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Business opportunities for Dutch companies in the Mexican renewable energy sector

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GREENID

BUSINESS OPPORTUNITIES FOR DUTCH COMPANIES IN THE MEXICAN RENEWABLE ENERGY SECTOR

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EXECUTIVE SUMMARY

Mexico´s energy reforms have since 2013 revolutionized the local energy market, breaking up the monopoly of state-owned institutions Petróleos Mexicanos (PEMEX) and the Federal Electricity Commission (CFE) and opening up the market to the private sector by 2016. The Mexican government's commitment to meet climate goals including a 35% energy consumption generated through renewable sources by 2024, combined with the innovative business climate in the Netherlands and its expertise in the renewable energy market point towards promising business opportunities. This report aims to explore and identify possible business opportunities for Dutch companies with sustainable energy technologies in the open electricity market and in distributed generation, particularly in the solar, wind, ocean technology, biogas and geothermal sectors in Mexico.

Since the late 1930´s, the public perception in Mexico has agreed that PEMEX and CFE ensured Mexican natural resources were kept within Mexican borders, benefiting the country, powering its economy and stimulating innovation and technology. In fact, the protective management of PEMEX and CFE has resulted in a lack of technology, innovation, infrastructure and expertise in Mexico´s energy sector. The 2013 energy reform allows international investments and invites innovation and foreign expertise. Current president Andrés Manuel López Obrador (AMLO) has chosen to protect the local energy market by making amendments to slow down – but not cancel - the reforms. There are no concessions granted to private sector players that offer distribution and transmission services, unless they are under contract by the Mexican State or CFE. Furthermore, private companies can participate in energy production and commercialization.

Mexico´s open electricity market trades several products: Energy (electricity), power (distribution), Clean Energy Certificates (CELs), complementary services concerning the operability of the grid, financial transmission rights. These products can be traded through the spot market, bilateral contracts, long-term auctions, and distributed generation.

- On the spot market, the National Electricity System (SIN) is divided into nine areas, made up out of multiple electricity nodes. The price of electricity fluctuates pending the price of each node; the Local Marginal Price (PML), which is determined by three factors: energy, loses and congestion.
- Bilateral contracts include Power Purchase Agreements (PPAs), which allow qualified users to buy electricity at a fixed favorable price from a specific generator for a fixed time.
- The concept of long-term auctions was introduced to reduce tariffs for end users and provide a beneficial climate for private investments in large-scale power plants. In the first three rounds (2016), service providers signed long-term contracts (15-20 years) with fixed fees per kWh to basic service suppliers (i.e. CFE), including solar, wind, and geothermal energy sources. A fourth auction round was cancelled

permanently by the AMLO administration, but the private sector in response has announced a 2020 energy auction for PPAs.

- Distributed generation forms a promising niche for Dutch companies, particularly in solar solutions. It forms an economically attractive alternative for the commercial sector and small industry, whom have been paying very high electricity prices in a government effort to finance subsidized low electricity costs for low-income regions. Independence through off-grid SMES, self-generation in residential areas and local energy agencies are in need of innovative technologies and solutions that are currently not available on the local market.

Analysis of different fields of expertise in Mexico´s renewable energy market, in combination with interviews with relevant industry representatives in both Mexico and The Netherlands, permit the identification of various business opportunities for Dutch companies.

Solar

Mexico has introduced public policies that promote the use of solar collectors in residential areas and is a leading player in terms of industrial solar thermal technology installations. Furthermore, the market shows an exponential growth in solar energy production. Considering the strengths and unique selling points of the Dutch solar market, there are opportunities specifically in solar floating PV, integrated PV panels, solar carports, solar PV-T systems and photovoltaic solutions in agri- and horticulture.

Wind

There are business opportunities in the wind energy sector in Mexico for service companies for currently installed turbines. The largest opportunity is found in small wind turbine technologies for distributed generation, particularly in the niches of the tourism industry, industrial parks and on high buildings in large Mexican cities. Dutch companies appear to lack a competitive advantage in Mexico's general onshore wind energy production, and offshore wind does not show any market opportunities.

Hydro energy

Traditional hydropower is the leading technology for the production of clean energy in Mexico, providing opportunities for Dutch companies particularly in energy storage through water management. Furthermore, opportunities are identified in floating solar panels as well as in small-scale innovations for distributed generation. Particularly in the field of research and pilot projects the Mexican hydro energy market shows ample opportunities.

Waste to energy

Mexico is a high waste-producing country facing a major challenge with almost 90% of waste ending up in unregulated open landfills. Local ownership, social factors and a lack of perceiving waste as public resource make centralized waste management, hence waste-to-energy projects currently very challenging. However, opportunities lie with generators of Special Management Waste (SMW), including hospitals, malls, hotel chains, factories and

schools. Furthermore, the agri- and horticulture and life stock sectors form good opportunities for companies in the biogas industry. This study could not identify a competitive advantage for Dutch companies specifically in the waste to energy sector in Mexico.

Transportation - Electric Vehicles

Mexico is one of the top 10 car manufacturers in the world, but currently only one out of 14 companies manufactures electric cars in Mexico. Barriers familiar also in the Dutch market, such as the cost of purchase, accessibility of charging points and public opinion are causing Mexico to adapt slower to electric vehicles (EVs) than their Chinese and European counterparts. The Mexican government shows a tendency towards electric public transport in major cities, creating opportunities for Dutch expertise and companies in this niche. There is also an opportunity in the creation of a network of charging points for EVs in the country, possibly in combination with innovations including smart charging or distributed solar power generation. As developments and innovations are made in The Netherlands concerning peak shaving, there may also be opportunities there in the future.

Green buildings

Developed and growing cities such as Mexico City show promising figures for investment opportunities in Green Buildings, particularly in the fields of energy generation and energy efficiency. Despite some experts in The Netherlands believing that the construction industry is too locally run to be compatible, there are currently several Dutch companies that offer Green Building innovations in Mexico.

In conclusion, there are numerous opportunities for Dutch companies in the renewable energy sector in Mexico, mainly in niche sectors; generated distribution, solar power innovations, the service industry for wind generation, energy storage through water management and electric public transport and smart charging solutions. Dutch innovation and expertise are highly valued in Mexico and can also contribute to research in still unexplored areas. Interested Dutch companies are advised to partner up with a Mexican company and seek help from local organizations including embassies, chambers of commerce and consultancy firms, to ensure their success on the Mexican market.

INTRODUCTION

Climate change and its consequences are no recent news. CO_2 emissions have been a subject of discussion for more than a decade. In Madrid at the COP 25 the scientific community warned society that we are reaching the point of no return. The global average temperature has already raised with 1ºC.

Together the transport (24.4%) and the energy (46%) sectors are responsible of 70% of the worldwide CO_2 emission in the world. (IEA,2017). In recent years the energy transition from fossil fuels to renewables has been a priority for many countries. In 2018 the use of renewables avoided 215Mt of emissions (IEA, 2019), a positive number in the current climate change debate.

Mexico is one of the many countries that are engaged to its greenhouse gas (GHG) emissions. Mexico has the goal to reduce 22% of its GHG emissions by the year 2030. To achieve this goal 35% of its electricity should be produced by renewable energy sources by the year 2024 (LGCC). Mexico's energy reform and the new energy market that was created due to the reforms, createsa unique opportunity for energy production including some of the latest technology and innovation.

To understand this opportunity, it is important to understand the energy transition Mexico has been going through since its energy market was liberalized in 2013 and opened up to private and foreign investment and projects. The constitutional reforms in Mexico that led to this liberalization provide for the possibility to modify, propose and amend laws and regulations in order to have a positive impact on strategic areas to boost the country's economy.

The energy reform broke the monopolistic control the government had on the energy framework. National Oil Company, Petróleos Mexicanos (PEMEX), was no longer the only company responsible for production and extraction of hydrocarbons and its by-products. At the same time, Mexico's Federal Electricity Commission (CFE), responsible for electric distribution, prices and tariffs was no longer the only player.

Competition is the largest impact of the energy reform. The private sector can now participate in the energy markets as a producer or a vendor. In the past, Mexico's private sector offered consulting or guidance services but was not allowed to produce or sell energy to either state, private sector or internationally.

According to the former chairman of the Mexican Energy Regulatory Commission (CRE), Francisco Xavier Salazar, Mexico is "on the right path" as the energy market "is moving from an emerging market to a market in transition" (2019). Four years into the energy market

transition private companies have been participating successfully while solid institutions have been created to act as regulators that guarantee the transparency that is necessary for a level playing field.

The success of the energy reform so far can be measured by the number of contracts and the total expected investment flowing from these contracts, which stands at approximately US$ 200 billion. (SENER, Secretaria de Energía , 2018)

The Netherlands is the 4th global leader in innovation according to the Global Innovation Index 2019 performed by the Cornell University, INSEAD and the World Intellectual Property Organization (WIPO).

One of the reasons for this is the close collaboration between universities, government and industries. In fact, the Netherlands has one of the best entrepreneurial ecosystems in the world, therefore it is no surprise that new energy technologies and applications are being developed by Dutch startups. (Papadopolus, 2019)

The Dutch energy technologies are boosting the renewable energy market, by offering innovative technologies in the solar, wind, ocean biogas and geothermal sectors.

The focus of this report is to explore the Business Opportunities (BO) that are available in the Mexican renewable energy market and where Dutch technologies can play a leading role in the Mexican Energy transition.

This report allows for the identification of possible business opportunities for Dutch companies and provides a framework to understand the basics of regulation in the Mexican energy market. The report serves as a starting point to design a roadmap for entering niche markets that match with Dutch technologies.

METHODOLOGY

The aim of this study is to create a report that identifies areas in which Dutch companies and institutions have a comparative advantage in the renewable energy and energy-efficiency market. This report will be useful to any party interested in participating in the Mexican energy market, creating a view of the "big picture" and serve as a possible roadmap to enter Mexico.

The structure of the report will guide Dutch companies in understanding how they can participate in the Mexican energy market in both the open market and the distributed generation sectors. The report consists of chapters per specific sector in which available technologies, industry status, opportunities and feedback from Mexican companies and organizations active in the market are discussed. The chapters are summarized in concise chapter highlights for a quick overview of opportunities and challenges.

Each of the sections mentioned are the result of desk- and field research; interviews with experts of each sector that will provide market dialogue and direct feedback. This combination ensures valuable insights identifying not only business opportunities, but also the main barriers for entering each sector. For the interviews, experts participate in personal interviews and group interviews. The recordings of the interviews executed in this report are available upon request.

Personal Interview: In the personal interview, the expert will give their opinion freely, and where desired anonymously. This is very important, since some of the experts work at organizations that limit open expression of opinion, such as the ministry of energy, regulation entities, or other public institutions.

