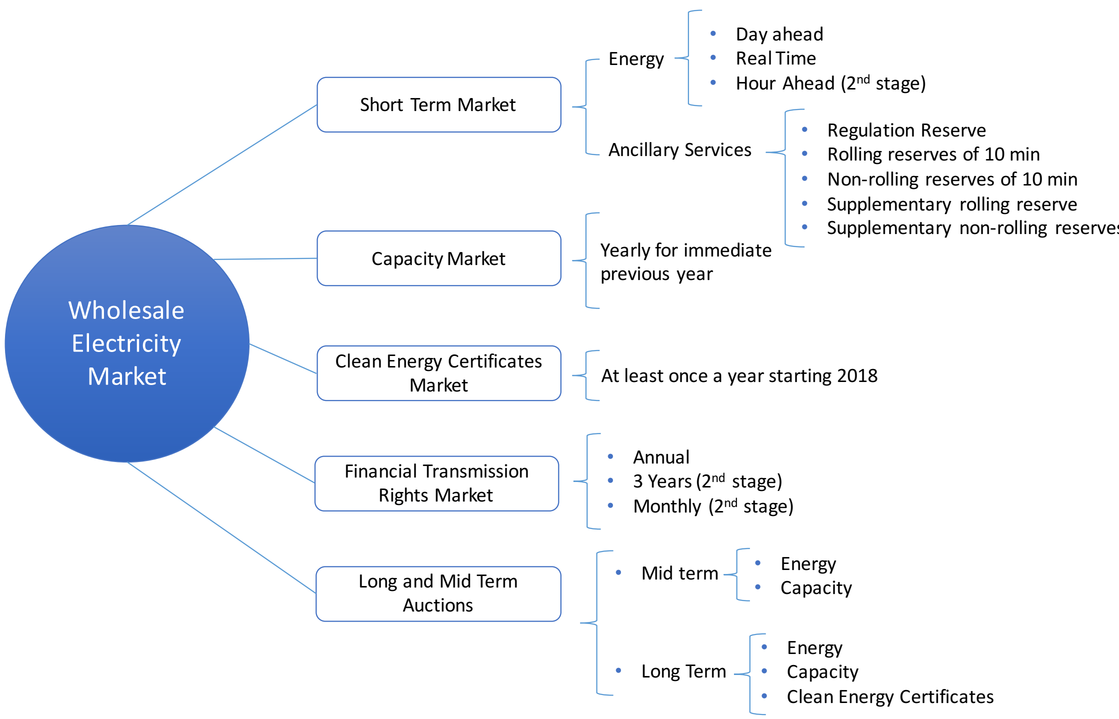


Figure 7: Wholesale Electric Market Structure
Figure Source: Adapted from CENACE, Mercado y Operaciones, undated, (CENACE, undated a)

The new regulatory framework delineates the specific responsibilities of Mexico's energy related agencies (e.g. SENER, CRE, and CENACE). Some main responsibilities of SENER are (i) designing and coordinating the country's electric energy policy, (ii) directing the formulation of the development plan of the SEN, (iii) creating a committee, in coordination with the CRE, for the evaluation of the performance of the CENACE and the wholesale electricity market, (iv) establishing the criteria and requirements for CELs, and (v) coordinating and supervising the transformation of CFE into a productive state company (LIE, 2014) (PwC, 2014). Some main responsibilities of the CRE are (i) regulating and granting electricity generation permits, and providing model interconnection contracts, (ii) emitting and applying tariff regulation for the transmission, distribution, operation of basic services, among others, (iii) issuing of the bases of the wholesale electricity market, and monitoring of its operation, (iv) verifying compliance with the CEL requirements, (v) establishing requirements for Qualified Suppliers and keep the registry of such users, and (vi) expediting the regulation on efficiency and quality of the SEN (LIE, 2014) (PwC, 2014).

Some main responsibilities of CENACE are (i) controlling the transmission and distribution lines and establishing the guidelines for the operators, (ii) operating the wholesale electricity market, as well as the setting and revising of its operating provisions, (iii) determining the economic dispatch of electric generation facilities, (iv) carrying out auctions for electrical coverage contracts between generators and representatives of load centers, and (v) calculating the contributions that the interested parties must make for the construction, expansion or modification of transmission and distribution networks when the costs are not recovered through regulated tariffs, and vi) formulating the plans for expansion and modernization of the national transmission grid, and for the elements of the distribution grid that correspond to the wholesale electricity market (LIE, 2014) .

CFE in the New Electricity Market

The new laws mandate vertical and horizontal unbundling of CFE to foster fair competition in the new market (Figure 8). The activities of generation, transmission, distribution, and marketing within the CFE will observe a strict vertical separation, which must be a legal type separation. Legal horizontal unbundling of generation business units is also required. The distribution activity must observe a horizontal separation by regions, which may be accounting, operational and functional, or legal (LIE, 2014) . Figure 9 illustrates the new structure of the CFE as a state productive company.

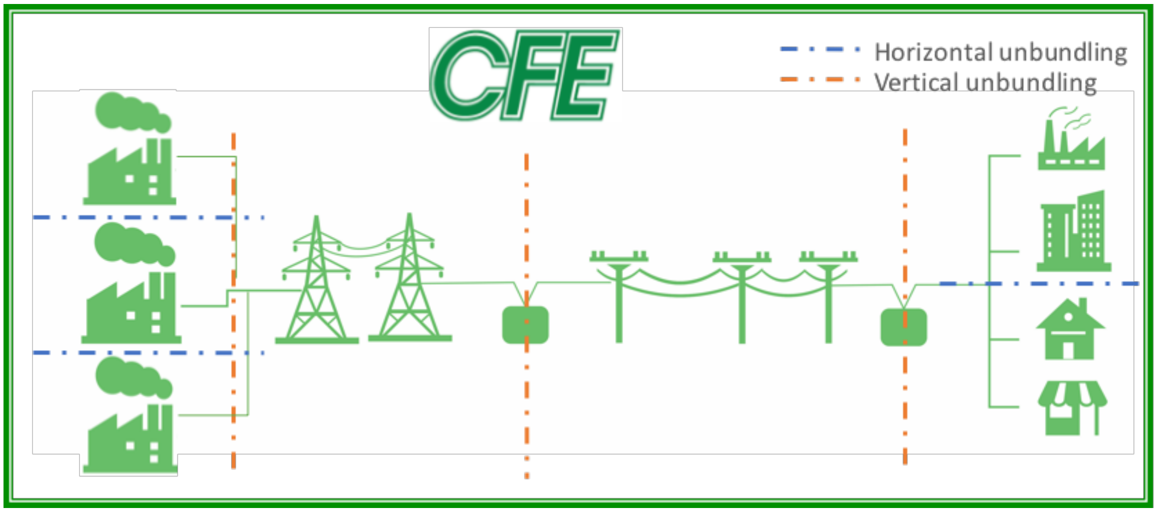


Figure 8: Comision Federal de Electricidad CFE vertical and horizontal unbundling

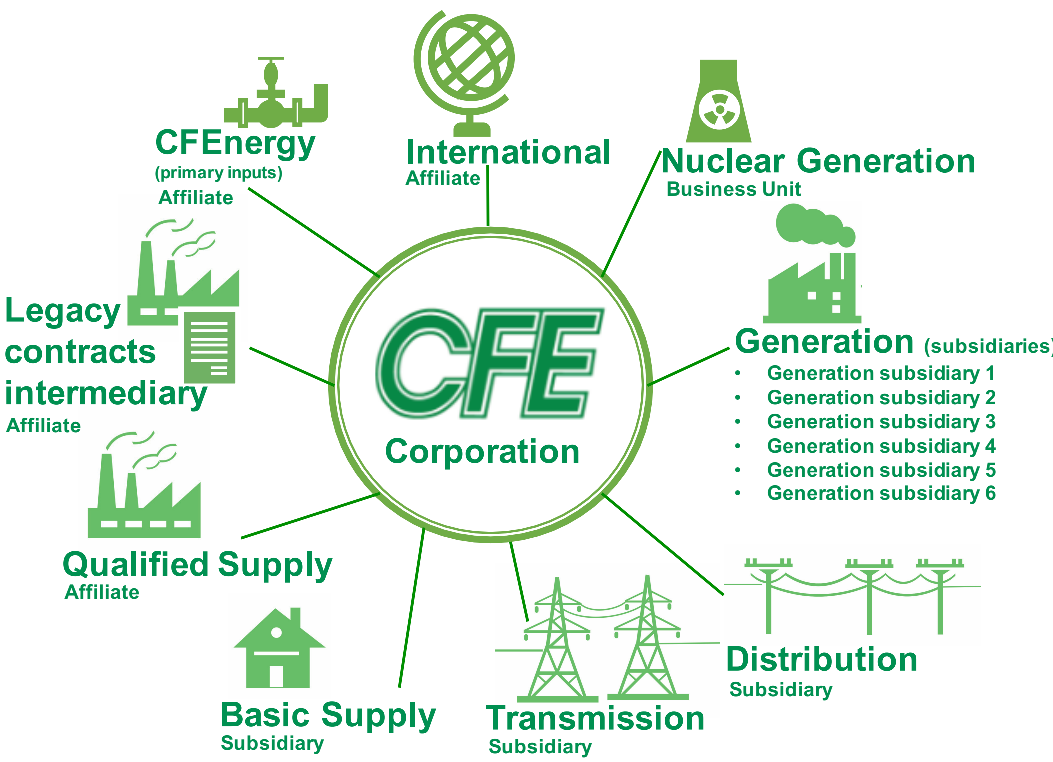


Figure 9: New Structure of CFE - State Productive Company.
Figure Source: Adapted from CFE Webpage (CFE, undated b)

With respect to the development of new power plants, CFE may participate in new projects through itself, subsidiaries, companies in which it participates in a minority way, directly or indirectly, or through any partnership or alliance that is not contrary to the law. Marketing activity within the CFE must observe a strict legal vertical separation. As in the case of generation, marketing can be carried out through subsidiaries and other associations in which the CFE does not have a 100% participation (PwC, 2014).

2.5 Clean Energy Goals and Clean Energy Certificates

The LIE introduces the Clean Energy obligations that will be established to fulfill the policies for energy diversification, energy security, and promotion of Clean Energy sources (LIE, 2014). The obligations for clean generation will be implemented through a system similar to the Renewable Portfolio Standards (RPS) implemented in the US.

According to the guidelines set by SENER, CELs are given to new facilities or generation capacity additions that meet the clean energy criteria. Qualifying generators will have the right to receive the certificates for a period of 20 years. The market will establish the value of the CELs and each one will represent 1 MWh of energy generated and delivered. The market participants required to comply with clean energy goals are i) Suppliers, ii) Qualified Users, iii) Final Users receiving energy through isolated supply, and iv) holders of Interconnection Contracts under previous regulation. Obliged parties will have to prove compliance every three months and will be able to buy CELs for this purpose (SENER, 2016a) (CRE, undated). CELs will be traded through contracts, in the CEL market operated by CENACE, through long-term auctions organized by CENACE, or in an annual settlement.

Penalties for not complying with CEL requirements are set by the CRE. The sanctions will be calculated as a function of i) significance of the infraction, ii) economic ability to pay, with penalties of up to 50 minimum wages per MWh of non-fulfilled obligations, iii) incidence, and iv) other elements of the gravity of the infraction. Frequency of incompliance will be taken into account, making the sanctions higher as incidence increases (CRE, 2015a). In 2015, Mexico generated 20.3% of electricity through clean energy (PRODESEN, 2016). The Clean Energy requirement will start at 5% of energy purchased in 2018 (SENER, 2015), aiming for a 25% participation of Clean Energy. This percentage is to be increased in future years to reach the goal of 35% clean electricity consumption by 2024 (CRE, undated).

2.6 Mexico's Development Program of the National Electric System (PRODESEN)

The Development Program of the National Electric System (PRODESEN) is published by SENER as an instrument for the planning of generation, transmission and distribution activities. The PRODESEN is meant to be the fundamental basis for defining the projects that the transmission and distribution operators will carry out. This plan is a result of the coordination of the Indicative Program for the Installation and Retirement of Electric Generation Facilities (PIIRCE) with the Expansion and Modernization Program of the National Transmission Grid (PAMRNT) and General Distribution Grids (PRODESEN, 2016).

The PIIRCE is the result of a long-term planning exercise to find the combination of new generation investments that minimizes the total cost (investment and operation) of the SEN needed to meet the forecasted demand and to comply with Clean Energy objectives. Minimum Clean Energy shares of 25% for 2018, 30% for 2021, and 35% for 2024 of the generation of electricity are used constraints in the PIIRCE model (PRODESEN, 2016). The PIIRCE 2016-2030 is meant to be a reference of the capacities by type of technology and geographical location of the new generation units needed to satisfy electricity demand and Clean Energy goals. The PIIRCE model considers the following inputs (PRODESEN, 2016):

- Forecasted Demand, considering assumptions for future population, electricity prices, transmission losses, and Gross Domestic Product (GDP). The model assumes that the gross electric energy consumption is expected to grow on average 3.4% per year. Peak demand is generally expected to grow faster than non-peak demand. Hourly projected demand by hour by control region can be found in Appendix A. The projected demand per control region used for the elaboration of the PIIRCE is shown in Figure 11.
- Transmission constraints under maximum demand conditions.
- Current and future pipeline infrastructure with respect to availability of natural gas for electricity generation, guided by the 5-year plan developed by CENAGAS on 2015.
- Expected evolution of the GDP, considering an average annual growth of 4.1%.
- Forecasted fuel prices based on estimations of PIRA Energy Group and according to official methodologies emitted by the CRE (Figure 10).
    - Coal: Annual average growth of 3.8%
    - Fuel oil: Annual average growth of 5%
    - Crude oil: Annual average growth of 4.3% for West Texas Intermediate, 4.7% for Brent, 4.9% for Mexican Mix for Exports.
    - Diesel: Annual average growth of 3.2%
    - Natural Gas: Annual average growth of 2.6%, and a 3.3% annual average growth for liquefied natural gas (LNG).