Group Interview: This type of interviewing is focused around open discussion and brainstorming of ideas, barriers, and express concerns and possible opportunities. Our network of experts in each of the presented subsectors on both the Mexican and Dutch side ensures the participation of high level and highly specialized companies.

It is recommended to read the introduction and energy reform chapter first, before moving to one of the sector specific chapters: solar, wind, hydro, waste to energy, transportation or green buildings. The report can be read based on chapter one, the field of the reader's expertise, and the conclusion and recommendations.

Chapter 1

1. MEXICO ENERGY REFORM

The long-awaited energy reform of 2013 opened the Mexican energy market to the private sector and the international community, after more than 75 years of a state-controlled energy market. To reach this reform, Mexico changed its mindset and overcame one of the most difficult barriers: public and political perception of the energy market.

For many years political discourse was oriented on protecting Mexican natural resources from the private sector: “A private sector that is greedy and will steal our natural resources, leaving Mexico with nothing”. Although this is not reality, the idea was shared by many Mexicans.

In a study performed by the Research in Economics Center in Mexico (CIDE) in 2006, Mexicans were interviewed about the international collaboration between Mexico and other countries. In that study 54% of the interviewees agreed with the idea of merging Mexico and USA as one country if this would improve the living standards. On the other hand, 76% of the interviewees rejected the idea of Mexico allowing other countries to invest in the exploration, production and distribution of the Mexican oil & gas fields.

This nationalistic ideology about the Mexican energy sector was created in the first energy reform that took place in 1938 under President Lazaro Cardenas. In this energy reform, called the oil expropriation, the Mexican government took control of the entire national and international oil infrastructure in Mexican territory at the time. Although the motive of the government was to ensure the country’s continuity of oil production, which was volatile at that time, it was seen as a patriotic act of how President Lazaro Cardenas gave back the control over resources to the Mexican state. Simultaneously the government tried to fuel public opinion on how international companies were stealing Mexican natural resources and making profit overseas.

The popularity of the nationalization of Mexico’s oil and gas sector increased following the Cantarell oil discovery in 1976, which was one of the biggest in the world at that time. The Cantarell oil find marked the start of Mexico’s ‘Golden Years’.

PEMEX plays an important role in Mexico as until 2013 it was the only company allowed to sell oil and gas to national and international markets. For years revenue generated from oil and gas marketed by PEMEX represented a large part of Mexico’s public budget. This meant that government programs, subsidies and projects were directly linked to the price of oil. With Mexico’s national income depending on PEMEX, the company was taxed heavily, causing unfavorable conditions for the national oil company which in some projects made no profits.

For many years the public perception was that CFE (electricity) and PEMEX (oil and gas) ensured Mexican natural resources were kept within the country leading to favorable conditions as increased revenue and the introduction of best practices and new technologies.

The reality was that, in comparison with other countries, both PEMEX and CFE were behind on new technologies to produce the required energy in the country. To date CFE produces nearly all of its electricity using natural gas, of which 60% is imported from the United States.

Mexico´s dependence on imports of oil and gas created a snowball effect of problems. Due to debts, lack of investments and high overhead costs, PEMEX and CFE were not able to install newer technologies or compete with them. In PEMEX's case this meant that oil reserves located in deepwater fields in the Gulf of Mexico were out of reach because the company did not have the technology, infrastructure or expertise to exploit the opportunity.

The energy reform allowed for the arrival of international companies with best practices and investments that contribute to national growth. Approved in 2013 by President Peña Nieto's administration, the energy reform showed its first results in 2016, when the first auctions of electricity, oil and gas took place.

Between 2016 and 2018 auctions have resulted in the participation of international and national companies, investments of over US$ 200 billion, (SENER, Secretaria de Energía , 2018) and creation of local jobs. With US$20 per MW the cheapest price in the American continent was achieved.

This report is focused on the electricity market segment of the energy reform. Rules and regulations concerning oil and gas are not included in the scope of this report.

With the reform came the new Electric Energy Market. CFE was divided into 9 subsidiaries, including energy production, clean energy production and transmission. To avoid monopolies, each subsidiary has a different role.

1.1 LAWS AND INSTITUTIONS

The Mexican Energy Reform, according to President Peña Nieto's administration, a 'bullet proof' energy reform, was promoted as a constitutional reform, due to changes in articles 25, 27 and 28 of the Mexican United States Constitution. In order to achieve this constitutional reform, most of the changes were created in the secondary laws and

regulations, first modified by President Lazaro Cardenas in 1938 and not in the constitution as it was promoted.

The risk that the energy reform is facing with the current administration of the President Andres Manuel Lopez Obrador (AMLO) is not changing the energy reform as such, but making modifications on this secondary laws and regulations for slowing the private participation in the energy sector and giving advantage for the state companies CFE and PEMEX. This report only focusses on the changes in the constitution, secondary laws, regulations and institutions that are part of this electricity market and distributed generation are listed in appendix I.

1.2 MEXICAN OPEN ELECTRICITY MARKET

The energy reform opened the door for private companies to participate in the energy sector. In the electricity market private companies can only participate in production, commercialization and as a consumer while distribution and transmission remain tasks of CFE and CENACE is responsible for operating the system.

The Electricity Industry Law (LIE) depicts all actors in the Mexican electricity market as well as the different characteristics of each of the possibilities to participate in the new open electricity market.

The different participants of the electricity open market that are considered in LIE are:

Generators: Participants that represent generation plants, including all types of technology. Generation plants with an installed capacity surpassing 0.5MW require a permit of the Regulatory Energy Commission (CRE) to participate in the open electricity market. Generation plants under 0.5MW of installed capacity that use sustainable energy technologies can participate in the distributed generation sector.

Qualified User: Represents the end user that consumes more than 1MW and wants to participate directly in the electricity market by buying energy. This participant can buy energy directly from the generator, although it is more common to purchase from a qualified supplier.

Basic Service Supplier: Represents all basic services users, such as the residential sector, small industry, among others. Currently the only participant in this sector is CFE. Private company participation as a Basic Service Supplier is permitted by law, but the reality is that it is not considered to happen in the near future.

Qualified Service Supplier: Represents Qualified Users that are not direct participants in the electricity market.

Last Resource Provider: Represent qualified users for a fixed period of time under emergency grid conditions. These are qualified users that operate under emergency grid conditions for a fixed period of time.

Broker No supplier: Is the only participant of the market that can buy and sell energy without representing any physical assets.

An overview of the market participants is shown in Figure 1.

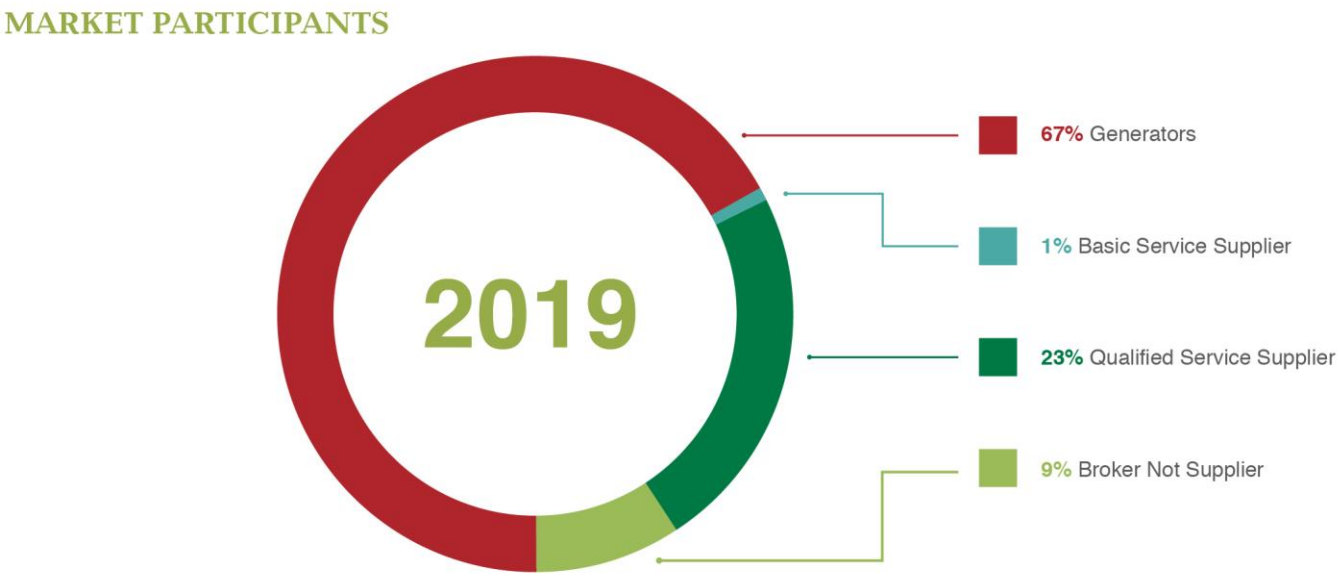


Figure 1. Source: CENACE

The open electricity market started operations in 2016. By October 2019 173 participants were registered, of which 100 were in operations (Figure 2). Foremost reason for this difference between active participants and non-active participants is that generation plants are still under construction. The electricity centrals that have a CRE permit and are located in isolated areas, are required to build electricity lines to the closest SIN connection. This may raise project costs greatly, forming an obstacle to potential participants. A list of the market participants can be found in the appendix II

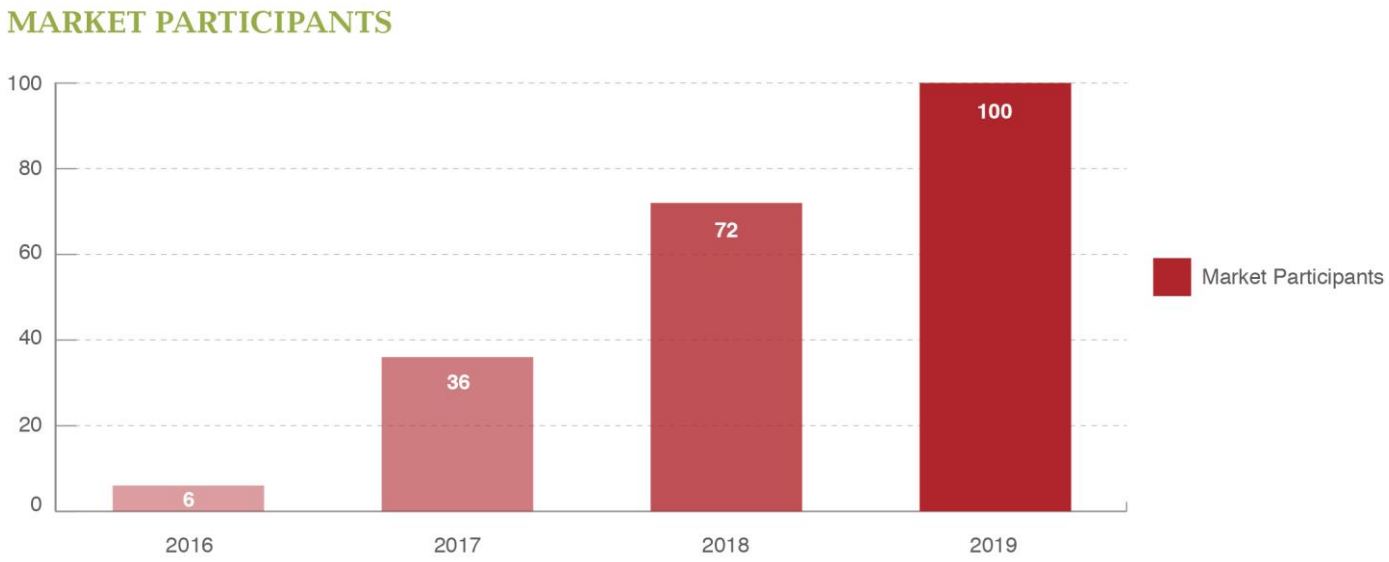


Figure 2. Source: CENACE

The structure of the open electricity market is shown figure 3.

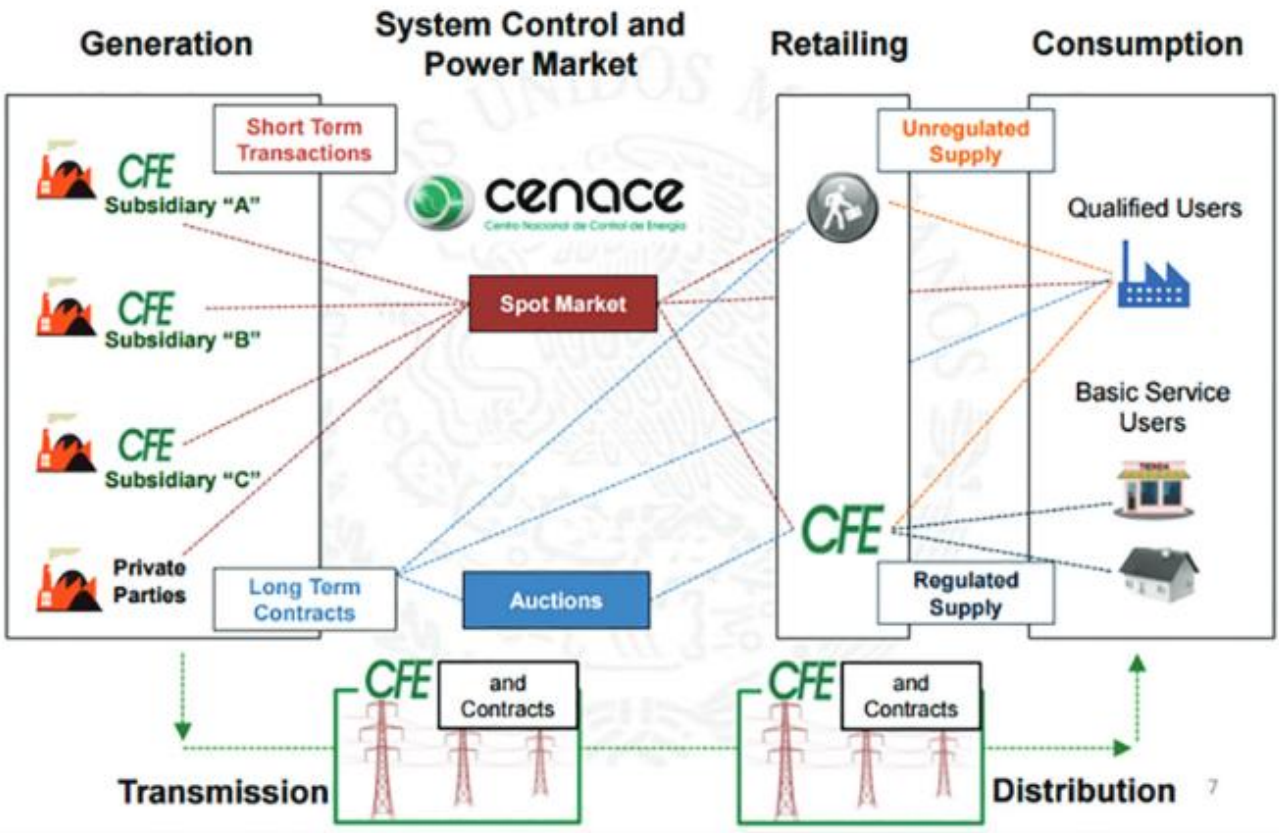


Figure 3. Source: CENACE

1.3 MARKET PRODUCTS

Energy (electricity) is not the only product that can be found in the open electricity market.

Power: The power market has a balancing function, providing power to qualified users in periods when energy consumption is at its highest. Power generators are required to have physical resources that produce electricity.

Clean Energy Certificates: A mechanism to promote investment in clean energy production by using sustainable energy technologies. Clean Energy Certificates are granted to generation plants built after 2014 and given out for each MWh produced

Generators can sell these clean energy certificates to qualified users and suppliers in the market. A minimum percentage of clean energy per year is to be complied with. This minimum percentage is set by SENER and is in accordance with Mexico's international agreement to reduce GHG emissions.

Year	CELs Targets (%)
2018	5
2019	5.8
2020	7.4
2021	10.9
2022	13.9

Complementary Services: These are services linked with the reliable operation of the grid and are normally referred to as the services necessary to maintain the operability of the grid, and the power necessary to reboot the system if needed.

Financial Transmission rights: Cover the difference in cost between two nodes in the transmission system, which is the node where electricity is being supplied to the grid, and the node where the end user is consuming electricity. This allows that the qualified users may sign contracts with generators in any place in Mexico, the financial transmission rights are normally paid by the qualified user to CFE.

1.4 GRIDS ON THE OPEN ELECTRICITY MARKET

Prior to the energy reform there were three separate synchronous grids:

- National Grid (SIN)
- The Southern Baja California Peninsula grid (BCS), which is isolated from the other grids.
- The Northern Baja California Peninsula Grid (BCN) which is synchronously interconnected with the California ISO CAISO in the United States.

The current National Electricity System (SIN) is divided into nine zones, each of which have different electricity nodes indicating the local price depending on the congestion of the area. Figure 4 shows the location of each of the zones. The electricity nodes per area are depicted appendix III.

Figure 4. Source: (Bancomext, GIZ, 2018)

The most important part of the SIN are the nodes of the system. Mexico City has 168 nodes to supply its large energy demand, while other cities or entire states, such as Oaxaca, have 16 nodes. These differences explain why there are some regions more attractive for companies to install generation facilities. The entire open electricity market is therefore depending on electricity prices of each node of the system.

1.5 PARTICIPATION ON THE ELECTRICITY MARKET

Participation in the open electricity market and distributed generation sector is possible through different schemes:

- Spot Market
- Bilateral Contracts
- Long-term Auctions
- Distributed Generation

1.5.1 SPOT MARKET

The spot market is the place where supply and demand meet and as a result the electricity prices are set. As any other open market this electricity prices vary over time. The volatility of electricity prices depends on the offer of generators, the demand of consumers and the distances electricity needs to travel from point A to B.

The Mexican spot market works under economic dispatch and is controlled by CENACE. In this scheme of economic dispatch, generators that offer the lowest electricity prices are to sell first. This principle is implemented to guarantee fair market conditions and lower the electricity price to the end user.

The LIE law promotes the use of sustainable energy technologies. The law depicts that when a generator of 'clean' energy offers the same price as a generator using fossil fuels, the producer of 'clean' energy is the preferred supplier. In practice, energy producers that adopt renewable energies offer a significantly lower price than their fossil fuel competitors. Therefore, electricity produced from renewable energy sources is sold first in the open market.

The most important elements of the SIN system are nodes. The price of each node is known as Local Marginal Price (PML) and is broken down in three components:

Energy: The last generator that supplies energy in the node sets the cost. In the case of renewable energy technologies this represents an area of opportunity, as the cost of producing clean energy is significantly lower than the cost of producing energy using fossil fuels. If the last generator is using fossil fuels the "clean" generators may have significant profit on that operation.

Loses: This cost takes into account the distance that the electricity needs to travel in the SIN from the node that is supplying to the node that is consuming. This varies per hour and is set by the energy demand.

Congestion: The nodes with higher demand need to consume energy from other nodes. This creates a price difference between nodes that is considered in this component. A price node analysis can provide insights on appropriate locations to supply electricity to SIN. A rule of thumb is that nodes with higher prices are most profitable. For example, Mexico City, as the largest city in Mexico, has a constant demand in energy but not enough available space to install new generation facilities. Therefore, prices of Mexico City's nodes are significantly higher than in areas with less demand.

1.5.2 BILATERAL CONTRACTS

Electricity prices vary according to demand; the highest demand in Mexico is during summer when the use of air conditioners boosts the energy consumption. This price volatility flowing from market conditions may become a risk for big consumers of energy, such as the manufacturing industry, where electricity forms a large part of the industry's costs.

For large energy consumers, the energy reform offers the option of sign contracts directly with generators that are already participants in the market. These contracts are known as PPAs (Power Purchase Agreements). PPAs allow qualified users to buy electricity at a fixed price from a specific generator at the lowest price offering for a specific period of time. Once the agreement is made both parties must notify CENACE.

The distance between the nodes of generation and consumption varies in each case. With a PPA agreement in place, qualified users are protected from volatility in the spot market. However, the PPA only covers the cost of kWh, transmission costs need to be paid by the qualified user. The transmission cost is set by taking the difference between nodes and by using CENACE's financial transmission rights.

The PPA scheme is only available for qualified users or qualified suppliers, but not for basic services suppliers as it is now CFE.

1.5.3 LONG-TERM AUCTIONS

Lowering electricity tariffs was one of the main goals of the Mexican Energy Reform. To achieve this, auctions were introduced in which basic service suppliers (i.e. CFE) were able to sign long-term contracts (15-20 years) with auction winners.
The auctions, carried out by CENACE, allow service providers to have contracts with fixed fees per kWh, reducing tariffs for end users and providing an investor-friendly climate for private companies to invest in large-scale power plants.

A total of three auctions were held, resulting in 19.8 TWh (terawatt-hour) of contracted renewable energy, surpassing expectations. Figure 5 shows an overview of the auction results.

- In the first auction, held in March 2016, 18 contracts were secured from 227 offers. Solar represented 74% of the winning projects, whereas wind represented 26%.
- The second auction held in, September 2016, secured 32 contracts. As expected, solar and wind offers were presented, but also geothermal with 25MW offered competitive prices.

- In November 2017 the third auction took place, securing 16 contracts. An average price of 20.57 USD per MWh, including the price of CELs was achieved.