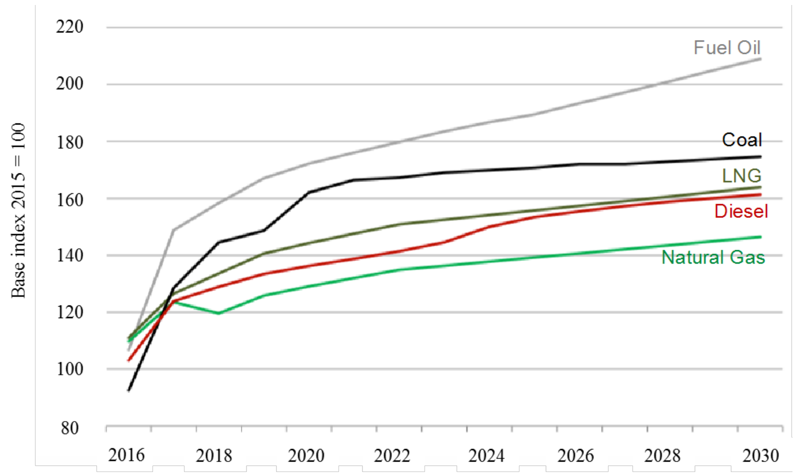


Figure 10: Projected fuel Prices 2016-2030. Planning Scenario. (Base index 2015 = 100)
Figure Source: SENER, PRODESEN 2016-2030, 2016. (PRODESEN, 2016)

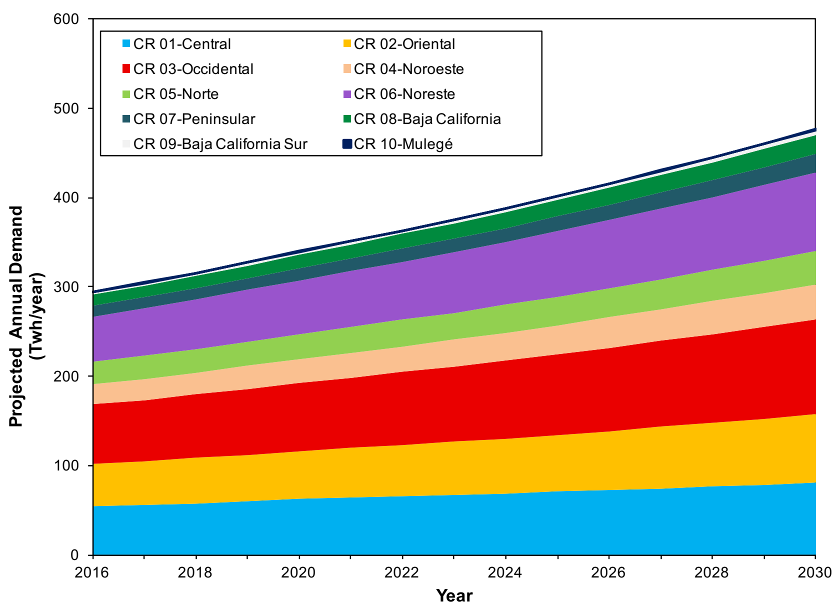


Figure 11: Projected Annual Demand by Control Region
Data Source: SENER, Base de datos de demanda horaria para PIIRCE 2016-2030, 2016. (SENER, 2016b)

For different control regions, peak demand occurs at different moments in the year. This is mainly due to differences in temperatures and specific uses of electricity between regions. All control regions reach their peak demand during summer, with the exception of the Central region, which reaches its peak load on winter when extensive heating is required (PRODESEN, 2016). Furthermore, the projected demand database published by SENER indicates that overall maximum demand is expected to grow at different speeds between control regions as illustrated in Figure 12 (SENER, 2016b).

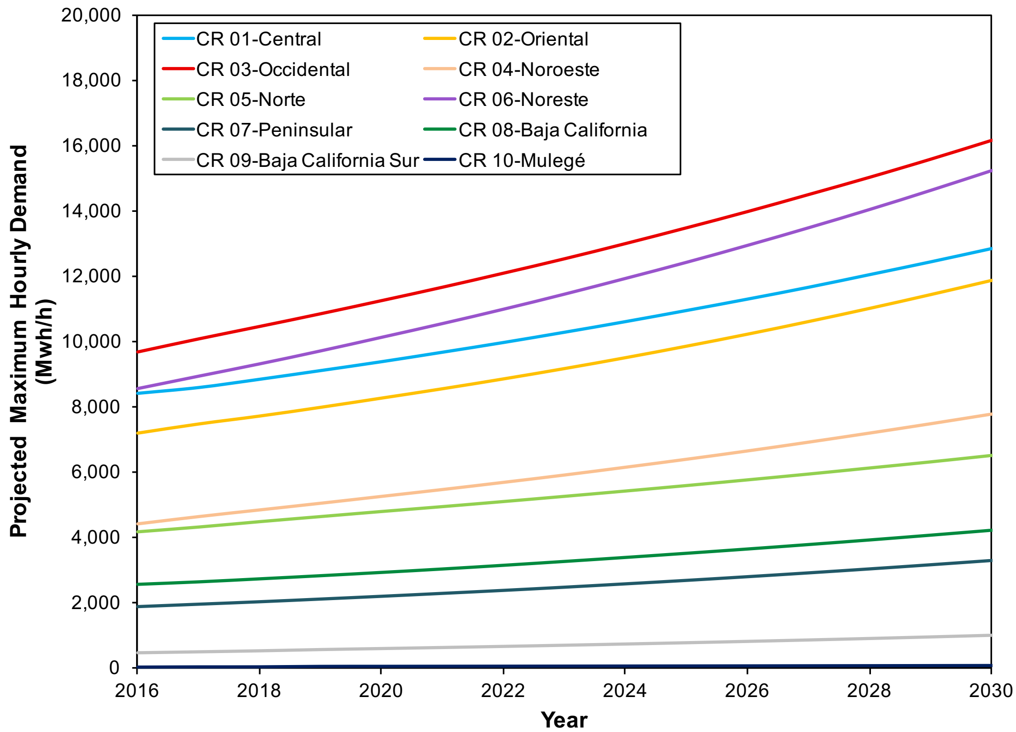


Figure 12: Projected Maximum Demand by Control Region
Data Source: SENER, Base de datos de demanda horaria para PIIRCE 2016-2030, 2016. (SENER, 2016b)

According to the PIIRCE 2016-2030 model, the projected additional capacity required will be comprised of 38% conventional technologies and 62% clean technologies. Among conventional technologies natural gas combined cycle is the largest. Of the clean technologies, wind has the lead, followed by efficient cogeneration and solar technologies (both PV and concentrated solar). The expected participation of each technology in the required additional capacity estimated for the years 2016 to 2030 is illustrated in Figure 13. In addition, Figure 14 shows the amount of additional capacity expected to be installed by State in the period 2016-2030 (PRODESEN, 2016), with the highest capacity additions in the States of Sonora, Veracruz, and Oaxaca.

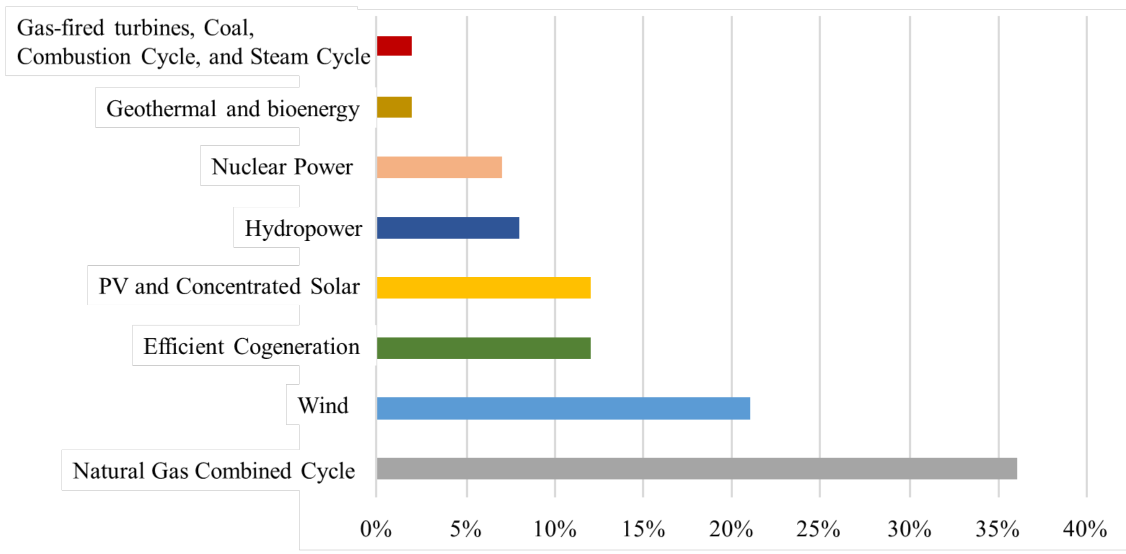


Figure 13: Participation of each technology in additional capacity for 2016-2030
Data Source: SENER, PRODESEN 2016-2030, 2016 (PRODESEN, 2016)

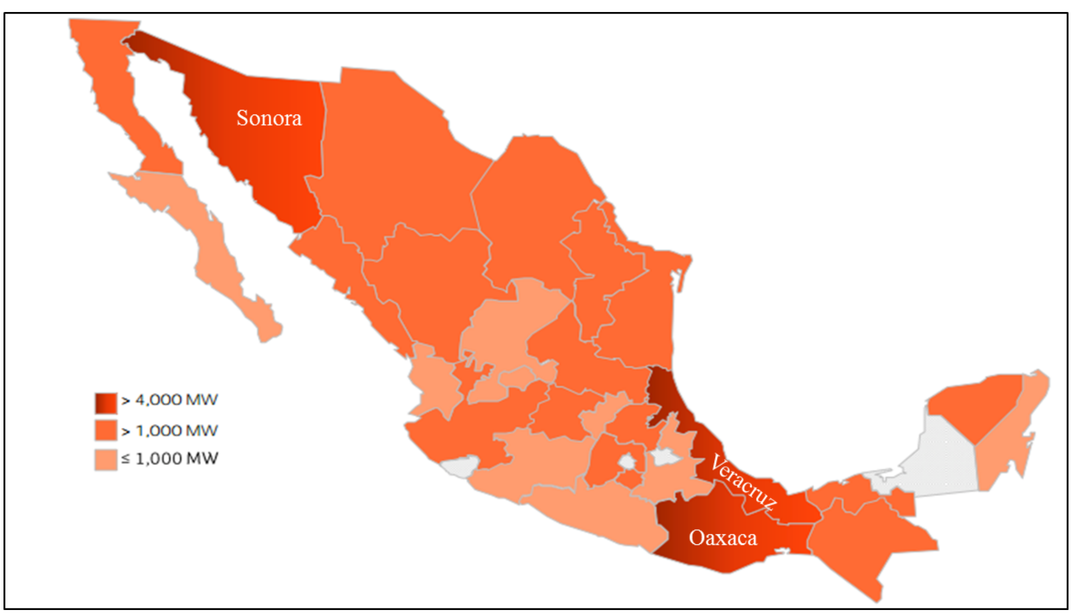


Figure 14: Map of additional capacity by State derived from PIIRCE 2016-2030
Figure Source: SENER, PRODESEN 2016-2030, 2016. (PRODESEN, 2016)

Based on these plans, SENER modeled and published the projected hourly Locational Marginal Prices (LMPs) for each of the 52 zone prices that correspond to the transmission regions considered for the PIIRCE. LMPs are the result of an economic dispatch model that minimizes the system costs through the optimal dispatch of generation units to satisfy demand, subject to the system operational restrictions (e.g. power ramps, variable costs, efficiencies, available capacity, and system losses). The main inputs for the calculation of the LMPs are (SENER, 2016c):

- PIIRCE 2016-2030
- PAMRNT 2016-2030
- Projections of gross electricity demand of the SEN elaborated by CENACE
- Estimates of natural gas prices, considering only the variable costs of the fuel, and the use of both Mexican and American pipelines

2.7 Latest developments and regulation

In March 2016, the CRE emitted requirements for Basic Suppliers and Qualified Suppliers to enter into long-term electric supply contracts with respect to capacity, energy, and CELs, establishing as well the minimum amounts to be included in these contracts. Each year, the Suppliers of Qualified Services and Basic Services shall estimate their demand for energy, power and Clean Energy Certificates (CEL) for each of the following 18 calendar years and enter into coverage contracts for the required percentage of their estimated demand of the three products (CRE, 2015b).

Table 1 shows the percentage of forecasted energy, capacity and CELs that Basic Suppliers are required to ensure through these contracts. For the first 3 years, Basic Suppliers will be required to purchase 100% of the CEL requirement, energy, and capacity that their customers will need according to their own projections.

Table 1: Required percentages of the estimated demand for Basic Suppliers

Year	Energy	Capacity	CEL
1	100%	100%	100%
2	100%	100%	100%
3	100%	100%	100%
4	CEL amount	90%	90%
5 to 6	CEL amount	0.7	0.7
7 to 9	CEL amount	70%	50%
10 to 12	CEL amount	30%	30%
13 to 18	CEL amount	30%	30%

Table Source: (CRE, 2015b)

As shown in Table 2, Qualified suppliers are required to cover 60% of their projected demand of energy, capacity and CELs for the first three years.

Table 2: Percentage of demand required for Qualified Suppliers

Year	Energy	Capacity	CEL
1 to 3	60%	60%	60%
4 to 6	CEL amount	50%	50%
7 to 9	CEL amount	40%	40%
10 to 12	CEL amount	30%	30%
13 to 18	CEL amount	0.2	0.2

Table Source: (CRE, 2015b)

CENACE is carrying out auctions as the mechanism by which the entities responsible for load can enter into contracts in a competitive and prudent way to meet the needs of capacity, cumulative electrical energy, and CELs. Such entities may participate in medium and long term auctions through the following roles (CENACE, undated b):

i) Basic Service Provider.

ii) Supplier of Qualified Services.

iii) Supplier of Last Resort.

iv) Qualified User Market Participant.