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

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

Figure5.Soure: (Wilson Center, 2018)

In 2018 a fourth auction was going to be carried out by the CENACE. The only purchaser was going to be CFE. The objective was to increase the physical infrastructure of the National Grid (SIN). However, later that year Mexico's new administration suspended it because it wanted to review the terms of the auction with the promise of launching it early next year.

Early 2019 the auction was cancelled, closing the door for private companies to participate in the expansion and improvement of the SIN grid, which in in some areas reached its full capacity.

In 2020 the private sector will organize its own energy auction, so it seems, which will be led by Bravos Energy. This auction is meant for qualified users on the quest for lower energy prices in comparison with current Node prices. As a result, the auction winners will sign PPA agreements with the qualified users. (Garcia, 2019)

1.5.4 DISTRIBUTED GENERATION

Possibilities to participate in the open electricity market are for generators with a CRE registration permit for plants exceeding 0.5 MW of installed capacity.

Distributed generators are generation plants under 0.5MW of installed capacity. These, generators do not require permits granted by the CRE, but are not allowed to directly sell their electricity in the spot market.

The only possibility for these generators to participate in the spot market is to sell electricity to CFE or qualified services suppliers. Data from July 2019 shows that 122 contracts in the distributed generation services are selling electricity to CFE.

Distributed generation offers all sectors, including small industry and residential, to participate in energy production. Experts claim that this empowerment for all the Mexicans is the strongest point of the energy reform (Ramirez, 2020). Figure 7 shows the increase of distributed generation contracts since 2007.

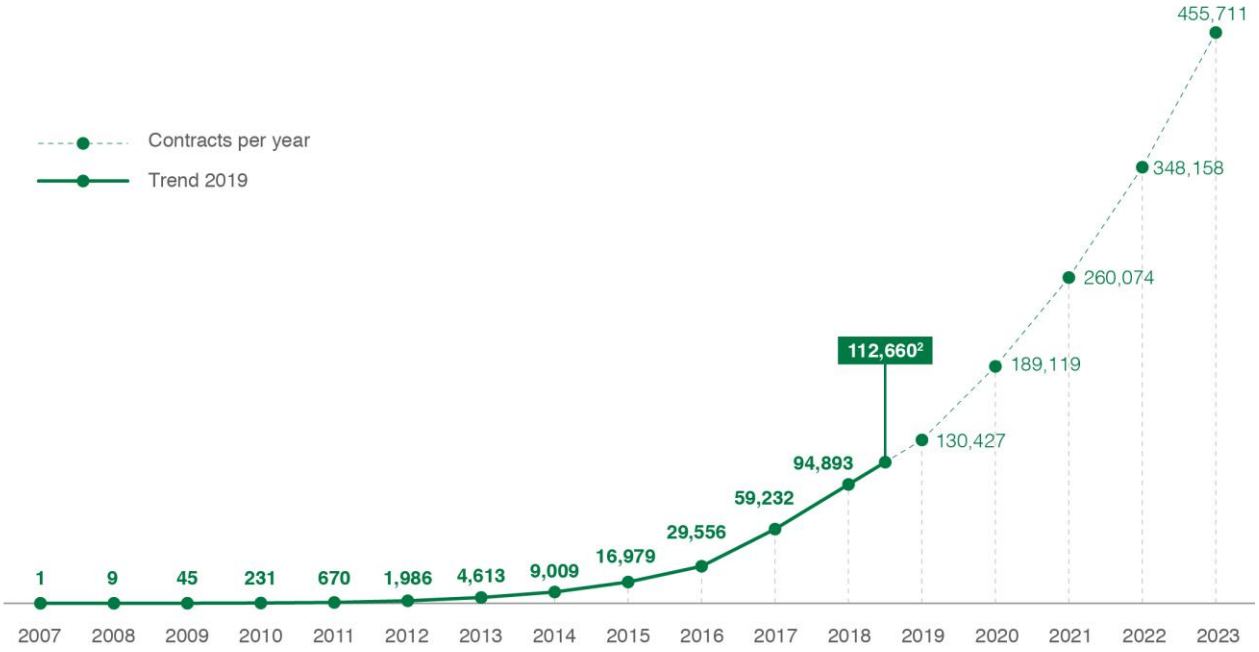


Figure 6. Source: (CRE, 2019)

To understand the importance of the distributed generation niche, it is important to understand the history of the electricity tariffs. Before the energy reform electricity was only produced by the state and it was considered necessary to subsidize electricity bills as much as possible to have political leverage during next elections.

This affected not only the operations of CFE, that made no profits, but caused higher electricity tariffs to be charged to the commercial sector and small industry in order to maintain subsidies in low-income regions.

Figure 7 shows the correlation between electricity tariffs and subsidies in the different sectors in 2015. The blue line of 100% represents the real electricity cost of CFE. (ABN, Iniciativa Climatica de Mexico, 2017)

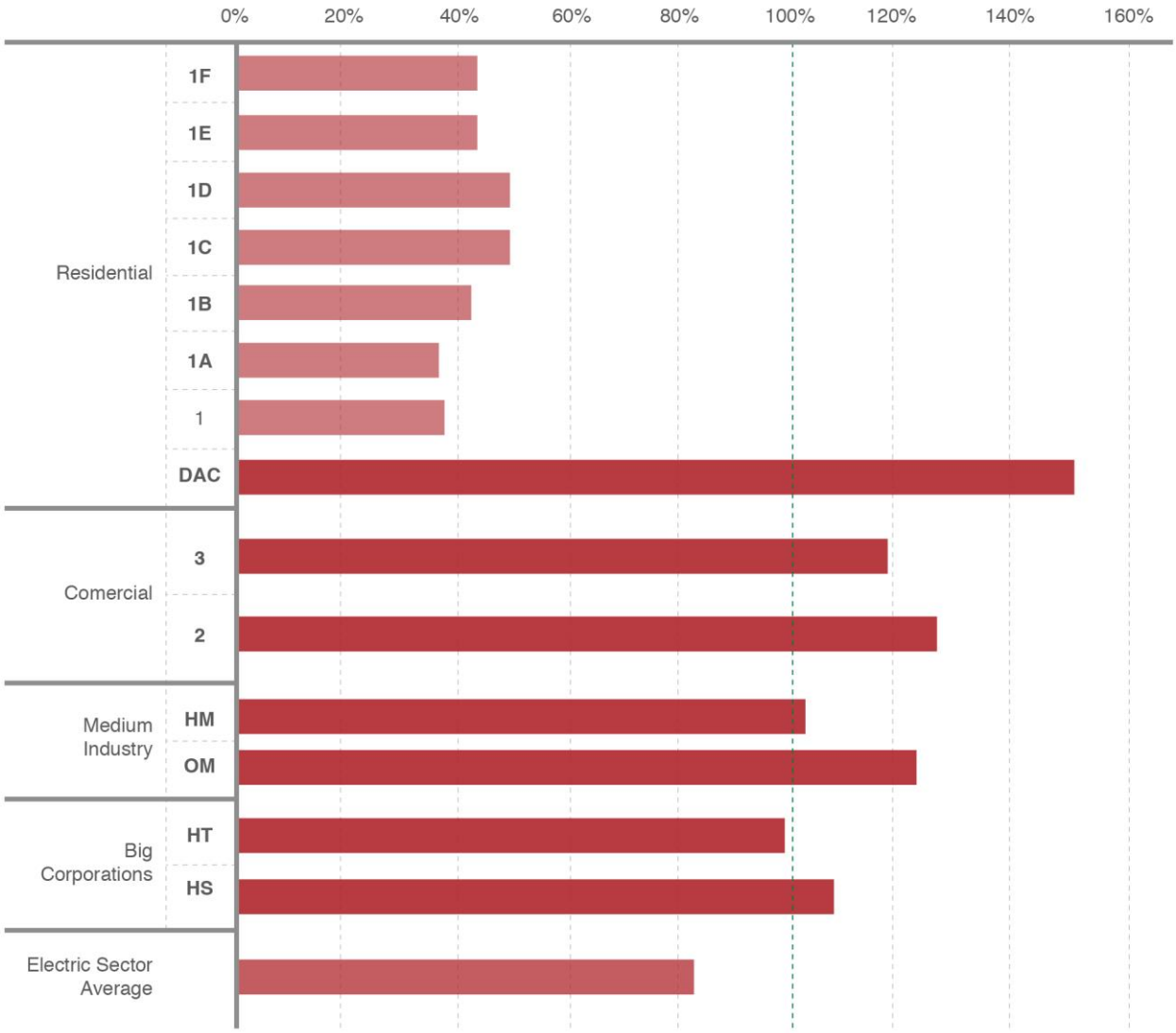


Figure 7. Source: (ABN, Iniciativa Climatica de Mexico, 2017)

The DAC tariff in the residential sector on average pays 150% the cost of a kWh. DAC is a high-consumption tariff and has the highest price in the residential sector. The commercial sector is paying an average 130%, whereas medium industry is charged with 130% of the cost of a kWh.

Mexico has 4.6 million high tariff users, of which 4 million belong to the commercial and small industry sector. Distributed generation presents an area of opportunity when using renewable energy technologies when the project is paid in less than 5 years, which is the

maximum period for a bank loan with this type of technology. (ABN, Iniciativa Climatica de Mexico, 2017)

Of the 4.6 million of potential new distributed generators, 4 million belong to the commercial and small industry sector. (ABN, Iniciativa Climatica de Mexico, 2017)

Distributed generators, either residential or commercial, have three options to be connected to the grid.