Long term auctions have the following three objectives (CENACE, undated b):

i) to enable Basic Service Providers to enter into contracts in a competitive and prudent manner to meet the needs of capacity, cumulative electrical energy, and CELs that they must cover through long term contracts in accordance with the requirements established by the CRE;

ii) to allow the other entities responsible for load to participate in them when they choose to do so, to enter into contracts for quantities of products in proportion to the portfolio of capacity, cumulative electric energy and CELs that is to be obtained for the Basic Service Providers; and

iii) to allow those who enter into these contracts, as sellers, to have a stable source of payments that contributes to support the financing of the efficient investments required to develop new Power Plants or to revitalize existing ones.

The terms of the contracts derived from the long term auctions will be of 15 years for capacity and cumulative electric energy, and 20 years for CELs (CENACE, undated b). Two long term auctions have taken place in the Mexican wholesale electricity market where CFE in the role of electric service supplier has offered to buy capacity, energy, and certificates. In the first 2015 long term auction the average price of energy plus CELs was 47.48 USD per (MWh+CEL). Prices of energy and certificates were bundled in the offers of this auction. Price averaged 55.39 USD for wind projects, and 45.15 USD for solar projects. The results of the 2015 auction are summarized in Figure 15 and Table 3 (PRODESEN, 2016). According to the auction rules, the exchange rate used to evaluate the offers received is the FIX exchange rate published by BANXICO 5 days before the offers were presented, that is 17.4 pesos per U.S. dollar. All projects are scheduled to start operations in 2018 (BasesSLP, 2016). On this first auction, 93.9% of the energy offers came from solar PV projects, and the remaining 6.1% came from wind projects.

Table 3: Summary of winner offers of the first Long Term Auction 2015

Name of project	Availability	Energy (MWh/year)	CELs (CEL/year)	Offered Price (MXN/year)	Technology	Transmission Region / Price Zone	Capacity (MW)
Energía Renovable de la Peninsula	23-Mar-18	275,502	275,502	$ 314,423,955	Wind	42-Merida	90.0
PE el Cortijo	1-Sep-18	585,731	585,731	$ 434,699,412	Wind	14-Reynosa	168.0
Parque Eolico Chacabal	28-Mar-18	113,199	113,199	$ 117,085,926	Wind	42-Merida	30.0
Parque Eolico Tizimin	27-Sep-18	291,900	291,900	$ 338,331,511	Wind	42-Merida	76.0
Parque Eolico Chacabal II	28-Mar-18	117,689	117,689	$ 121,730,100	Wind	42-Merida	30.0
Sol de Insurgentes	30-Jun-18	60,965	60,518	$ 50,500,753	PV Solar	50-Villa Constitu	23.0
Parque solar don Jose	25-Sep-18	539,034	539,034	$ 421,005,400	PV Solar	30-Queretaro	207.0
Guajiro 2	1-Aug-18	269,155	263,815	$ 209,932,823	PV Solar	30-Queretaro	100.0
Aguascalientes potencia 1	20-Sep-18	140,970	140,970	$ 116,936,169	PV Solar	24-Aguascalientes	63.0
Las viborillas	28-Sep-18	277,490	277,490	$ 226,975,665	PV Solar	24-Aguascalientes	100.0
Concunul	28-Sep-18	176,475	176,475	$ 178,133,177	PV Solar	42-Merida	70.0
San Ignacio	6-Jun-18	48,748	48,748	$ 53,447,999	PV Solar	42-Merida	18.0
Kambul	1-Jan-18	54,975	53,477	$ 64,307,962	PV Solar	42-Merida	30.0
Ticul 1	1-Aug-18	740,135	725,450	$ 727,122,881	PV Solar	42-Merida	500.0
Parque Solar Villanueva 3	25-Sep-18	737,998	737,998	$ 489,680,736	PV Solar	11-Laguna	250.0
Parque Solar Villanueva	25-Sep-18	972,915	972,915	$ 597,503,346	PV Solar	11-Laguna	330.0

Data Source: SENER and CENACE, 2016. (PRODESEN, 2016) (CENACE, 2016)

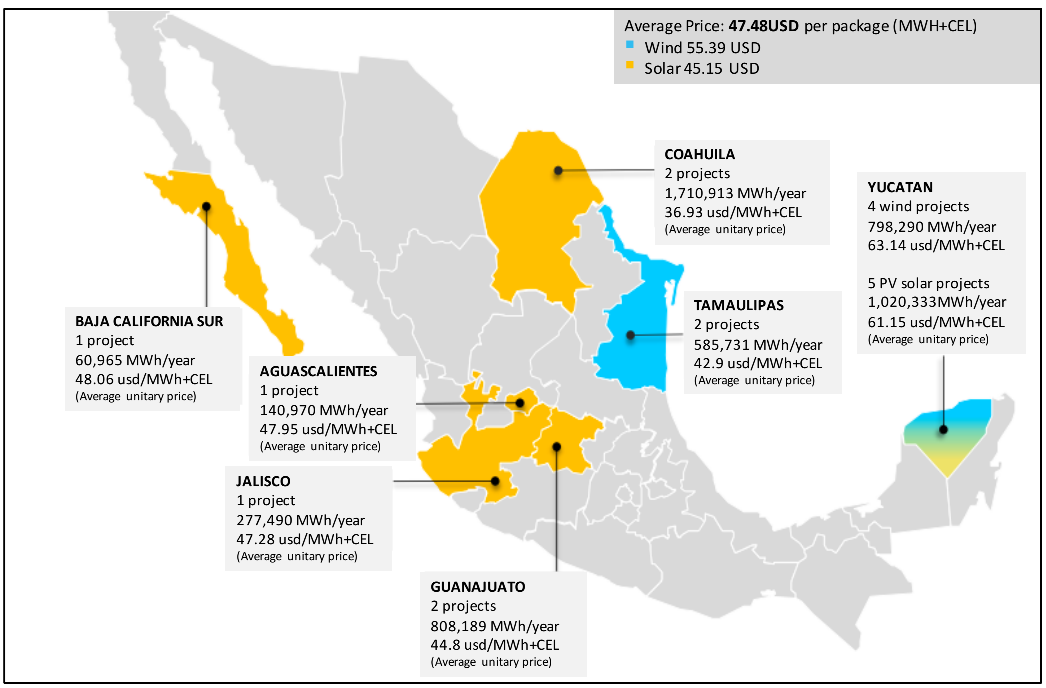


Figure 15: Map of winner projects of the first long term auction 2015
Figure Source: SENER with data from CENACE, PRODESEN 2016-2030, 2016 (PRODESEN, 2016)

The second long term auction took place in 2016. This auction resulted in contracts that total 8.9 million MWh of energy, 9.3 million CELs, and 1,187MW of capacity per year. The average price for the long term auction 2016 was 33.47 USD per package (MWh+CEL). In this auction several bids presented a separate price for energy and certificates (CENACEc, 2016). The winning power plants are required to start operations in 2019 (BasesSLP, 2016).

Table 4: Products acquired through the first Long Term auction 2016 by technology

Technology	Products assigned per Technology			Participation per Technology		
	Power (MW)	Energy (MWh)	CELs	Power	Energy	CELs
Solar	184	4,836,597	4,933,382	16%	54%	53%
Wind	128	3,874,458	3,828,757	11%	43%	41%
Geothermal	25	198,764	198,764	2%	2%	2%
Hydropower	-	-	314,631	0%	0%	3%
NG Combined Cycle	850	-	-	72%	0%	0%
Total	1,187	8,909,819	9,275,534	100%	100%	100%

Table Source: Adapted from Transparencia Mexicana (TM, 2016)

Chapter 3. Methodology

The methodology followed to achieve the research objectives is illustrated in

Figure 16. Two different models were developed for the three utility scale PV solar projects, shown in Table 5, that were chosen for this analysis. The first model calculates the future revenue of the projects under the long term contracts scenario, and under the short term market scenario. The second model calculates the net present value of the projects under both scenarios using a discounted cash flow analysis. In both scenarios the project lifetime is assumed to be 30 years. Each of the solar projects is to be located in a different transmission region or price zone, and will be subject to different resource characteristics depending on its location. The Offered Price shown in the Table 5 is expressed in Mexican Pesos (MXN) and corresponds to the bid price, or sale offer price, of the electric energy plus CELs to be delivered per year. The offered price corresponds to the two bundled products. This is the price that, adjusted according to the rules of the long term contracts explained in section 3.1.2, will be paid by CFE in the role of service supplier under the corresponding electric supply contract to the generation project sponsor. The offers of the past auctions were indexed to US dollars, so the future prices modeled for this research depend on projections of the peso-dollar exchange rate.

The amount of CELs and the amount of energy offered matches for most projects. In the Ticul1 project offer there is a difference of 2% between the amount of certificates and the amount of energy. The reason for this difference is not clear. The offer is made in the form of an annual price that corresponds to the amount of each product offered per year, even if the amount of the two products does not match. In strict sense, the project could sell that 2% of certificates in the spot market or to an industrial customer, and get an income additional to the income from the long term contract. Nevertheless, the difference is so small that it is not taken into account in the calculations pertaining this research, as it has little impact on the overall revenues.

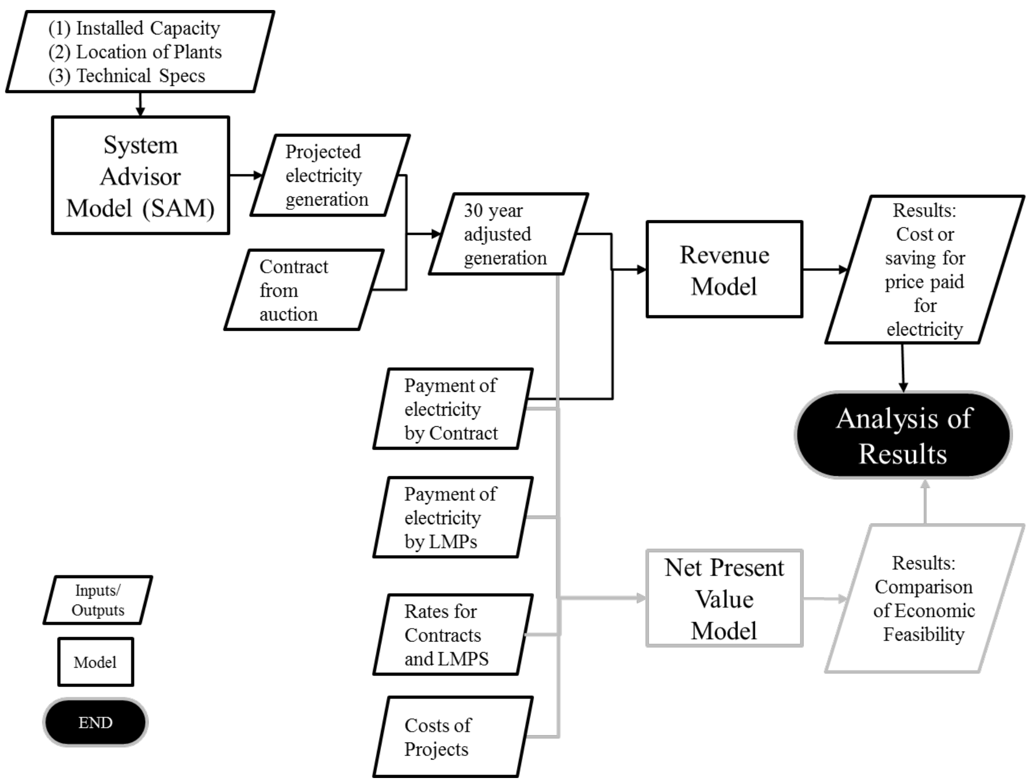


Figure 16: Methodology chart

Table 5: Projects considered in analysis

Sponsor	Name of Project	Operations Start Date	Energy (MWh/year)	CELs (CEL/year)	Offered Price (MXN/year)	Capacity (MW)
Enel Green Power Mexico	Parque Solar Don Jose	25-Sep-18	539,034	539,034	$ 421,005,400	207
Vega Solar 1	Ticul 1	1-Aug-18	740,135	725,450	$ 727,122,881	500
Enel Green Power Mexico	Parque Solar Villanueva	25-Sep-18	972,915	972,915	$ 597,503,346	330

Data Source: PIIRCE 2016-20130 and databases published by SENER (SENER, undated), and the results from the First Long Term Auction 2015 (CENACE SLP, undated).

The location of the three projects within the National Interconnected System is shown Figure 17. The Villanueva project site is located in the Norte Control Region, in the Viesca municipality in the State of Coahuila (Milenio, 2017). The don Jose solar PV project is to be located in the Occidental Control Region, in the municipality of San Luis de la Paz, in the State of Guanajuato (El Economista, 2017). Lastly, the Ticul 1 project will be built in the Peninsular Control Region, in the Ticul Municipality, State of Yucatán (BNamericas, undated). According to the solar resource map provided by the National Inventory of Renewable Energies (INERE) the three projects are located in high insolation areas. The Don José project has the highest solar resource with 6 to 6.5 kilowatt-hour per meter square per day (kWh/m^2/day) of Global Horizontal Irradiance, followed by the Villanueva project with 5.5 to 6 kWh/m2/day, and the Ticul project with 5 to 5.5 kWh/m2/day (INERE, undated).