1. Net Metering: The difference of electricity produced in a year and given to the grid, minus the electricity consumed. In each billing period the difference is calculated and if a surplus is reached at the end of a year, CFE pays the difference according to the node price. Net Metering is the most common option in distributed generation, as depicted in figure 8. (CRE, 2019)

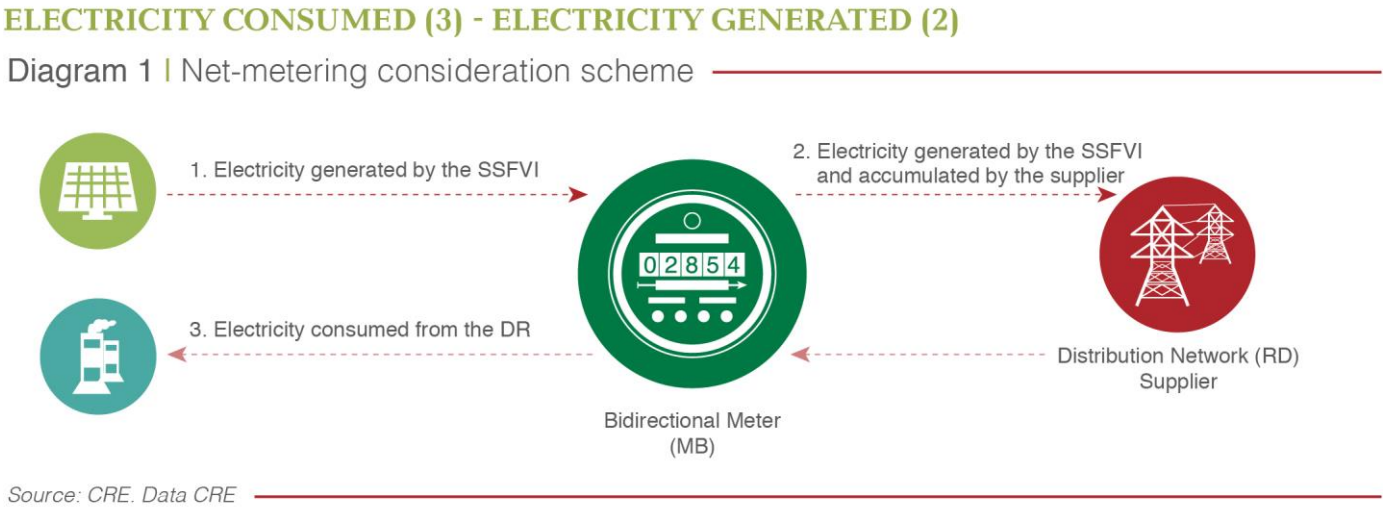


Figure 8. Source: (ABN, Iniciativa Climatica de Mexico, 2017)

2. **Net Billing:** Similar to Net Metering, however, the main difference is that in each billing period of two months, the difference between the energy given to the grid and the energy consumed of the grid is paid. For example, is the user is consuming more electricity in winter, but its solar panels produce less than in summer In this case there is no backup in case of winter if the solar panels produces less than in summer and the user is consuming more electricity they will pay more for those months (figure 9).

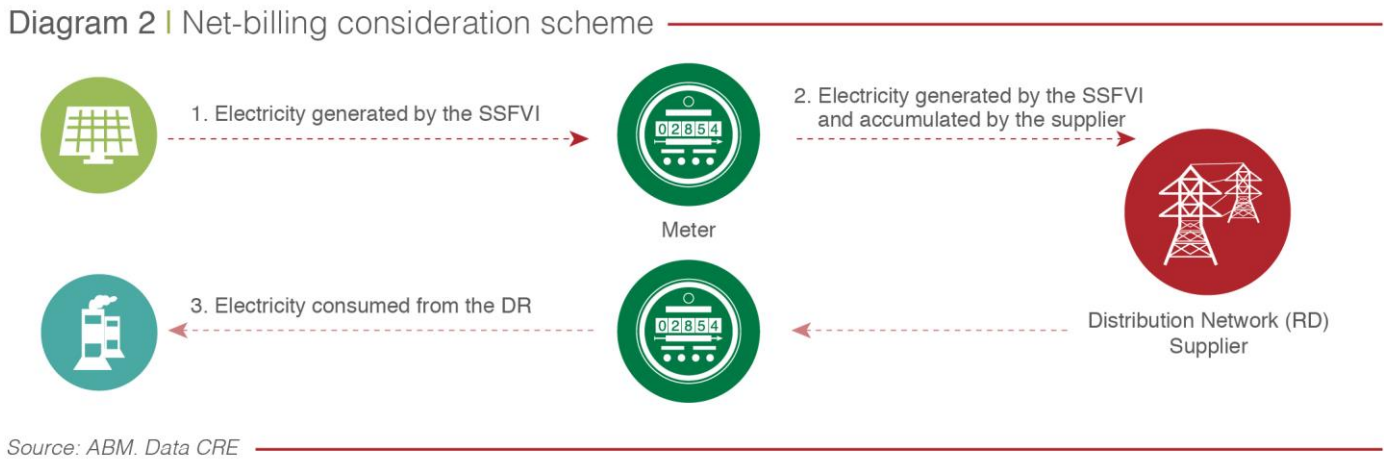


Figure 9. Source: (ABN, Iniciativa Climatica de Mexico, 2017)

3. **Total Sale:** In this case, the entire energy that is given to the grid is sold to the company most probably CFE. The same user will have another measurement device for the consumption of electricity. Therefore, the user has two different and separate accounts, one in selling the electricity, and the other is paying the electricity that has been consumed (figure 10).

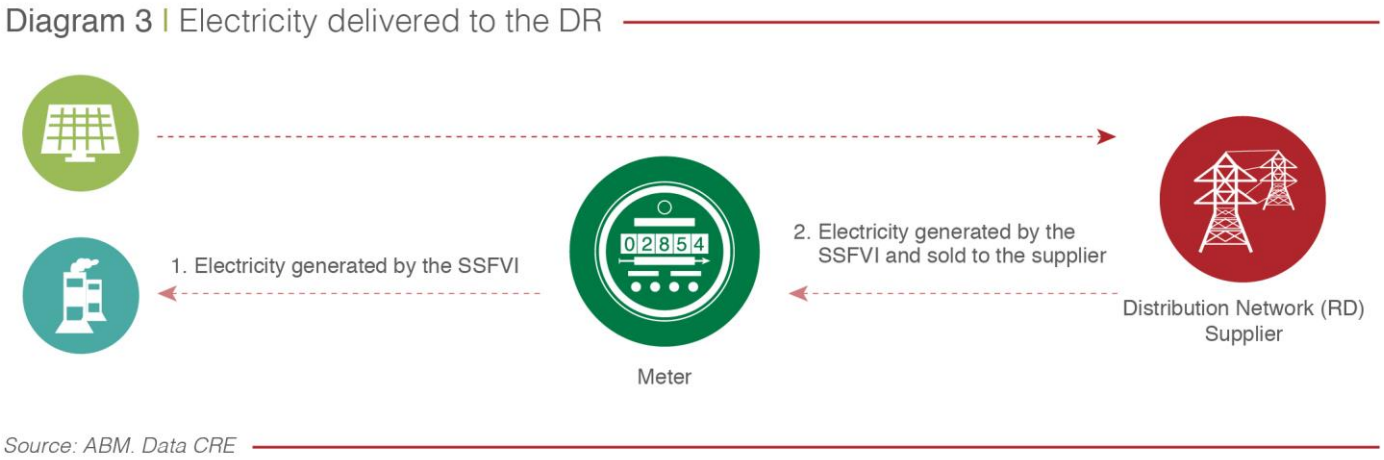


Figure 10. Source: (ABN, Iniciativa Climatica de Mexico, 2017)

In 2012, before the energy reform and its corresponding laws and regulations, the number of contracts in distributed generation amounted to 1,986, representing 14.86 MW of installed capacity. In July 2019 distributed generation had grown by 121%, reaching 112,660 contracts and 817.85 MW of installed capacity. (CRE, 2019). Figure 11 shows an overview of installed capacity and contracts in distributed generation.

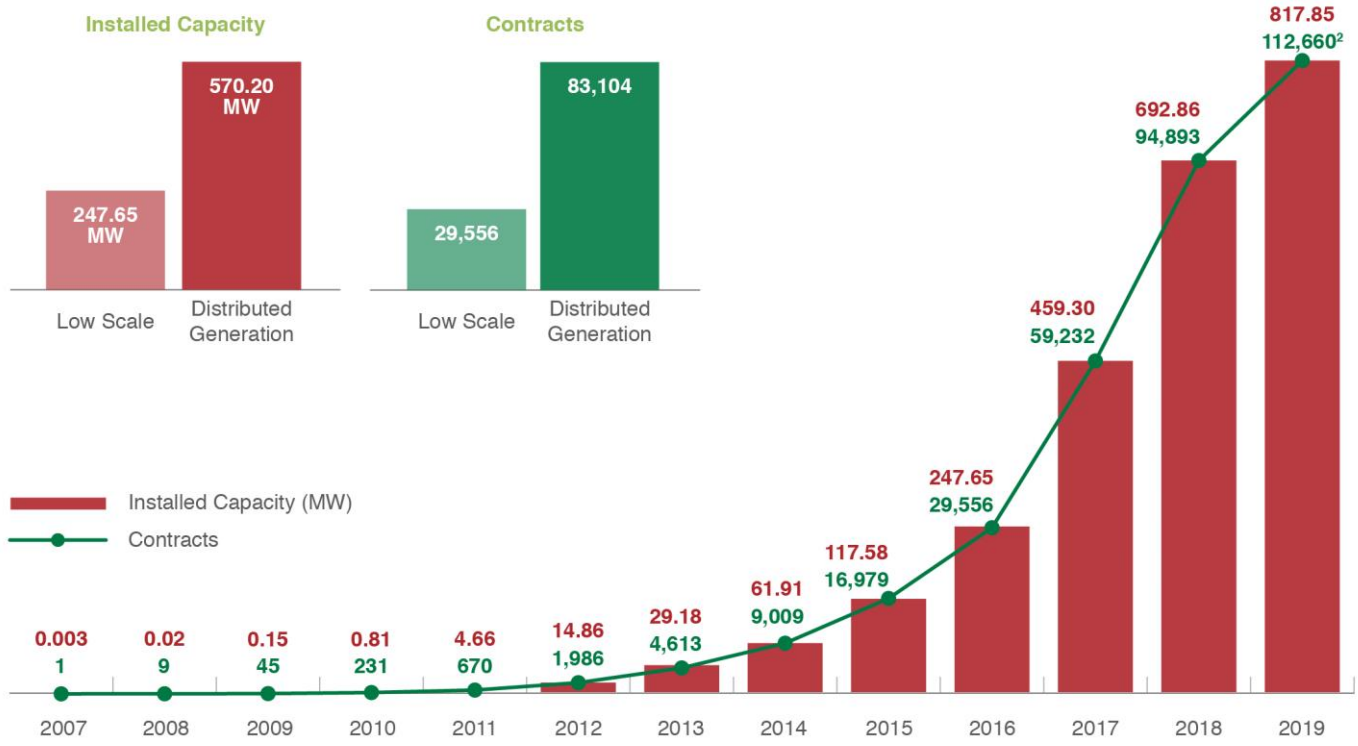


Figure 11. Source: (ABN, Iniciativa Climatica de Mexico, 2017)

Solar technology is the leading technology in distributed generation with 812.6 MW of installed capacity and 112,556 contracts, representing 99,3% of all technologies. Biogas produces 3.97 MW of installed capacity in distributed generation, followed by biomass technology (0.81 MW), wind technology (0.19 MW), hydro technology (0.009 MW).

The scenario is promising for the insertion of sustainable energy technologies in this sector. The forecast for the year 2020 is that the accumulated installed capacity can reach over 1,300 MW, expanded to more than 4,000 in 2023. (Source: Energy Regulatory Commission, CRE)

Dutch innovations could play an important role in this sector, due to the lack of new technologies in Mexico.

1.6 ENERGY REFORM AND THE AMLO ADMINISTRATION

One of the election promises of the current President López Obrador, was to undo partly the energy reform in order to return to the former nationalistic scheme. Upon winning the elections in July 2018 López Obrador promised the private sector that the energy reform would be reviewed and improved, but not be changed.