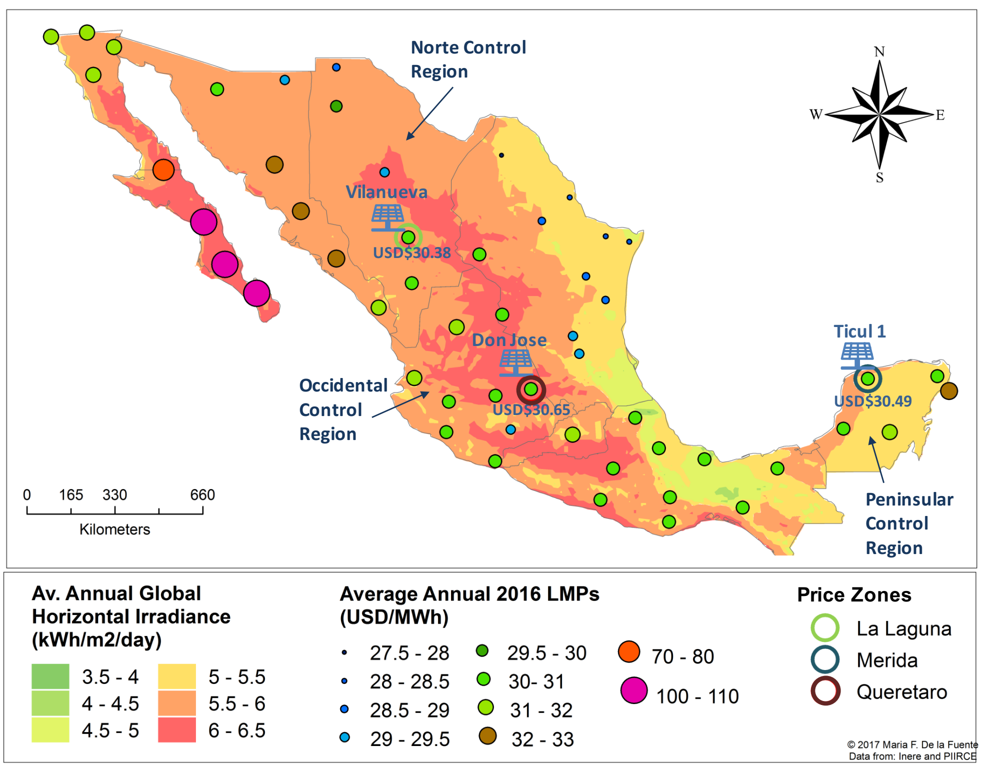


Figure 17: Solar resource map, price zones, and selected solar projects
Data Source: INERE, SENER and CENACE (PRODESEN, 2016) (CENACE, 2016) (INERE, undated)

The annual average projected LMPs of the three Price Zones (PZ) that correspond to the three projects are shown in Figure 18. The Villanueva project corresponds to the La

Laguna PZ, the Don José project corresponds to the Querétaro PZ, and the Ticul 1 project corresponds to the Mérida PZ. It can be seen that the prices in La Laguna are expected to be lower than the other two zones.

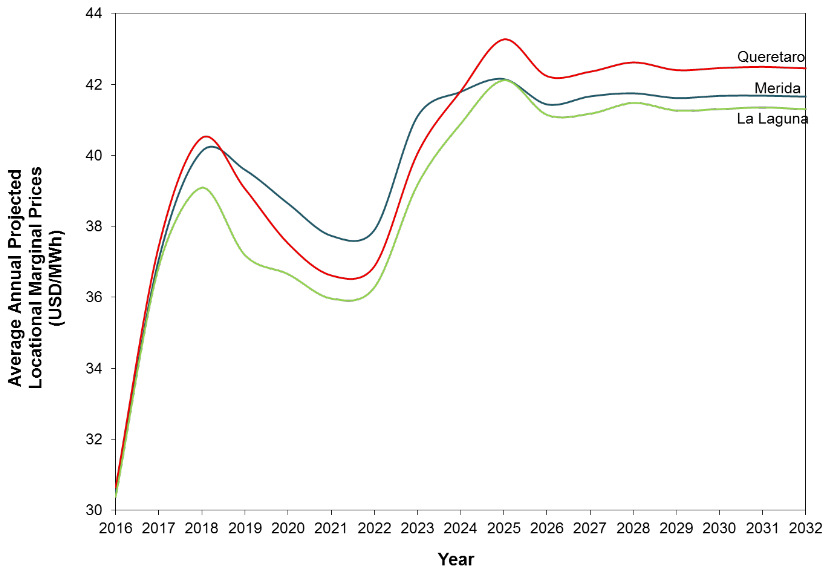


Figure 18: Average annual LMPs for 2016–2032 in the Laguna, Mérida, and Querétaro price zones.
Data Source: SENER, 2016 (SENER, 2016d)

Looking at intra-day variation of LMPs in La Laguna in summer and winter on Figure 19 we can evaluate how well prices align with generation of the Villanueva project. During summer, the higher prices during day, between 11am and 7pm, fall within the PV solar generation interval. In the winter, although peak prices occur in the evening, there is a second relatively high price interval between 9am and 3pm that could help the profitability of PV solar installations.

The La Laguna transmission region, or zone price, is located in the Norte control region. Comparing the winter LMP curve in La Laguna and the load curve in the Norte control region also shown in Figure 19, we can confirm that prices follow the demand curve in winter. Overall, PV solar generation matches the current peak demand around 4:30pm.

If enough PV solar comes online, the new peak could be pushed to 10pm. This can be confirmed by looking at the comparison between the intra-day load curve and net load curve (load net of generation from the Villanueva project) in Figure 20. Looking at the load curves in winter, it can be observed that load starts hiking up quickly around 7pm, close to the time new PV solar generation will fade. This effect is amplified in the net load curve.

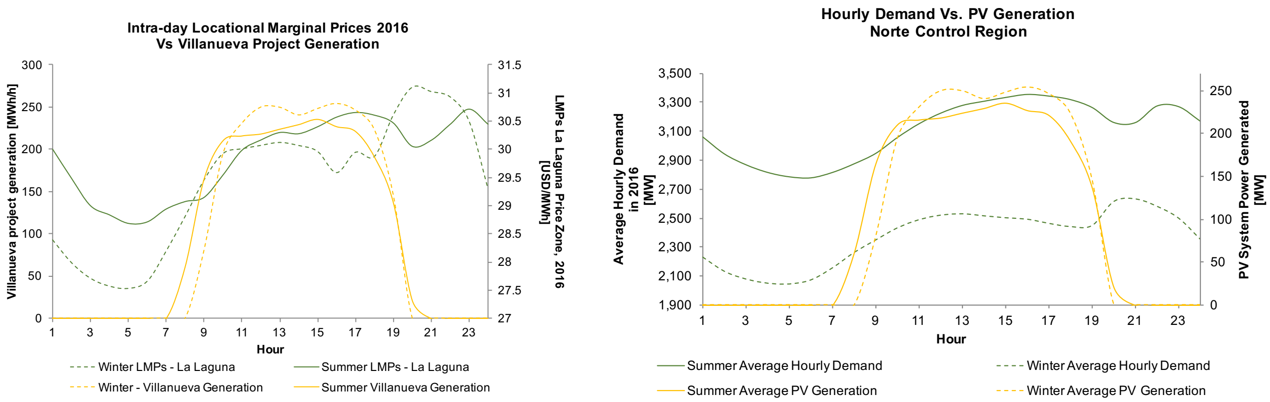


Figure 19: Left: LMPs intra-day La Laguna price zone, 2016; Right: Load curve Norte Control Region, 2016
Data Source: Elaborated *with LMP and Hourly Demand databases from SENER. (SENER, 2016d)*

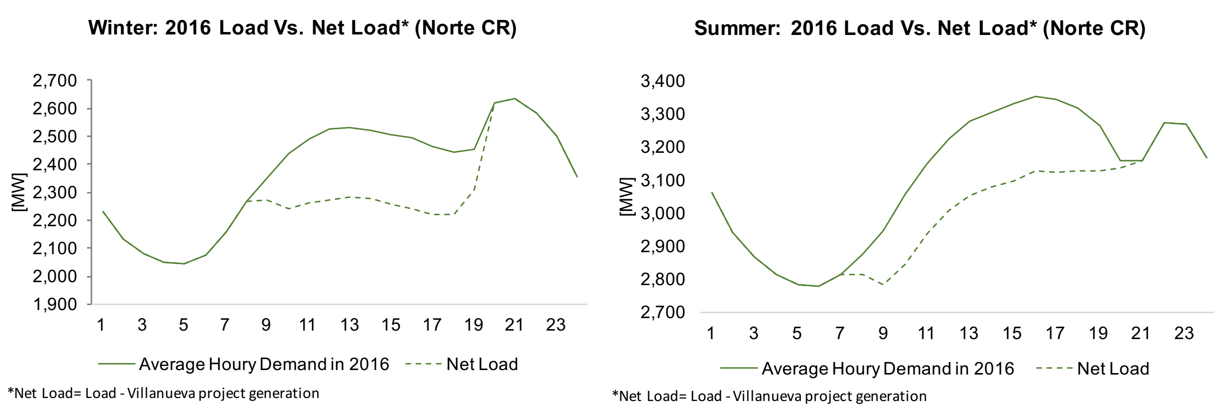


Figure 20: Left: Winter Load and Net Load*; Right: Summer Load and Net Load* Norte Control Region, 2016
Data Source: Elaborated Hourly Demand databases from SENER (SENER, 2016d), and project generation modeled using NREL's System Advisory Model

The LMPs for the Mérida transmission region are displayed in Figure 21 below. This is the price zone that corresponds to the Ticul 1 project. During the winter, prices are the highest between 3:30 pm and 6 pm, which will align with a portion of the Ticul project generation window. In the summer, prices peak around 11pm, but the second highest peak occurs approximately at 4:30 pm within the PV solar generation window. The overall peak demand in the Peninsular control region takes place in the evenings. As Ticul generation fades, other generators will need to ramp up more quickly to keep up with the rapid climb in demand in the end of the winter days as shown in Figure 22.

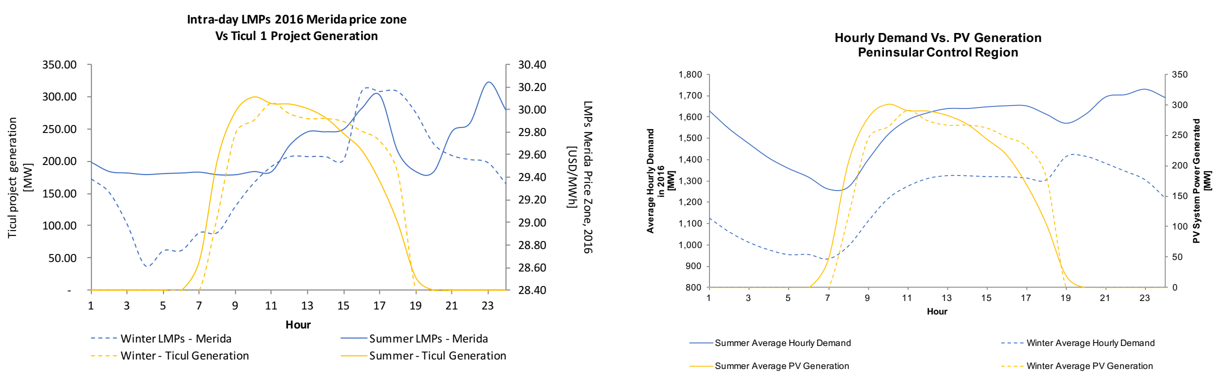


Figure 21: Left: LMPs intra-day Mérida price zone, 2016; Right: Load curve Peninsular Control Region, 2016

Data Source: Elaborated with LMP and Hourly Demand databases from SENER. (SENER, 2016d)

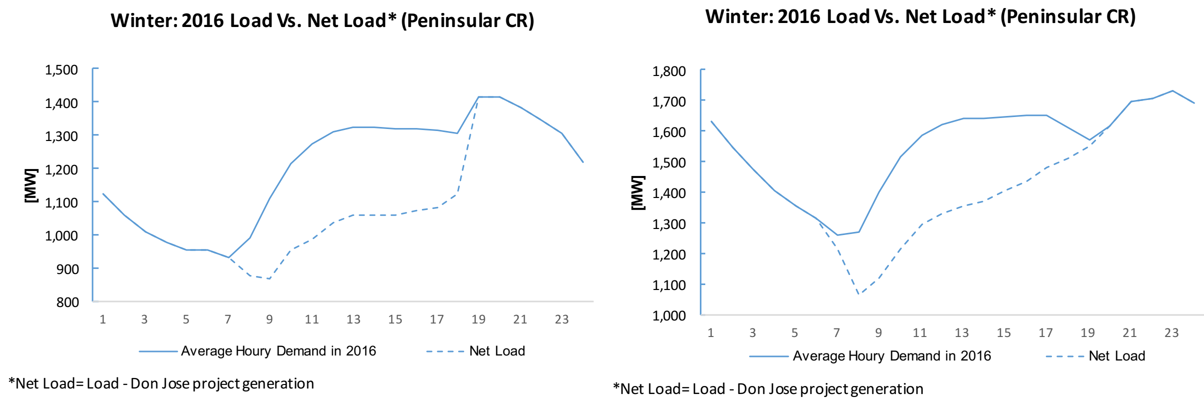


Figure 22: Left: Winter Load and Net Load*; Right: Summer Load and Net Load* Peninsular Control Region, 2016

Data Source: Elaborated Hourly Demand databases from SENER (SENER, 2016d), and project generation modeled using NREL's System Advisory Model.

The LMPs for the Querétaro Transmission Region are shown in Figure 23. The Don Jose project corresponds to this price zone. As in the other regions, lower prices occur roughly between midnight and sunrise. In this price zone prices in winter are generally higher than in the summer, in contrast with the La Laguna and Mérida price zones. Generation from the Don Jose project will help address peak demand, which occurs in the summer, as can be seen in Figure 24.

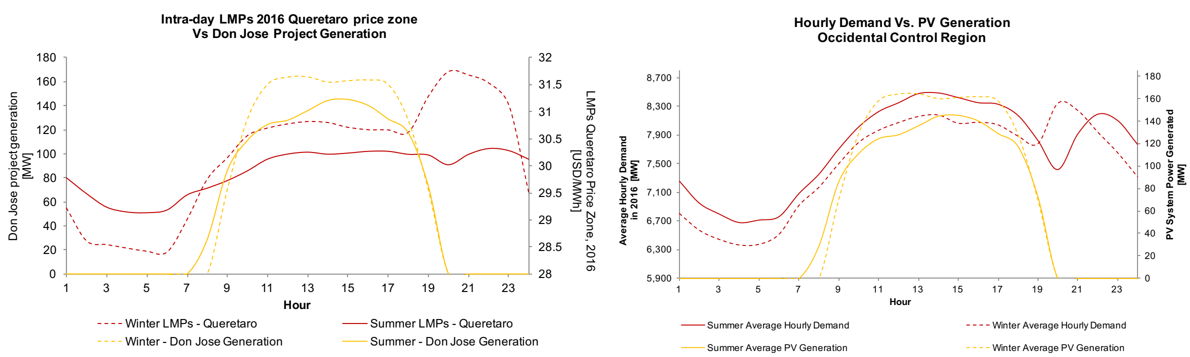


Figure 23: Left: LMPs intra-day Querétaro price zone, 2016; Right: Load curve Occidental Control Region, 2016

Data Source: Elaborated with LMP and Hourly Demand databases from SENER. (SENER, 2016d)

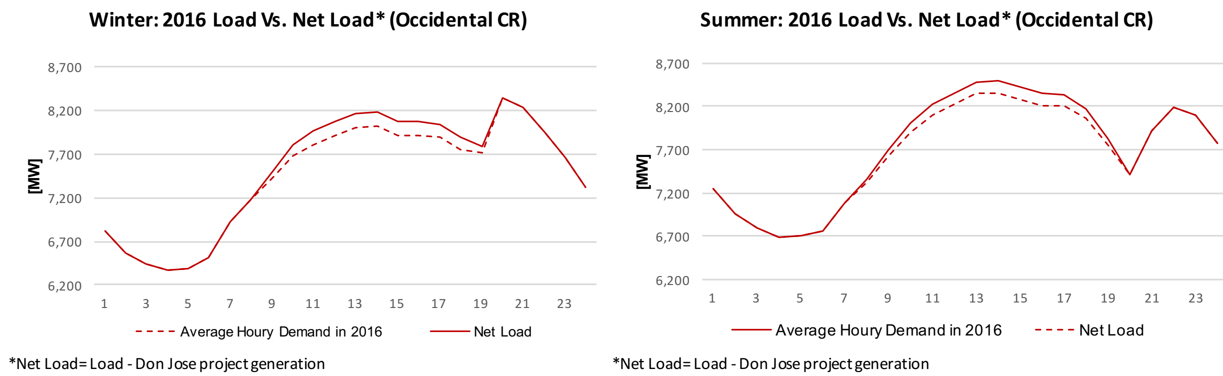


Figure 24: Left: Winter Load and Net Load*; Right: Summer Load and Net Load* Occidental Control Region, 2016

Source: Elaborated Hourly Demand databases from SENER (SENER, 2016d), and project generation modeled using NREL's System Advisory Model.

While PV solar generation aligns well in general with current the rises in load during day time, it also phases out around the time when demand starts to grow. It will be important to analyze how this will affect reliability, as load could increase at a faster rate than other generation sources can turn online. This acceleration of the evening hike in demand can be seen already with just the offset of this projects in the Norte and Peninsular control regions in winter (Figure 20 and Figure 22). A similar phenomenon has been observed in some places with high PV solar penetration. For example, in California the net load (difference between load and variable generation) has received the name "duck curve", since the valley in mid-afternoon load that ramps up around sunset time looks like the neck on a duck (California ISO, 2016). Practical solutions have been already studied and proposed in other parts of the world. Mexico can learn from this experience and plan ahead for the best ways to address this integration issue.

3.1 REVENUE MODEL

The first goal of this research is to estimate the cost of reaching the Clean Energy goals through the implemented energy policy. This cost was estimated by subtracting (a) the real weighted LMP per year, from (b) the projected price, or amount of money that the projects will receive under the long-term electricity coverage contracts per year divided by electricity generated and delivered per year. For the purpose of this research it is assumed that there will be no curtailment of energy.

To calculate (a) the real weighted LMP, the analysis used the projected hourly LMPs derived from the PIIRCE and published by SENER (SENER, 2016d). The LMPs were weighted based on the hourly generation modeled by SAM. Next, an annual weighted average LMP was calculated for each year. The weighted average LMP was then adjusted for inflation using the National Producer Prices Index with services and without oil published by INEGI (INEGI, undated). The LMPs correspond to the year 2016 to 2033, and the project life extends to year 2036. A three year moving average was used to forecast the hourly LMPs for the year 2033 to 2048. Equation (1) shows the calculation for annual weighted LMP, and Equation (2) shows the adjustment of LMPs for inflation.

(1) $$\text{Weighted av. LMP}_i = \sum_{h=1}^{h=8,760}[\text{LMP}_{h,i} \text{ x } (\text{E}_{h,i}/TE_i)]$$

Where: Weighted av. LMP_i: weighted average LMP for year i

$\text{LMP}_{h,i}$:Locational Marginal Price of hour h, and year i

$\text{E}_{h,i}$: Electric energy produced in hour h, and year i

TE_i: Total energy generated in year i

i: 1 to 30 years

h: 1 to 8,760 hours in each year

(2) $$\text{WALMP}_i = Weighted\ av.\ LMP_i \text{ x } \frac{\text{INPP}_{\text{ i}}}{\text{INPP}_{\text{ i}-1}}$$

Where: WALMP_i : Weighted Adjusted LMP in year i

$INPP_i$: Average National Index of Producer Prices in year i

$INPP_{i-1}$: Average National Index of Producer Prices in year i -1

i:1 to 30 years

The offered price cannot be compared directly to the LMPs since the payments of electricity under the contract are more complex than multiplying the unitary offered price times the energy delivered. The long term contract lasts 20 years, and the project is assumed to last 30 years. Therefore, to calculate (b) the projected price per MWh of electricity, the revenue for the first 20 years of the project under the contract was divided by the amount of electricity in MWh delivered (3). For the last ten years of the project life, energy will be sold in the short term market; therefore, the price will be the same as in (2) (4).

(3) $$\text{Projected Price}_i = \frac{Revenues\ under\ long\ term\ contract_i}{MWh\ of\ energy\ delivered\ _i}$$

for i: 1 to 20 years

(4) $$\text{Projected Price}_i = \text{WALMP}_i$$

for i: 21 to 30

Finally, the cost of reaching Clean Energy goals through the implemented policies for the project is obtained with equation (5) for each year. Afterwards, the results of equation (5) is brought to present value by discounting each value using the social discount rate (used to calculate value of public infrastructure projects in Mexico), and averaging the discounted values. The social rate is currently 10% and it is published by Mexico's ministry of finance.

(5) $$\text{Cost of policy}_i = \text{Projected Price}_i - \text{WALMP}_i$$

for i: 1 to 30 years

Both the revenues under the long term contract and the weighted average LMPs depend on the amount of energy and CEL's generated and sold by the projects. Under the terms of the long term contracts, the projects will sell electric energy for 15 years, and CELs for 20 years. The last 10 years the project will be selling energy at LMPs.

3.1.1 Resource and Energy Assumptions

The estimation of energy generation of the three utility scale PV solar projects was obtained using the System Advisor Model (SAM), a simulation tool developed by the National Renewable Energy Laboratory (NREL). SAM models hour-by-hour electric output of the power system, and generates hourly values of the system's electricity production over a single year (Nate Blair, 2014). SAM has built in assumptions for losses derived from the different components of the solar array (e.g. soiling loss, inverter power consumption loss, inverter efficiency loss, inverter clipping loss, AC wiring loss, DC wiring loss, and DC module loss). Default settings for efficiency and losses were used to model the generation of the solar arrays. Since SAM provides generation data for one year, a 0.5% reduction of generation per year was assumed to model the generation of the following years.

The resource information used by the SAM model comes from NREL's National Solar Radiation Database (NSRDB). According to the NSRDB webpage the current version was developed using the Physical Solar Model (PSM) which was developed by NREL in collaboration with the University of Wisconsin, the National Oceanic and Atmospheric Administration (NOAA), and Solar Consulting Services (NREL, undated a). The data for Mexico and Central America has a temporal resolution of 30 minutes, spatial resolution of 4 X 4 kilometers, and uses data from 1998 to 2014 (NREL, undated b). The meteorological data is derived from the NASA Modern Era-Retrospective Analysis (MERRA) datasets. PSM takes into account cloudy conditions using the cloud properties retrieved from satellites to calculate surface radiation (NREL, undated a).

The following assumptions were chosen from the SAM model database for the components and characteristics of the solar installations:

- Modules: SunPower SPR-X22-475-COM
  - max power: 476.495 Watts DC
  - module area: 2.162 m^2
  - material: Mono-c-Si
  - nominal efficiency: 22.0395%
- Inverters: TMIEC – PVH-L1350GR 960V [CEC 2016]
  - Nominal AC voltage: 960 V AC
  - Max DC voltage: 1200 V DC
  - max AC power: 1.35 x 106 Watts AC
  - max DC power: 1.38506 x 106 Watts DC
  - CEC weighted efficiency: 97.72%
- Racks: one axis tracking racks
- DC to AC ratio: 1.2
- Location of the project to retrieve resource information from PSM database

The useful life of the projects was assumed to be 30 years, following the facility life assumption used by LAZARD to estimate the levelized cost of electricity of utility-scale solar PV projects (LAZARD, 2016). Annual generation modeled by SAM resulted in a smaller magnitude than the amount of energy offered in the bid for the Villanueva and Don Jose projects. Thus, for this exercise generation modeled by SAM for the Don Jose project was adjusted up 5.9% and the generation of the Villanueva project was adjusted 15% up. These differences in the generation modeled by SAM and the expected generation reported by the project sponsor could mean that they over-estimated their ability to generate electricity. Nevertheless, the decision of adjusting the generation modeled by SAM to match at least the amount of energy that companies expect to generate, was based on the assumption that the companies sponsoring the projects had access to resource data with a better quality and resolution than the resource data that SAM software can model. For the Ticul project, the generation modeled by SAM was higher than the energy offered in the auction. In this case the surplus energy is assumed to be sold at LMPs for the long term contract scenario.

3.1.2 Payments under Long Term Electricity Coverage Contract

According to the terms of the Long Term Auction Manual, sale offers can be indexed to United States Dollars (USD) or to Mexican Pesos upon request of the seller. Auction rules provided a formula for the comparison of offers indexed to the two currencies reflecting the preference over offers indexed to Pesos (ManualSLP, 2015). The model contract published as the basis for the long term auctions provides the formulas that will be used to calculate the future payments of energy, CEL's and Capacity under the long term electricity coverage contracts derived from the auctions.

Calculation of Revenues for the First 15 Years

As mentioned before, the term of the long term coverage contracts is 20 years. During the first 15 years, the projects sell electricity and CELs under the long term contract terms. During this time, both products are sold at the coupled offered price. These formulas do the following: i) update the offered price, made in march 2016, by inflation and variation of the peso-dollar exchange rate, to obtain an initial price for the month in which the project will start operating, ii) establish the rules to adjust the price for each future month to reflect the monthly variation of the exchange rate and inflation, iii) compensate any imbalances, iv) apply an hourly adjustment factor that is meant to reflect the fluctuation of the hourly locational marginal prices in the payments under the long term contracts. This adjustment factor is a function of the hourly generation and a set of values calculated and published by the CENACE. These formulas do not allow opportunities to influence factors in the formula, since all variables come from either the amount of product generated and delivered, or transparent economic indicators, such as exchange rate and producer index prices, published by unrelated public entities. All formulas used for the calculations of payments under the contract are detailed in Appendix B.

<u>Calculation of Revenues from Year 16 to Year 20</u>

This period corresponds to the last 5 years of the long term contract. From year 16 to year 20, the projects will no longer be selling energy under the long term contract, so electricity sales are calculated using the LMPs for this 5-year period. During this period the projects will be selling CELs under the long term contract at the CEL Notional Price (PNCEL), defined in the contract with Equation 6:

$$(6)\ PNCEL_{PC} = \frac{PAA_{PC}}{(\#MW \times 70{,}000) + (\#CEL \times 20)} \times (\#CEL \times 20)$$

Where: $PNCEL_{PC}$: is the notional price of the CEL for that year

PAA_{PC}: is the Annual Adjusted Price for that year

#MWh: is the total amount of MWh of electric energy agreed by the parties to be sold per year

#CEL: is the total amount of CELs agreed by the parties to be sold per year

<u>Calculation of Revenues for the Last 10 Years of Project Life</u>

On year 20 the electric energy coverage contract will end. As the project is assumed to last 30 years in operation, for the remaining 10 years the project is assumed to be selling electricity in the spot market. The revenues for the last 10 years of the project’s useful life are therefore the same as the revenues calculated under the spot market scenario in the same years.

3.2 Net Present Value Model

A discounted cash flow analysis was used to estimate the value of the projects and compare their profitability under i) the scenario where the project enters the long term contract and ii) under a scenario where the project does not enter a long term contract, and therefore sells all generated electricity in the short term market at LMPs. For projects to be built there has to be an investor willing to provide the required capital. For the investment to happen the expected returns need to be attractive enough to the potential investor. The projects that are being analyzed have investors who have committed to undertake these projects under the provided conditions. Therefore, these projects should have a positive Net Present Value (NPV) under long term contract scenario, given the cost of capital of the investors. The cost of capital reflects the rate of return expected to be obtained from an investment with similar risk characteristics (Titman & Martin, 2016). In this analysis, the capital structure of each project is assumed to be comprised by 60% common equity and 40% debt.

The following steps were taken for each of the three projects to compare their profitability under i) long term contract conditions, and ii) short term market conditions:

1) Calculated the revenue of the projects each year
2) Estimated the investment costs that the solar PV projects will require
3) Built a model using Microsoft Excel to calculate the project free cash flows

4) Calculated the project Net Present Value for a range of cost of capital assumptions and a range of investment cost assumptions, presented in a two-way data table.

3.2.1 Revenue of the Projects

The revenue of the projects under the short term market prices scenario was calculated using the weighted average LMPs described in section 3.1 and calculated according to Equation 1. The calculations of the revenue under the long term contract the revenues that the project will receive under the long term contract were also explained in Section 3.1.2. In addition, information about the SAM model, as well as assumptions of the PV solar project characteristics were presented in Section 3.1 above.