Since the installation of Mexico's current government on December 1st, 2018, the participation and importance of state companies CFE and PEMEX has grown, while the participation of the private sector has been pushed to the background.

The first signs of slowing down private sector participation were the cancellation of the fourth auction at the start of 2019 and legislative changes in the Clean Energy Certificates (CELs) in November 2019. The changes in the law would have ment that CFE's would also receive CELs for hydro plants built before 2014. But the legislative change was challenged and ultimately won in court by the private sector. (Ramirez, 2020)

Mexico's current energy policy has its focus on fossil fuels. PEMEX received a capital injection and a tax cut in order to restore oil production and financial health of the company. At the same time, CFE's new power plants are to run on fossil fuels, mainly natural gas imported from the United States.

1.7 EXPERT OPINION

Three Mexico experts were asked four questions about their view of the future of the Mexican energy sector and the continuity of the energy reform.

• Victor Ramirez, Spokesperson for the Mexico Climate and Energy Platform (PMCE), Energy Consultant, and former Executive Director of the Mexican Solar Energy Association (ANES)
• Aaron Muniz, CEO of Proterra Capital
• Roberto Lozano, Senior Energy Specialist

Their collective answers are presented below. All answers of the interviewees are personal opinions and do not represent the point of view of the institutions where they are employed.

Q. What was your first impression of the energy reform?

Best practices and lessons learned from abroad were taken into consideration, making the fundamentals of the energy reform solid. Amongst other aspects, reaching competitive energy prices, development of the national energy sector, private participation and a swift

energy transition were factors that struck the eye. Despite having its imperfections, expectations and positivity surrounding the energy reform were high.

Some critics argue that the energy reform has lacked a strong social component. For local communities, cities and regions there is no clear legislation that indicates how to become a stakeholder in the energy sector. Apart from this the capacity (operation, execution, commitment) of regulators CRE, CNH and CENACE was questionable at the beginning. Finally, it was uncertain how the market would react to the liberation of the sector.

Q. From your perspective, what are the lessons learned and what is the outcome after 6 years of energy reform?

The Mexican energy market today is a solid structure, which is also recognized internationally by bodies such as the International Energy Agency (IEA), that acknowledged Mexico's swift launch and execution of the energy reform with limited resources in a short timeframe.

The strongest achievement of the energy reform was the empowerment of Mexicans to participating in the new energy sector. As a clear result, in the electricity sector, many companies have become qualified users having the opportunity to choose the best option for their energy demands and support the renewable energy transition. The participation of SMEs in distributed generation has been surprisingly strong. This is without a doubt the biggest achievement of the energy reform.

One of the weak points of the energy reform is the learning curve of all involved stakeholders. The initial hurdles to overcome in regulation and the time to understand all characteristics, for example electricity prices of nodes and distribution, was something learned along the way. Also, in order to achieve positive results in a short timeframe, technical considerations prevailed over environmental and social components. In some projects this led to a negative perception by local communities.

What can be expected in the energy market under Mexico's current administration?

The near future of the Mexican energy sector can be described in two words: uncertainty and resilience.

Mexico's current administration has shown a strong support for its state-owned energy companies, not being as conducive and favorable to private players.

In addition, in the electricity market the use of renewables has been placed on a second place, slowing down the strong growth and success the sector had experienced during the first three auctions. Clear indicators of this are the cancellation of the fourth auction and the attempt to include the CFE's pre-2014 hydroelectric plants under the CELs scheme.

It is important to mention that despite of the uncertainty and different political messages that characterize the current administration, there has not been any modification to the Mexican Constitution and laws, which suggests that the energy reform will not be changed to accommodate the current government´s energy policy vision.

Despite of uncertainty, the private industry has become creative and in particular cases, as in the distributed energy sector, more active. The resilience of the private sector is pushing the adoption of new technologies as energy storage, new and efficient technologies and securing their energy in the near future with PPAs.

It is likely that distributed generation will surpass its expected growth. The indicators for this are the independence of SMEs of the grid, self-generation in the residential sector and local energy agencies that search for alternatives to secure energy supply.

Q. What would be your advice to Dutch companies seeking to enter the Mexican energy market?

In essence, there are two main messages for Dutch companies that want to participate in the Mexican energy sector.

The first is an open invitation to come to Mexico, especially aimed at companies that have innovative technologies or solutions that can be linked with opportunities in niches that Mexican companies have yet to solve. For instance, renewable energy technologies that can be applied in buildings is an example of such opportunity.

The second advice is to partner with an experienced Mexican company that has already mastered the learning curve and is well positioned in the market. This will reduce the risk significantly and increase the chances of success. In order to meet such suitable companies, it is recommended to contact organizations as associations, chambers of commerce, consultancy firms, or energy clusters that can identify business opportunities facilitate coupling with Mexican partners.

Alberto de la Fuente, President and Director General of Shell Mexico, was asked about his views on the current government's policy towards renewable energy. De la Fuentes views on the future of renewable energy and the role of Shell are depicted in appendix IV.

Q: How do you see the current government policy in relation with the energy reform? And how do you see the future?

We are convinced that hydrocarbon production is a fundamental factor to strengthen the country's productivity and to continue to promote further development of its industrial and commercial sectors.

To achieve this, it is critical to successfully address significant challenges along the value chain of the oil and gas industry.

Among the most important ones are infrastructure development, simplification of regulatory processes and building strong and mutually beneficial relationships with the authorities and communities where we operate.

These are complex issues that require the concurrence of efforts of the three levels of government, operating companies and civil society, in order to make the best from a vigorous and competitive energy sector. These sum of efforts and commitments is an indispensable factor to successfully circumvent contingencies and continue to build a competitive, sustainable and safe energy future for Mexico.

President Andrés Manuel López Obrador has pointed out the urgency of hydrocarbon companies to fulfill their investment commitments and contributing to increasing hydrocarbon production. We share the President's goal and continue to work to comply with our commitments and help Mexico take advantage of more and more resources to promote the development and well-being of its people.

Investors from various countries are asking legal certainty, a competitive market and a favorable business climate in Mexico; all of them fundamental elements to continue to drive sustained productive investment.

Hence the desirability of continuing to promote bidding rounds and partnership processes with Pemex. We believe these instruments are most useful to maintain current investment levels looking ahead, increase the hydrocarbon output and continue to generate synergies between international operators and local companies that are key to continue to build a more competitive, efficient and sustainable oil and gas industry for Mexico.

CHAPTER 1 | HIGHLIGHTS

OPPORTUNITIES

SOLID REGULATORY FRAMEWORK

Constitution and the creation of a regulatory framework based on international best practices.

MARKET GROWTH

Long-term auctions resulted in 66 contracts and 19.8 TW of contracted renewable energy. Distributed generation grew by 121%, reaching 817.85 MW of installed capacity.

COMPETITIVE PRICES

Electricity prices reached 20.57 USD per MWh, a record price in the American continent.

PRIVATE SECTOR TAKING THE LEAD

Private sector has become more active and is pushing the adoption of new technologies.

CHALLENGES

UNCERTAINTY CAUSED BY CURRENT GOVERNMENT POLICY

Mexico's current energy policy has its focus on fossil fuels.

CANCELLATION LONG-TERM ELECTRICITY AUCTIONS

The cancellation of auctions is slowing down the participation of international and national companies and corresponding investments.

PROMINENT POSITION CFE AND PEMEX

Private participation in the energy sector is slowed down by the government and advantage is given to the state companies CFE and PEMEX.

Chapter 2

2. SOLAR ENERGY

90% of Mexico's territories are located under the solar irradiation belt of the planet, providing for favorable conditions to produce energy using solar PV technologies. [1]With an average of 5.5 kWh/m2 per day Mexico scores high in comparison with for instance, Germany, where the average is 3.2 kWh/m2. Some areas in Mexico, such as the Sonora desert, can reach a maximum of 8 kWh/m2. (PROMEXICO, 2017). Figure 12 shows the irradiance levels in Mexico.

This chapter will analyze the business opportunities in PV solar technologies. To a certain extent, also solar thermal technologies are addressed to in this chapter, due to limitations in Mexico's Energy Reform, which is focused on geothermal technologies and its corresponding law.

Figure 12. Solar Irradiation Map Mexico (Rocio del Carmen Alatorre Eden Wynter, Radiación Solar, 2017)

[1] [1] Solar Photovoltaic (PV) is a technology that converts sunlight (solar radiation) into direct current electricity by using semiconductors. When the sun hits the semiconductor within the PV cell, electrons are freed and form an electric current. Solar PV technology is generally employed on a panel (hence solar panels).

2.1 SOLAR PHOTOVOLTAIC SYSTEMS (PV)

One of the main purposes of the energy reform is to allow that the Mexicans can participate in the energy sector, create a competitive market and consequently lower the electricity tariffs. Solar PV is the perfect technology for boosting the participation of both the private sector and the citizenship into this energy transition.

2.1.1 SOLAR PARKS

Between 2013 and 2019 Mexico has seen an exponential growth of solar parks and distributed generation installations, from 60 MW to 4,986 MW of installed capacity. Figure 13 shows the yearly increase of installed PV capacity. It is expected that this number rises to 30 GW by 2030. (SENER, 2018)