3.2.2 Estimating Investment Costs of Utility Scale PV Solar Projects

Total Installed Costs or Engineering Procurement and Construction (EPC) costs add up to $1.40 USD/Watt, and are classified into Direct Costs, and Indirect Costs. As a reference, the installed cost used for the PIIRCE model was $1.488 USD/Watt (SENER, 2016d). According to NRELs model for a 100 MW PV solar farm with one axis tracking the EPC is approximately $1.23 USD/Watt in Texas, and the benchmark in the US is $1.49 USD/Watt as shown in Figure 25 (Fu, et al., 2016). The installed cost assumption made by LAZARD in their LCOE analysis is $1.45 USD/Watt (LAZARD, 2016). In reality these costs could be even lower since the costs are sourced from 2016 reports and the PV solar projects will start construction in 2017. Furthermore, labor costs in Mexico are generally lower than in the U.S. The assumptions used for investment costs are summarized in Table 6 and Table 7.

Table 6: Direct Installed Costs

Direct Capital Costs	USD/W
Modules (USD)	$0.64
Inverters (USD)	$0.09
Racking (USD)	$0.16
BOS equipment (USD)	$0.10
Installation labor (USD)	$0.16
EPC & Developer overhead (USD)	$0.13
Total Direct Cost	$1.28

Data source: (Fu, et al., 2016)

Table 7: Indirect Installed Costs

Indirect Capital Costs	USD/W
Permitting	$0.01
Grid Interconnection	$0.03
Engineering and development overhead	$0.05
Land prep and transmission	$0.02
Land Costs (estimated by comparables)	~ $0.1
Total Indirect Cost (USD/W)	$0.12

Data Source: (Fu, et al., 2016)

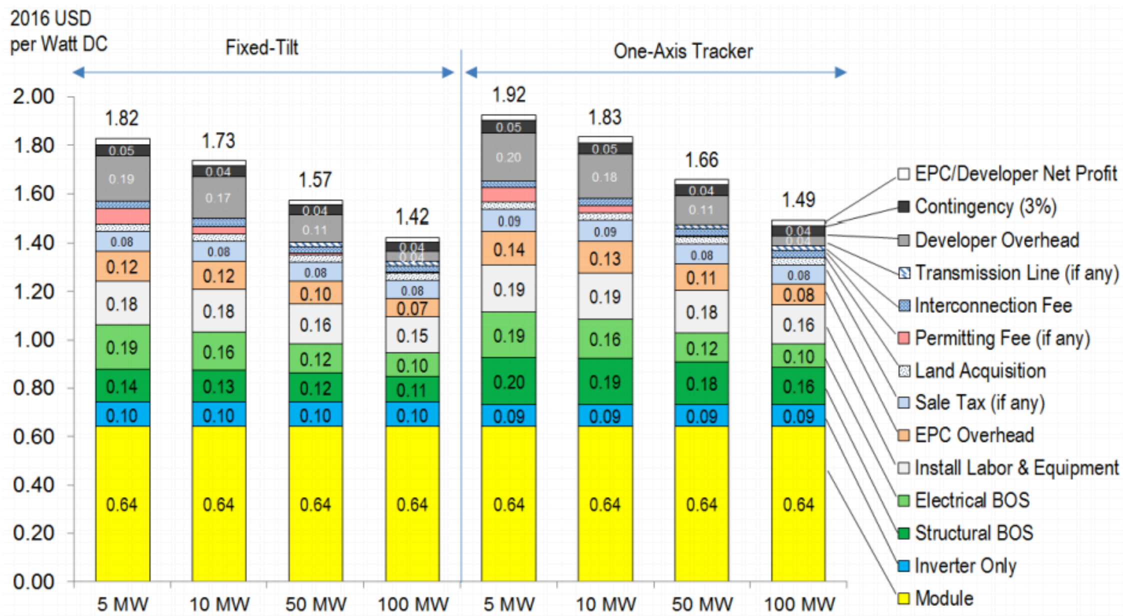


Figure 25: Q1 Benchmark utility scale PV solar total cost (EPC + developer) 2016 USD/Wdc
Source: NREL (Fu, et al., 2016)

The land acquisition cost was estimated using real state valuation through market comparables. The project assumes purchasing the land at the beginning of the project and selling it at the end. This approach is adopted for the property (land, and site improvement), which are commonly transacted in the market, and therefore market data and transactions records of them are readily available for comparison. The process consisted of three steps: i) identify lands that are similar in area, location, shape and surface to the land required, and ii) estimate an average value per square meter according to the comparable example found, and iii) multiply the average value per square meter times the area in square meters needed for the project.

3.2.3 Modeling Project Free Cash Flows and Equity Free Cash Flows

Operation and Maintenance costs were considered to be $12 USD/KW (LAZARD, 2016). The project Free Cash Flows (FCF) were modeled in Microsoft Excel and calculated as follows (Titman & Martin, 2016, pp. 24-25):

Revenue less: Operations & Maintenance Costs less: Transmission and operation costs less: Depreciation expense / virtual expense
equals: Earnings Before Interest and Taxes less: Taxes (IVA and ISR)
equals: Net operating profit after tax (NOPAT) plus: Depreciation Expense / virtual expenses less: Capital Expenditures (CAPEX / Investment outlays)
equals: Project FCF less: after tax interest and principal payments to creditors
equals: Equity FCF

With respect to taxes, the project is subject to the federal income tax (ISR) of 30%. Under the ISR law 100% of investment expenses, made of machinery and equipment, and related installation costs, can be depreciated in the first year of operations of renewable generation projects. Any negative taxable income can be carried over to the next year until the project reaches the tenth year (ISR DOF, 2016). In addition, the project pays the federal sale tax (IVA). Under the long term contract rules, the IVA will be paid in addition to the adjusted offer price, so it does not impact the project. Nevertheless, the IVA paid for the purchase of the equipment and machinery can be deducted from the IVA liability, and the Ministry of Finance (SHCP) returns the IVA in favor within six months of the tax return report.

3.2.5 Calculating Project Net Present Value (NPV)

Lastly, a discounted cash flow analysis of the projects was performed to compare the value of the project under the two described scenarios, and to evaluate if the projects could be financially feasible under the scenario where they sell energy only at market prices. The discounted cash flows analysis consists in bringing all future cash flows of the project to year zero and can be denoted as (7):

$$(7) \qquad \text{Project value}_{t=0} = \sum_{t=1}^{N} \frac{Project\ FCF_t}{(1+cost\ of\ capital)^t}$$

The Project Value at t=0 in equation (20) is the Net Present Value (NPV) of the project. If the NPV were negative under the second scenario, companies would need to charge a premium over the short term marker price, or LMP, to achieve a positive NPV though the sale of CELs.

The discount rate, or cost of capital, required for the long term contract scenario could be lower than the discount rate for the short term market prices scenario, because the lack of a long term contract increases the revenue risk, and therefore increases the cost of capital. The long term contract provides certainty for energy sales and prices. The Brattle Group states in a report on importance of long term contracts for renewable project development that "increased price certainty for renewable energy projects reduces risk to the project's lenders and investors and thereby reduces the cost of capital for the project". It also states that without the price certainty provided by a long term power purchase agreement "a renewable energy project (all else equal) will attract less and more costly debt and more costly equity than traditional power project operating in the same wholesale power market" (Weiss & Sarro, 2013). In addition, Mexico's electricity market is new, which can create information problems and uncertainty about risks. Uncertainty about risks could prevent both lenders and investors from investing, or at least increase their required rates of return (Weiss & Sarro, 2013). It could be that investments in this types of projects are only possible with the presence of a long term contract that enables investors to overcome uncertainty and risk avoidance. To examine the effect of the price certainty on the value of the project, the range of discount rate values used to calculate the NPV for the short term market prices scenario is 100 basis points higher than the discount rates for the long term contract scenario.

Chapter 4. Results

4.1 Results from Revenue Model

4.1.1 Don Jose PV Solar Project

The projected average contract price for the Don Jose project is generally lower than the projected weighted average LMPs. This is true for all years except for a five-year period when the project is being paid only for CELs at their nominal value under the contract, and selling electricity at LMP price (Figure 26). The average present value of the difference between the projected weighted average LMP and the projected average contract price is -\$1.34 USD/MWh. This present value was calculated using the social rate used to evaluate the social profitability of public investments in Mexico. This means that there was no overprice paid per MWh under the contract, on the contrary, the short term market would have paid a present value of \$1.34 USD more per MWh.

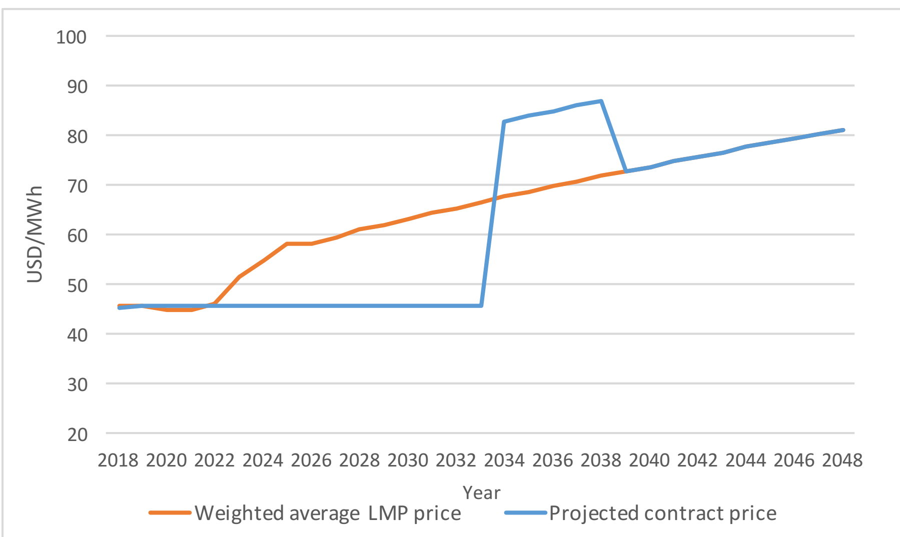


Figure 26: Projected weighted average LMP vs projected contract price for Don José project.

4.1.2 Villanueva PV Solar Project

As can be seen in Figure 27, the projected contract price is also generally lower than the projected weighted average LMPs. In this case, the average present value of the difference between the projected weighted average LMP and the projected average contract price is -$4.03 USD/MWh. The short term market would have paid a value of $4.03 USD more per MWh than what will be paid under the long term contract.

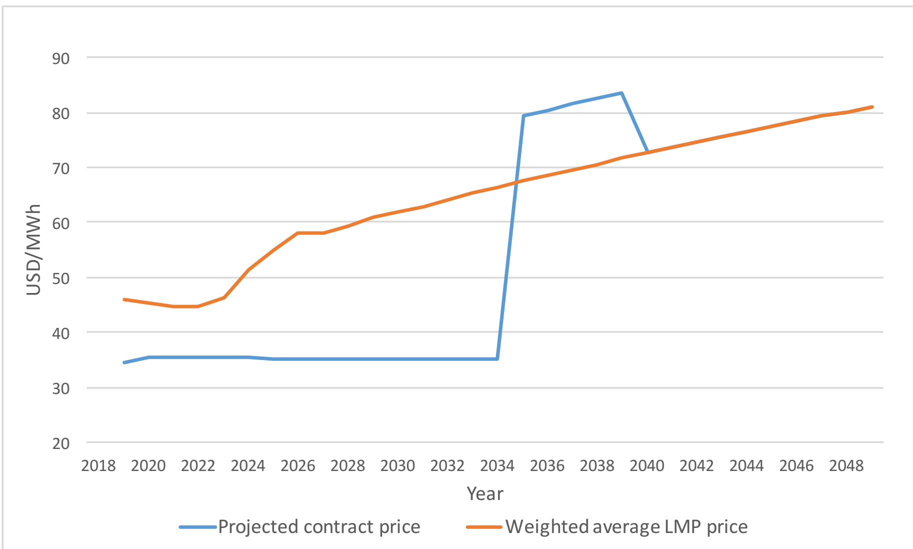


Figure 27: Projected weighted average LMP vs projected contract price for Villanueva project.

4.1.3 Ticul 1PV Solar Project

In the Ticul project, LMPs start lower than long term contract prices in the first few years (Figure 28). Today's value of the difference between the projected weighted average LMP and the projected average contract price is $1.29 USD/MWh. In this case there is a small premium over the market rate. Therefore, the cost of the policies for this project under long term contract conditions, which could be conceptualized the CEL value under the contract, is equivalent to at least $1.29 USD/ MWh.

As explained in Section 3.2.5, if the project were to be implemented under the scenario where the project sells only at short term market prices, a higher discount rate than the one used for the long contract scenario could have been required. Assuming an increment of 100 basis points in the discount rate for the short term market prices scenario, the project would have required an increment in revenues of 7.6% to have a NPV equal to zero, which would imply a premium over the weighted average LMPs of at least $1.49 USD/MWh.

Looking at these results it can be concluded that the implemented policies are achieving savings for the customer, since prices under long term contracts for the Don José and the Villanueva projects are on average lower than market prices. In addition, for the Ticul project the application of the long term contracts coupled with the CEL incentives most likely reduced the cost of capital required to make this investment, allowing for a slight reduction in the required premium over the LMP price. Based on this assumption, we can say that the long term contract auction strategy made the provision of PV solar energy cheaper than what it would have been through the CEL policy alone.

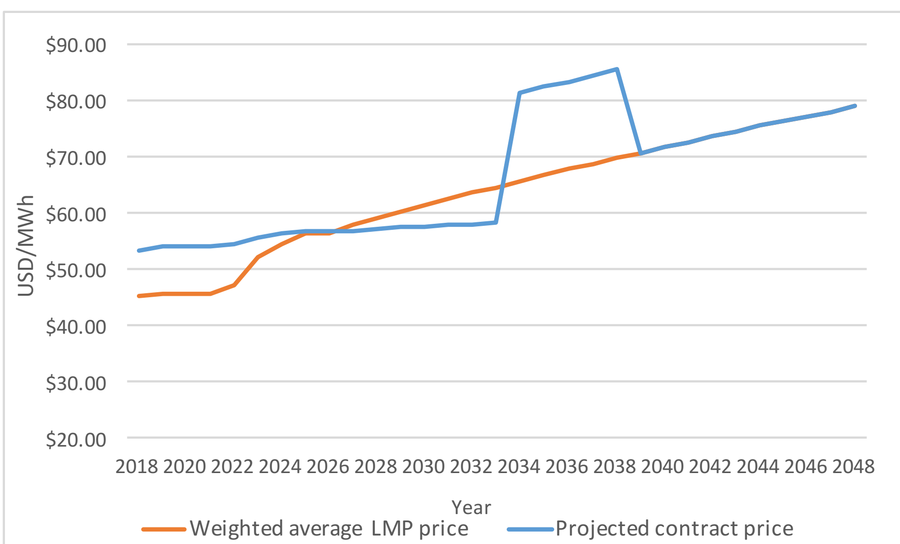


Figure 28: Projected weighted average LMP vs projected contract price for Ticul project.

4.2 Results from Net Present Value Model

A discounted cash flow analysis was made to compare the profitability of the projects under the long term contract scenario, and under short term market prices scenario. This analysis also helped evaluate the impacts of the implemented policies on investors. We have established previously that the fact that the projects are taking place, under the long term contract scheme, means that investors consider this project to be profitable. In addition, the Don Jose and Villanueva projected short term market revenues are higher than projected long contract revenues. These facts could lead us to think that a premium over the short term market prices was not needed for the economic feasibility of the projects. This is not necessarily true because the project could have been subject to a higher risk without the long term contract than with it, since there is no guarantee of selling the energy and the is no contract to reduce the uncertainty of the sale price. This higher risk could result in a higher discount rate, which reduces the net present value of the project, and could make it negative. Long Term contracts reduce price uncertainty and reduce the investor's required rate of return, as well as the cost of debt.

Lower costs of capital can benefit developers by increasing the project value, but also allows them to charge lower prices. This in turn benefits customers. The new regulation is effectively requiring that a group of technologies provide a portion of the demanded electricity, even if cheaper options exist. Whatever the size of the overprice needed (if any) to accommodate these technologies, a long term contract scheme can help reduce it. Furthermore, the bidding process carried out by the wholesale market operator, where large amounts of energy can be publicly auctioned at the same time, provides the opportunity to accesses a large universe of investors and therefore more competitive prices for this long term contracts. There will be additional collateral benefits from the auction process, derived from the publication of information and stakeholder engagement that the process implies. Information generated around the auction processes and spaces for discussion of issues, such as information sessions and training sessions, will accelerate the investors' process of getting to know the new market rules and market environment, helping to the reduction of perceived risk.

To assess the impacts of potential reduction of the cost of capital, net present values were obtained for several combinations of project discount rates and investment costs, and are shown in the tables below. In the two-way data tables that show the net present value of the projects under the scenario of sales at short term market prices, the discount rates range reflects an additional spread of 100 basis points over the discount rates used for the long term contract scenario.

4.2.1 Don Jose PV Solar Project

Looking at table Table 8 and Table 9 it can be seen that the net present values of the Don José project under long term contracts are lower than the value under the short term market scenario that has a 100 basis points spread over the discount rate. In contrast, when the spread is 150 basis points, the NPV of the project under the contract is higher than the NPV of the project under the short term market prices scenario. The breakeven point is at 137 basis points. When the incremental risk from the lack of price certainty translates into a spread higher than 137 basis points in the cost of capital, it can be said that the long term contract results in higher value of projects for the investor. These break-even points can be seen in

Table 10. For example, for a 1.4 USD/Watt investment cost, the policy will have been favorable for the investor if the increase on the project discount rates due to the lack of a long term contract were more than 174 basis points. This results indicate that the long

term contracts auction policy is most likely increasing the value of the projects to the investors, even if sales under short term market prices are expected to be higher than sales under long term contracts.

Table 8: Don José project net present value under long term contract.

		Installed Cost				
		1.5	1.4	1.23	1.14	1
Discount Rate	10.00%	$ 48,702,086.05	$ 68,460,714.58	$ 102,050,383.08	$ 119,833,148.75	$ 147,495,228.69
	10.50%	$ 34,265,972.97	$ 53,982,027.42	$ 87,499,319.98	$ 105,243,768.99	$ 132,846,245.22
	11.00%	$ 20,888,708.81	$ 40,562,572.73	$ 74,008,141.41	$ 91,714,618.94	$ 119,258,028.44
	11.50%	$ 8,473,244.65	$ 28,105,296.44	$ 61,479,784.49	$ 79,148,631.10	$ 106,633,503.61
	12.00%	$ (3,067,239.94)	$ 16,523,373.04	$ 49,827,415.10	$ 67,458,966.78	$ 94,885,824.95
	12.50%	$ (13,810,520.32)	$ 5,739,022.19	$ 38,973,244.46	$ 56,567,832.72	$ 83,937,192.24
	13.00%	$ (23,826,363.47)	$ (4,317,527.97)	$ 28,847,492.37	$ 46,405,444.32	$ 73,717,814.02
	13.50%	$ (33,177,437.32)	$ (13,708,950.18)	$ 19,387,477.96	$ 36,909,116.39	$ 64,164,998.38

Table 9: Don José project net present value under short term market prices.

		Installed Cost				
		1.5	1.4	1.23	1.14	1
Discount Rate	11.00%	$ 54,583,340.27	$ 74,257,204.20	$ 107,702,772.87	$ 125,409,250.41	$ 152,952,659.90
	11.50%	$ 40,856,488.12	$ 60,488,539.91	$ 93,863,027.96	$ 111,531,874.57	$ 139,016,747.08
	12.00%	$ 28,056,850.04	$ 47,647,463.01	$ 80,951,505.08	$ 98,583,056.76	$ 126,009,914.93
	12.50%	$ 16,104,874.21	$ 35,654,416.73	$ 68,888,638.99	$ 86,483,227.25	$ 113,852,586.77
	13.00%	$ 4,929,022.60	$ 24,437,858.10	$ 57,602,878.44	$ 75,160,830.39	$ 102,473,200.09
	13.50%	$ (5,535,128.89)	$ 13,933,358.25	$ 47,029,786.39	$ 64,551,424.82	$ 91,807,306.81
	14.00%	$ (15,345,680.81)	$ 4,082,811.91	$ 37,111,249.52	$ 54,596,892.96	$ 81,796,782.75
	14.50%	$ (24,555,105.59)	$ (5,166,258.01)	$ 27,794,782.88	$ 45,244,745.70	$ 72,389,132.31

Table 10: Don José project internal rate of return under long term contract and under short term market conditions.

Investment Cost (USD/Watt)	Project IRR short term market (i)	Project IRR under long term contract (ii)	Difference (i - ii)
1.50	13.23%	11.86%	1.37%
1.40	14.22%	12.78%	1.44%
1.23	16.20%	14.64%	1.56%
1.14	17.45%	15.82%	1.63%
1.00	19.78%	18.04%	1.74%

4.2.2 Villanueva PV Solar Project

For the Villanueva project the numbers are more extreme. The value of the project under long term contract scenario is much lower than under the short term market prices scenario (Table 11 and Table 12). For example, the increment in discount rate derived from the lack of a long term contract would have to be above 490 basis points for the 1.4 USD/Watt project to be more valuable under a long term contract, than under the short term market prices (Table 14). If that spread is in reality smaller, the investors may have chosen to bid into a long term contract anyway, because the mandate made to suppliers to go on long term electricity supply contracts highly reduces the space for short term market demand outside this structure.

Table 11: Villanueva project net present value under long term contract.

		Installed Costs				
		1.5	1.4	1.23	1.14	1
Discount Rate	10.00%	$ 32,645,889.57	$ 64,145,889.57	$ 117,695,889.57	$ 146,045,889.57	$ 190,145,889.57
	10.50%	$ 9,943,553.19	$ 41,375,679.89	$ 94,810,295.27	$ 123,099,209.30	$ 167,104,186.67
	11.00%	$ (10,994,855.81)	$ 20,370,009.05	$ 73,690,279.33	$ 101,918,657.70	$ 145,829,468.51
	11.50%	$ (30,336,912.14)	$ 961,294.14	$ 54,168,244.81	$ 82,336,630.46	$ 126,154,119.25
	12.00%	$ (48,232,142.54)	$ (16,999,999.68)	$ 36,094,643.18	$ 64,203,571.75	$ 107,928,571.75
	12.50%	$ (64,814,141.69)	$ (33,647,475.03)	$ 19,335,858.31	$ 47,385,858.31	$ 91,019,191.64
	13.00%	$ (80,202,423.73)	$ (49,100,653.82)	$ 3,772,355.03	$ 31,763,947.95	$ 75,306,425.83
	13.50%	$ (94,504,044.02)	$ (63,466,599.08)	$ (10,702,942.69)	$ 17,230,757.75	$ 60,683,180.65

Table 12: Villanueva project net present value under short term market prices.

		Installed Costs				
		1.5	1.4	1.23	1.14	1
Discount Rate	11.00%	$ 172,170,843.12	$ 203,535,707.99	$ 256,855,978.26	$ 285,084,356.64	$ 328,995,167.45
	11.50%	$ 146,836,365.00	$ 178,134,571.27	$ 231,341,521.95	$ 259,509,907.60	$ 303,327,396.39
	12.00%	$ 123,205,866.53	$ 154,438,009.39	$ 207,532,652.25	$ 235,641,580.82	$ 279,366,580.82
	12.50%	$ 101,133,218.39	$ 132,299,885.06	$ 185,283,218.39	$ 213,333,218.39	$ 256,966,551.73
	13.00%	$ 80,487,011.19	$ 111,588,781.10	$ 164,461,789.95	$ 192,453,382.87	$ 235,995,860.75
	13.50%	$ 61,148,902.85	$ 92,186,347.78	$ 144,950,004.17	$ 172,883,704.61	$ 216,336,127.52
	14.00%	$ 43,012,166.59	$ 73,985,850.80	$ 126,641,113.96	$ 154,517,429.75	$ 197,880,587.64
	14.50%	$ 25,980,413.70	$ 56,890,894.05	$ 109,438,710.64	$ 137,258,142.96	$ 180,532,815.45

Table 13: Villanueva project internal rate of return under short term market and under long term contract conditions.

Investment Cost (USD/Watt)	Project IRR short term market (i)	Project IRR under long term contract (ii)	Difference (i - ii)
1.50	15.33%	10.73%	4.59%
1.40	16.42%	11.53%	4.90%
1.23	18.63%	13.13%	5.50%
1.14	20.02%	14.14%	5.88%
1.00	22.61%	16.04%	6.57%

4.2.3 Ticul 1PV Solar Project

The Ticul project is in a different situation than the previous two projects. When comparing Table 14 and Table 15, the value of the project is considerably lower under market prices than under long term contract. The results shown in Table 15 indicate that this project needed the CEL requirement policy and a premium over the short term market price to be financially viable, unless the investment costs are in the lower extreme of the range.

The internal rate of return under the short term market prices scenario is consistently lower than under the long term contract scenario (Table 16). This fact implies that revenues under short term market prices would need to be higher than the prices under the long term contract for the project to have a positive net present value. This result also indicates that having generation from this technology in this price zone requires a premium over the short term market price, impacting consumers negatively. The average LMP in the Merida price zone (corresponding to Ticul) is higher than the average LMP for the La Laguna price zone (Villanueva). Thus, the need of a premium over the projected LMPs and the lower value of this project with respect to the others can be attributed to the lower resource potential of the area.

Table 14: Ticul project net present value under long term contract.

		Installed Cost				
		1.5	1.4	1.23	1.14	1
Discout Rate	10.00%	1,697,254.79	49,424,527.52	130,560,891.15	173,515,436.61	240,333,618.43
	10.50%	(26,523,491.71)	21,100,942.68	102,062,481.14	144,924,472.09	211,598,680.24
	11.00%	(52,768,170.51)	(5,245,647.98)	75,542,640.30	118,312,910.57	184,844,442.11
	11.50%	(77,211,340.92)	(29,789,816.26)	50,826,775.67	93,506,147.87	159,896,282.40
	12.00%	(100,009,599.54)	(52,688,170.97)	27,758,257.60	70,347,543.32	136,597,543.32
	12.50%	(121,303,627.79)	(74,081,405.56)	6,196,372.21	48,696,372.21	114,807,483.33
	13.00%	(141,219,988.00)	(94,096,094.19)	(13,985,474.72)	28,426,029.70	94,399,481.03
	13.50%	(159,872,700.80)	(112,846,269.09)	(32,901,335.17)	9,422,453.38	75,259,457.79

Table 15: Ticul project net present value under short term market prices.

		Installed Cost				
		1.5	1.4	1.23	1.14	1
Discout Rate	11.00%	(110,223,776.09)	(62,701,253.57)	18,087,034.72	60,857,304.99	127,388,836.52
	11.50%	(133,252,972.60)	(85,831,447.93)	(5,214,856.00)	37,464,516.19	103,854,650.72
	12.00%	(154,716,019.96)	(107,394,591.39)	(26,948,162.82)	15,641,122.89	81,891,122.89
	12.50%	(174,747,094.73)	(127,524,872.51)	(47,247,094.73)	(4,747,094.73)	61,364,016.38
	13.00%	(193,466,871.81)	(146,342,978.00)	(66,232,358.53)	(23,820,854.11)	42,152,597.22
	13.50%	(210,984,039.59)	(163,957,607.87)	(84,012,673.95)	(41,688,885.40)	24,148,119.00
	14.00%	(227,396,631.15)	(180,466,806.59)	(100,686,104.84)	(58,449,262.73)	7,252,491.66
	14.50%	(242,793,195.24)	(195,959,134.10)	(116,341,230.17)	(74,190,575.15)	(8,622,889.56)

Table 16: Ticul project internal rate of return under short term market and under long term contract conditions.

Investment Cost (USD/Watt)	Project IRR short term market (i)	Project IRR under long term contract (ii)
1.50	9.01%	10.03%
1.40	9.80%	10.90%
1.23	11.39%	12.65%
1.14	12.38%	13.76%
1.00	14.22%	15.83%

Chapter 5. Conclusions

Mexico has recently enacted energy policies that incentivize the generation of electricity through clean generation technologies. These policies are being implemented mainly through the CEL requirements and long term contract obligations that electricity suppliers will be subject to starting in 2018. These policies have already resulted in long term electricity supply contracts for new clean projects that add up to 3,272 MW of installed capacity.