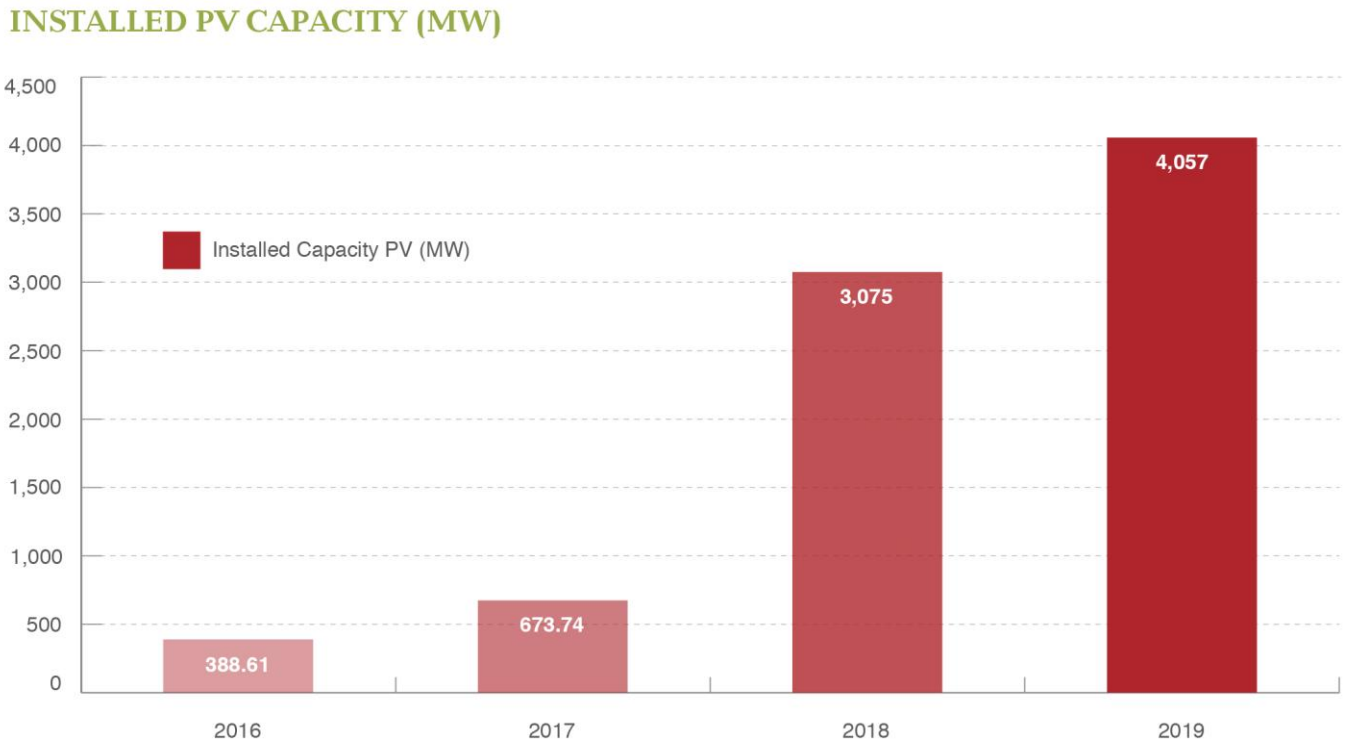


Figure 13. Source: ASOLMEX

To date, Mexico has 61 solar parks totaling 3,973 MW of installed capacity. Chihuahua tops the list as state with the largest number of solar parks; 11 parks corresponding to 444 MW. With 949 MW the State of Coahuila is the region with the highest number of installed capacity (ASOLMEX).

Villanueva Solar-park, located in the state of Coahuila, is the biggest solar part in the American continent, with 468 MW generated by 2.3 million solar panels. The list of the 61 Mexican solar parks can be found in appendix II (ENEL, 2018).

2.1.2 SOLAR PV THROUGH DISTRIBUTED GENERATION

In 2013 the distributed generation sector Mexico had a total of 15MW of installed capacity from 4,613 CFE contracts. In 2019 this had grown to a total 112,660 contracts representing 817.85MW. Of this number solar PV is the leading technology, accounting for 99.3% or 812MW of capacity.

Figure 14 shows an overview of Mexico's states with the highest number of installed capacity:

State	Number of Contracts	Installed Capacity (MW)
Jalisco	23,388	126.92
Nuevo Leon	12,606	105.03
State of Mexico	4,814	77.54
Mexico City	7,694	67.45
Chihuahua	7,571	50.15

Figure 14. Source: ASOLMEX

Solar PV is the leading technology in distributed generation. There are two drivers that reinforce the use of solar panels in Mexico: competitive prices and the lack of small-scale projects that use technologies as wind, biogas, tidal and hydro.

Currently there are more than 1,000 companies in Mexico participating in the solar market. These companies can be divided into EPCs[2] for the open market and solar integration companies oriented to distributed generation companies.

During the past years the number of Mexican companies dedicated to the installation of solar parks has grown. EPC companies as ENEL, ENGIE and ZUMA are participating in the open market for solar parks in projects ranging from 1 to 30MW.

To date, Mexico's distributed generation solar sector has created 50,000 jobs. It is expected that the number of companies will decrease but that more jobs will be created as the distributed generation market grows. It is expected that leading companies, with a focus on high quality and service standards, will gain a majority of market share.

The current market shows signs of oversupply, which is related to the ease of installation and the competitive price of solar panels, in combination with a high return on investment rate in the residential sector.

A hurdle to overcome in the sector is the lack of regulation and certificates. Local demand is affected by unreliable installation and poor client service. Although thus far only 4 out of 112,660 installations have presented fires, a more regulated sector is needed to prevent poor practices. Market regulators as CRE and industry associations could play a role in safeguarding industry practices and share warranties of certified companies and installers.

There are three main solar associations in Mexico:
- Mexican Solar Energy Association (ANES)
- Mexican Association of Solar Energy (ASOLMEX)
- Mexican Association of Photovoltaic Equipment Manufacturers (AMFEF)

ANES is the leading association with approximately 150 members and is oriented at building bridges between knowledge and industry. ASOLMEX, with 128 members, has its focus on the solar market and the promotion of new solar parks. The third association, AMFEF, targets companies that import Chinese solar cells and assemble these locally.

The exact number of distributors and solar technologies available in Mexico is unknown, but there is a significant number of players in the market. The distributors sell all the necessary equipment for the installation of solar parks and small installations.

[2] EPC = Engineering Procurement Construction
This is a prominent form of contracting agreement in the construction industry. Companies that deliver EPC Projects are commonly referred to as EPC Contractors.

Most solar panels in Mexico have the certification TIER1. The solar panels that can be found in Mexico are mono, poly, (between 320W and 400W) and bifacial solar panels. Products offered in the market are, amongst others, installation racks, inverters, string inverters, mini-inverters, installation software, design software and sun tracker devices.

The first company to install bifacial solar panels in Mexico was ENEL Green Power, for their Magdalena II solar park in the state of Tlaxcala.

Due to the presence of established companies as Trina, Risen LG, Canadian Solar and Jinko, the average price per watt currently stands at US$0.30/W. This price forms a barrier for entry into the Mexican market for new technologies.

Recent developments in solar PV include the announcement of a Solar City Program by the Mexico City government. The program, released on 27 January 2020, is aimed at reaching 300 installed solar systems, each with a capacity of 50kW and resulting in 15MW installed on government buildings. (Almazán, 2020)

On the same date, Mexico City's Ministry of Economic Development (SEDECO) launched the first solar installation of a total of 220 solar panels, each generating a capacity of 95kW. Included in the Solar City Program is a project to install 40 MW of solar cells on the roof of Mexico City's Central de Abastos, the largest wholesale market of its kind in the world and a vital source for merchandise for the Mexico City metropolitan area. (Páramo, 2017)

The program also offers credits to smes to have solar technologies, including solar thermal and PV, installed by certified local companies.

2.2 SOLAR THERMAL TECHNOLOGIES

The energy reform focuses on the electricity production and the oil and gas sector and does not include the use of heat in the industry and residential sectors. The use of heating technologies as solar thermal can play an important role in the reduction of CO2 emissions, as 67% of the energy used in industry is related with heating purposes or uses. The opportunity of creating this heat by using renewable technologies, as solar thermal, is an alternative for the fossil fuels.

Knowing the potential of this resource and committed to reduce the CO2 emissions, Mexico has launched government programs to impulse the use of solar thermal technologies focusing on the residential sector.

In the period 2007-2012 Mexico's government launched the program PROCALSOL with the objective to stimulate solar heating technologies from 1 million m2 to 3.5 million m2 of solar

thermal energy installed. PROCALSOL was focused on small industry, the residential and agricultural sector. Other government programs included, Hipotecas Verdes and 25,000 Techos Solares Para Mexico, both aimed at the residential sector, and FIRCO, which was focused on covering the demand for heating in agro-business installations.

In 2015 Mexico ranked 4th worldwide in terms of installed solar heating capacity, with 44 Solar Heat for Industrial Processes plants. In 2019 the installed capacity reached 83 projects destined for industrial applications.

Solar thermal technologies must comply with the following norms to be allowed for commercial use in Mexico:

- NMX-ES-001-NORMEX-2005: This norm applies for flat plate collectors and vacuum tube collectors. The methodologies for testing the products are detailed in this norm, which also depicts the characteristics and information that product labels need to comply with.
- NMX-ES-002-NORMEX-2007: Creates a standard for the words used in these products to avoid misunderstandings for the end user.
- NMX-ES-003-NORMEX-2007: This norm establishes the minimum requirements for the installation for solar thermal technologies.
- NMX-ES-004-NORMEX-2010: Depicts a methodology for testing and comparing solar thermal technologies destined to the residential sector with a maximum capacity of 500 liters and a maximum temperature of 90ºC.
- DTESTV: Measures the overheating protection systems of the thermal technologies when under extreme solar irradiation.

After the industrial and transport sector, the third sector to consume most energy in Mexico is the residential sector, with a total 14.8% of the energy production. The residential sector increased its share from 743,000 m2 in 2005 to 3,166,000 m2 in 2015, as is shown in Figure 15 (SOLAR PAYBACK, 2018).

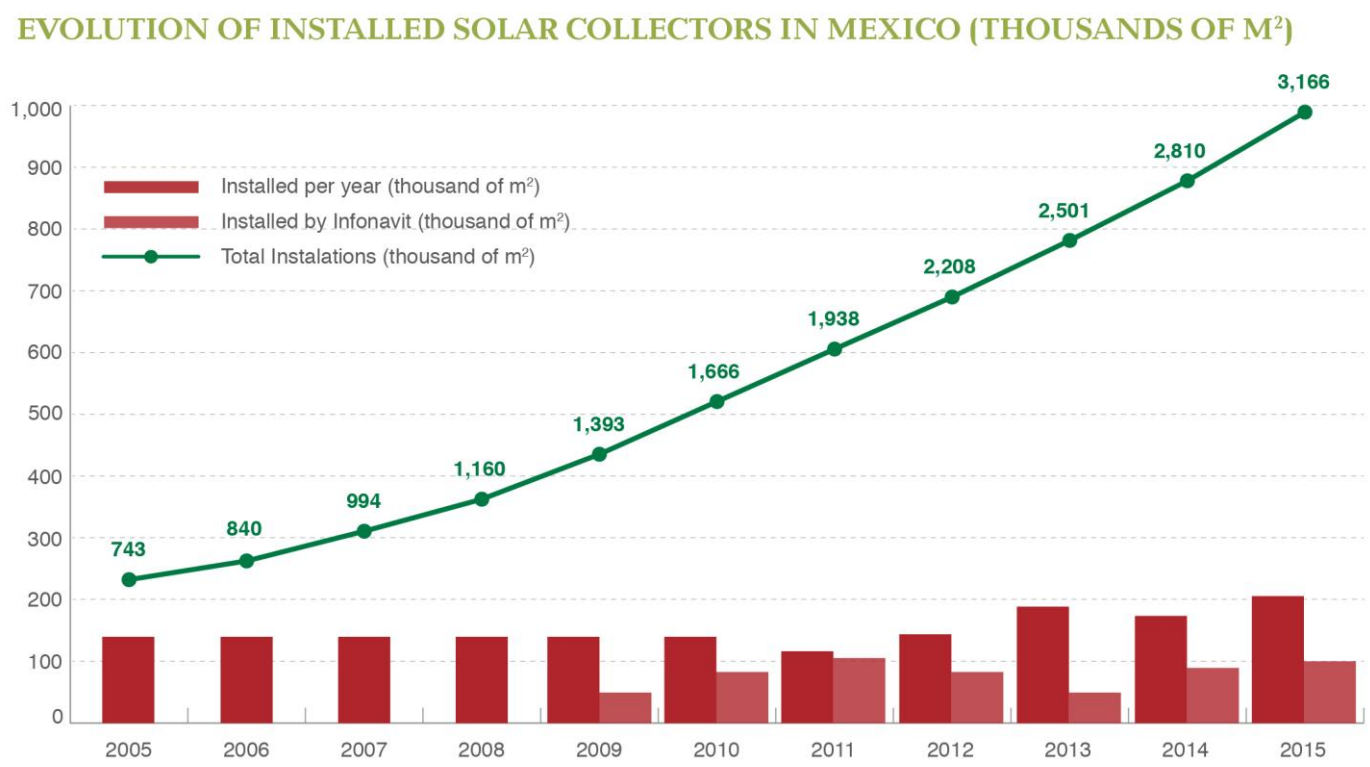


Figure 15. Source: Solar Payback, 2015

For the residential sector the flat solar collectors and the vacuum tubes collectors are the most used technologies. Both technologies are produced by Mexican companies, but in the last decade the entrance of Chinese products has increased the market participation of Chinese companies.