The results of this research suggest that the impact of the implemented policies on customers will be positive overall when looking at these three cases. Furthermore, benefits are potentially being shared by both customers and investors. First, the decrease in electricity wholesale prices for the Villanueva and Don José projects, that represent 1.5 GWh of generation per year, is greater than the increment in prices for the Ticul project, that represents 0.98 GWh of generation per year. This benefit was achieved thanks to the combination of the long term contract auctions with the CEL requirements, which was successful in protecting the customers from higher increments in electricity prices. On the side of the investor, while the long term contracts in some cases curbs the potential value of the projects for investors given the currently high LMPs (Villanueva project case), it can also make projects more valuable to investors through the reduction of price uncertainty (Don Jose project case). It also helped achieve a positive value for investors in areas where the resource has a lower generation potential, while minimizing the price increment needed to procure generation from this technology though the auction mechanism (Ticul project case).

5.1 FUTURE WORK AND SOURCES OF UNCERTAINTY

For future work an equity tax structure could be included in this analysis. Tax equity structures are not being used in Mexico yet. A tax equity structure is a financing tool that helps developers, that usually don't have enough tax liability, use the tax benefits available. The most common structure is the partnership flip. In a partnership flip a tax equity investor joins the sponsor as a partner to own a renewable energy project. The partnership allocates most of the taxable income and loss to the tax equity investor during the initial years of the project life (e.g. 99%), until the investor reaches a target yield. After that target is reached, the tax equity investor's share of income and loss drops to a small percentage, such as 5%, point from which the sponsor receives the majority of income and loss. The sponsor usually has an option to buy the investor's share after the flip (Martin, 2015). This type of structure could help projects to take full advantage of the ISR tax deduction benefit available for renewable generation projects.

Future research could include the modeling of a tax equity structure in the NPV analysis, to assess how this structures could increase the project value for investors, and if their use could help lower sale prices further. Additionally, the analysis made with the revenue model could be applied to all projects from different technologies that have won contracts through the long term auctions, for a more exhaustive assessment of the policies' impact on wholesale prices. This research only considers direct economic impacts on consumers and investors, omitting environmental and health benefits, as well as indirect economic benefits that could come from climate change mitigation. This research could be made more robust if these positive externalities were taken into account.

Furthermore, sources of uncertainty could be considered in future work. The results of this research depend on several assumptions, and are therefore subject to uncertainty. The following sources of uncertainty are identified:

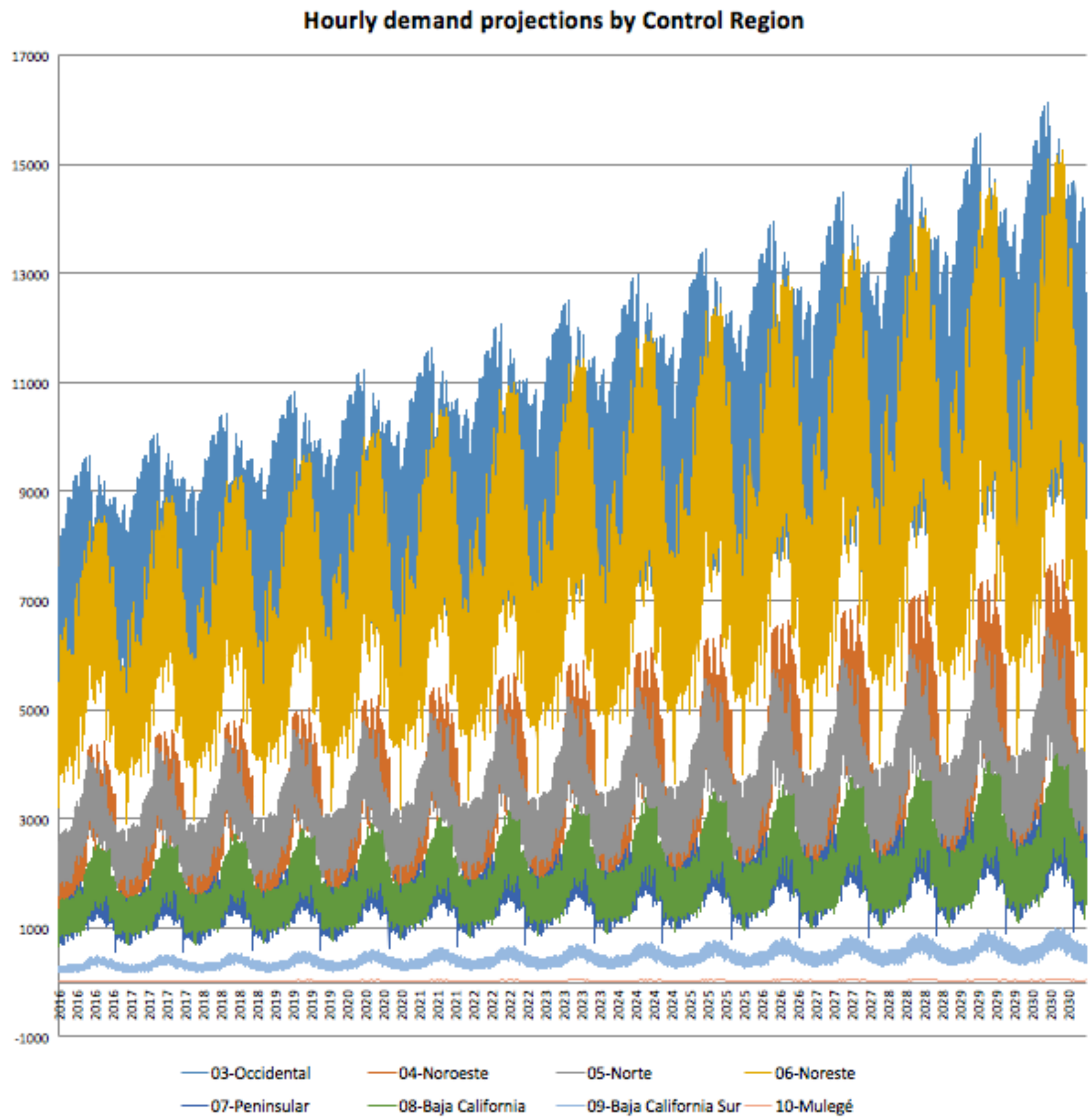
1) On revenue and estimated wholesale prices:

   - For estimation of short term market sales there is uncertainty from the underlying assumptions of the LMPs, such as fuel price projections, investment cost, and discount rate assumptions used in the PIIRCE Model. A sensibility analysis could be done to assess how different values of this parameters could affect the results. An optimization model that includes transmission constraints, such as the one used to obtain the PIIRCE, would have to be performed for different scenarios that vary these assumptions. This could be done in a software such as PLEXOS. Then, LMPs would have to be calculated for the different projections of installed capacity derived from those models.
   - For long term contract sales most uncertainty comes from projections of inflation and exchange rate. The formula of the payments under the long term contracts has a component dependent on the LMPs, but this component only represents around 0.0216 % of the revenue value.
   - For both scenarios there is uncertainty in the generation projections, since this is a variable resource that depends on weather. SAM only provides one sample year of generation for these locations. Historical data, with better resolution, and from various weather stations would be required to estimate the probability distribution of the global horizontal irradiance. Then confidence intervals for the generation of the projects could be calculated. This could help determine if the Villanueva and Don Jose project sponsors overestimated the generation of the projects.

2) On valuation of projects: In addition to the uncertainty that comes from revenue estimation, the conclusions depend on the specific characteristics of the investors, since they have discount rates that reflect their systematic risk, and could potentially

incur in different investment costs. Net present value of projects is very sensitive to both of these values. This factors were considered in this analysis as a sensibility analysis, calculating the NPV of the projects for a range of discount rate and investment cost values.

Appendix A



Data source: Data bases PIIRCE 2016-2030 (SENER, 2016c)

Appendix B

Since the sale offers studied in this research were indexed to US dollars, the rules for adjusting the price at the operations start date or Initial Price are estimated with Equations 6 to 11 (Contract, 2015):

(1) $$\mathrm{PI} = \mathrm{PO} \times \mathrm{FI}$$

(2) $$\mathrm{FI} = (\mathrm{FTC} \times 0.70) + (\mathrm{FTC} \times \mathrm{FIUS} \times 0.20) + (\mathrm{FIMX} \times 0.10)$$

(3) $$\mathrm{FTC} = \frac{\mathrm{TC_{FOC}}}{\mathrm{TC_0}}$$

(4) $$\mathrm{FTC} = \frac{\mathrm{TC_{FOC}}}{\mathrm{TC_0}}$$

(5) $$\mathrm{FIUS} = \frac{\mathrm{USPP_{FOC}}}{\mathrm{USPP_0}}$$

(6) $$\mathrm{FIMX} = \frac{\mathrm{INPP_{FOC}}}{\mathrm{INPP_0}}$$

where PI: Initial Price (or start price)

PO: Offered Price

FI: Initial Factor (*multiplier that updates the offered price made in march 2016 by the inflation and variations in exchange rate from that date to the date of start of operations*

FTC: Adjustment factor for the FIX Exchange rate Peso/Dollar.

FIUS: Inflation adjustment factor in the United States

FIMX: Inflation adjustment factor in Mexico

TC_0: Is the Peso / Dollar FIX exchange rate published by the Bank of Mexico on the fifth business day prior to the date of receipt of the sale offer by CENACE.

TC_{FOC}: Is the average of the Peso / Dollar FIX Exchange rate published by the Bank of Mexico during all the days of the calendar month prior to the date of commercial operation.

$USPP_0$: Is the USPP corresponding to the calendar month prior to the date of receipt of the Sale Offer by CENACE.

$USPP_{FOC}$: Is the USPP corresponding to the last available month prior to the date of commercial operation.

$INPP_0$: National Producer Price Index (Mexico) from previous the month to the date of the reception of the sale offer

$INPP_{FOC}$: National Producer Price Index from the month previous to the date of commercial operation.

The monthly price is updated to reflect the variation of the exchange rate, and inflation according to the electricity coverage contract using Equations 7 to 11 (Contract, 2015):

(7) $$PAM_m = PI \times FAM_m$$

(8) $$FAM_m = (FTC_m \times 0.70) + (FTC_m \times FIUS_m \times 0.20) + (FIMX_m \times 0.10)$$

(9) $$FTC_m = \frac{TC_{m-1}}{TC_{FOC}}$$

(10) $$FIUS_m = \frac{USPP_{m-1}}{USPP_{FOC}}$$

(11) $$FIMX_m = \frac{INPP_{m-1}}{INPP_{FOC}}$$

where PAM_m: is the Adjusted Monthly Price for month m

PI: initial price

FAM_m: monthly adjustment factor for month m

FTC_m: adjustment factor for the FIX Peso/Dollar exchange rate for month m

$FIUS_m$: adjustment factor for the inflation in the United States of America for month m

$FIMX_m$: is the adjustment factor for inflation in México for month m

TC_{m-1}: is the average of the FIX Peso/Dollar exchange rate published by the Bank of Mexico during all the days of the month prior to the month m

TCF_{OC}: is the average of the FIX Peso/Dollar exchange rate published by the Bank of Mexico during all the days of the calendar month prior to the date of commercial operation

$USPP_{m-1}$: is the U.S. Producer Price Index (USPP) corresponding to the last available calendar month prior to month m

$USPPF_{OC}$: is the USPP corresponding to the calendar month prior to the date of commercial operation

$INPP_{m-1}$: is the INPP corresponding to the calendar month prior to the month m

$INPPF_{OC}$: is the INPP corresponding to the calendar month prior to the date of commercial operation

Monthly payments conceptually correspond to one twelfth of the offered price. The amount of each monthly payment under the contract is estimated using Equation 12 (Contract, 2015):

$$\text{(12)} \qquad \text{Payment } M_m = \left(\frac{PAM_m}{\#months_{PC}}\right) + AMDCEL_m + AMDEE_m + PMAH_m + B_m$$

where Payment M_m: is the monthly payment for the calendar month m.

PAM_m :is the Adjusted Monthly Price for the calendar month m

$\#months_{PC}$: is the total number of calendar months covered in the year to which the calendar month belongs.

$AMDCEL_m$: is the Monthly Adjustment for CEL Imbalances for the calendar month m

$AMDEE_m$: is the Monthly Adjustment for Imbalances of electrical energy for the calendar month m

$PMAH_m$: it is the monthly payment that corresponds to the hourly adjustment calculated using the Hourly Adjustment Factor (FAH).

B_m: bonus payments that correspond to transmission and operation fees for the calendar month m

For the purposes of this research, the imbalance adjustments (AMDCELm and AMDEEm) are assumed to be net zero each year. In addition, the transmission and distribution fees will not be included in the analysis since the project will disburse these fees in each period it receives them. Other rules that are included in the contract, such as penalties for under-delivery of energy, and delivery of energy under negative market prices, are not included in the analysis. It is assumed that there will be no curtailment of energy scenarios, and no penalties for deficit generation.

The PMAHm is meant to reflect the fluctuations of the LMPs hour by hour. This payment is calculated with Equation 13 (Contract, 2015):

$$\text{(13)} \qquad PMAH_m = \sum_{d=pd}^{ud} \sum_{h=1}^{24} \left(EP_{h,d,m} \times FAH_{h,m}\right)$$

where $PMAH_m$: is the monthly payment for Hourly Adjustment for the calendar month m in Pesos (using the average FIX Peso / Dollar Exchange rate published by the Bank of Mexico during all days of the calendar month prior to the calendar month m)

pd: is the first day of the calendar month m.

Ud: is the last day of the calendar month m.

$EP_{h,d,m}$: is the energy produced at the hour h of the day d of the calendar month m.

$FAH_{h,m}$: is the hourly adjustment factor corresponding to the hour h of the average day of the calendar month m, according to the Hourly Adjustment Factors (FAHs) released by CENACE for the Long Term Auction 2015. In case of requiring data for years after those included in such FAHs, those corresponding to the last year are to be used.

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