Although the industrial sector consumes 31.4% of Mexico's energy, there is no government program to promote the use of solar heating technologies. Nonetheless, 83 projects that use this technology have been installed in 20 years (SHIP Plants), which makes the country world leader in this segment (in the number of plants, not in installed capacity).

It has been forecast that Mexico will have an installed capacity of 33GWt in 2030. Of this figure, 24GWt is destined as heating water for buildings. 8GWt will be used in the low and medium heat demand industry. The buildings niche is considered as the fastest growing element, including hotels, hospitals, sports centers and public offices. (SOLAR PAYBACK, 2018)

In 2014 in Mexico 142,000 m2 of solar heating technology was produced by mainly 8 Mexican companies: Inventive Power, Modulo Solar, Desarrollo, IUSA, Captasol, Sunway, Oro Solar and Kioto Clean Energy. (Solar Payback Mexico)

Of these companies, Inventive Power is the only one that produces solar collectors that provide hot water in the range of 50°C-200°C, to serve mainly the food productions industries.

"La Parrena Copper Mine" is the biggest solar heating installation for industrial application in Mexico with 6,270 m2 (4,400kWt) and the 7th biggest installation in the world. In comparison, the largest plant is Oman's Miraah with 210,000 m2 of installed capacity, used to enhance oil recovery (SHIP Plants).

Figure 16 shows the technologies used for industrial solar heating purposes in Mexico in 2019.

Figure 16. Source: Ship Plants

In 2017 the leading technology was the Flat Plate Collector, which in 2019 was surpassed by the Parabolic Collector, which is produced in Mexico and is capable of reaching higher temperatures.

2.3 EXPERT OPINION

Three Mexican experts were asked four questions about their view of the future of the Mexican solar sector and the continuity of the energy reform. Additionally, an expert representing a Dutch company was asked to give his view on the Mexican solar sector and the opportunities for Dutch companies.

The following Mexican experts were interviewed. Their collective answers are presented below.

- Daniel Calderon, Finance Consultant Solar Projects and Finance Secretary for Mexican Solar Energy Association (ANES)
- Javier Romero CEO of Ecovalue, Executive Director Mexican Association of Photovoltaic Equipment Manufacturers (AMFEF)
- Pablo Cuevas, Independent Consultant and former collaborator of the solar thermal sector project PNUD

Q: What was the impact of the energy reform on Mexico's solar sector industry?

The energy reform was positive news for the solar sector. It provided the sector with a new regulatory framework, that was long-awaited by the industry. The energy reform created certainty about the possibilities for private companies that wanted to participate in a new energy market. Incentives such as CELs were created to promote the use of renewable resources to produce electricity and decrease GHG emissions.

A negative side of the energy reform for the solar sector is the exclusion of thermal technologies for electricity production. Instead the focus of the reform is on the electricity market. Therefore, the solar sector is divided in two sectors.

The PV solar market started growing has grown exponentially in big-scale solar parks and distributed generation. With this exponential growth, the price of solar panels in Mexico has dropped significantly, creating a strong and competitive market. An average price of US$ 0.30 per watt, together with competitively priced Chinese solar panels have formed a barrier to the national industry to compete.

In contrast, in the solar thermal sector business there were no opportunities as a result of which that market remains limited. It is important to create favorable market conditions for thermal energy, as was done in the electricity sector. Consequently, it is expected that the market will see more players. Similarly, a shift from selling technology to selling energy or energy efficiency services is expected to occur.

It will be the role of local governments to develop attractive conditions to increase the participation of solar technologies, as is the case with the Solar City Program by Mexico City's government.

Q: What can we expect in the coming years in terms of big-scale solar facilities?

The current administration has created some uncertainty for big-scale power plants, resulting into risks for investors and EPC companies to sign PPAs. These uncertain conditions are opening the door to novel solutions as energy storage systems, micro-grids, and other solar PV technologies to enter the Mexican Market.

New efficient energy technologies will have to compete with competitive prices in the market, or niches must be identified.

In the thermal market, it is expected that the number of big scale facilities will increase if developers can offer integral and tailored solutions oriented to energy efficiency, and not just by selling equipment. The barrier for market entry for new energy technologies can be lowered by introducing options for financial schemes, which are currently not in place in Mexico.

Q: What can we expect in the coming years in terms of small-scale solar facilities?

Small-scale solar facilities are all about the distributed generation sector. It is expected that this sector will continue to grow as it has been doing over the last years. In this case, the uncertainty created by the government is giving the small industry sector an impulse to start adopting new technologies and to produce their own energy.

In the next few years, it is expected that technologies as efficient solar panels, energy storage, smart metering, or technologies that contribute to reduce the peak demand and enhance the control of energy production or consumption, will make their entry into the market.

In the case of the solar thermal sector, efficient technologies that are oriented to small-scale applications on buildings are possible business niches. A current niche is that of existing buildings and homes where new technologies can be installed. New technologies will become more attractive for sale when financial incentives and complimentary services are in place. New technologies will become more attractive when financial incentives and complimentary services are in place.

Q: What would be your advice to Dutch companies that want to enter the Mexican energy sector?

It is important to contact local companies to get a clear picture of the status of the market and to understand the main barriers to entry. With this information niche markets and local partners can be identified.
Despite the current market uncertainty, the Mexican energy market is growing and there are several business opportunities.

Next to the interview with Mexican experts, an interview with Marcel Langone, Project Manager Solar Asset Management of Solar Plaza, was conducted. The answers are presented below.

Q: Can you tell us about the current trends and the history of the solar park market in The Netherlands, globally and in Mexico?

The boom of the utilities scale (large scale electricity generation either through a photovoltaic power station on a large scale or concentrated solar power) in the Netherlands has been happening over the past two years, with most of the growth taking place in 2018 and 2019.
Globally we surpassed 400 GW of solar energy installed by 2018. The leading market is China, with over 175 GW installed, followed by the US and Japan.
Mexico reached an interesting milestone at the beginning of 2020. In the past few years, the North American country installed over 5 GW of capacity in solar energy which makes it the biggest solar market in Latin America. Identically to The Netherlands, the boom in the utilities scale in Mexico came in 2018, when more than 2 GW was installed. Many solar projects started development in 2016 with most of the capacity coming from tenders. Currently, some projects also sell electricity to the spot market or are in PPA agreements with corporate consumers.

Q: What have been the obstacles for the expansion and implementation of solar parks?

From an asset management perspective, the beginning of Mexico's solar market was marked by pressure in terms of pricing, which naturally reflects on a tight OPEX. The tenders in Mexico had one of the lowest prices in the global market at that time.

Feedback from different players in the market taught us that there are construction and installation issues that should not be there in the first year of operations. Therefore, a big focus of the market is on how to guarantee the quality of the plants to ensure that the long-term operation is secure and to ensure a sustainable source of electricity for the future.
Other obstacles are related to business models. Now that the long-term electricity tenders have been cancelled, it is very important to understand project risks associated with merchant and PPAs and the effects that these risks could have on project cash flows.

These are just a couple of challenges. Experts in the Mexican market will be able to tell you more.

Q: Solar Plaza organizes different exhibitions around the globe. How does the Mexican market compare to others?

We organize different conferences around the world in which we discuss all aspects of asset management. Speaking of these asset management conferences, we are present in countries like Germany, US, Japan, Australia, amongst others. With regard to the Mexican market, we are having discussions in the early stage of operations. We are talking about how to integrate design and installation learnings during operations on new plant development, best practices for reporting, contract management, performance indicators, etc. When the market matures, we will start talking about secondary market, how to do asset management at a portfolio level, refinancing and repowering.

Q: What has been the influence of the Mexican Energy Reform for the sector?

The Mexican Energy Reform was the precursor of the tenders and open market competitiveness. In that sense, the reform was the trigger for the solar industry to boom in Mexico

Q: Are Dutch companies prepared to enter the international markets? What are the possibilities?

In terms of strengths of the Dutch solar industry, we are seeing a strong technical research regarding modules, new materials and new applications. Currently, the solar Dutch market is very strong on ''double functions'', meaning floating solar, carports, solar and agriculture, and on landfills given the lack of available land in the Netherlands. But also more and more storage and hydrogen pilots are coming up. In general terms, Mexico is an attractive market with a big energy demand and good irradiance levels. Therefore, it is really interesting for international players to support the Mexican industry maturation with their know-how.

Q: How do you see the future of solar energy?

Many say the industry is still in its very early stages, even though annual growth is at around 30%. I believe that many countries are taking the proactive steps to change their energy mix. However, there are still some common challenges that are valid in many parts of the world, for example: how to control the output of renewable energy resources. The solar technology cannot be seen in isolation. There will be more aggregation models and for instance, hybrid plants with solar and wind. Storage will naturally play a big role.

We are working in a rapidly growing industry and there are many opportunities that solar stakeholders can tap into.

2.4 BUSINESS OPPORTUNITIES

Mexico, together with numerous other countries, has experienced an exponential growth in its solar energy production. The downturn in production cost of solar technologies, increased use of local resources, and low barriers for market entry have made solar energy one of the most important renewable technologies.

Mexico seized the opportunity that local solar resources offer the country. Mexico is leading in terms of the number of installations for solar thermal technologies applied directly to the industry. Mexico introduced public policies to promote the use of solar collectors in the residential sector.

Since the 2013 energy reform, Mexico increased its installed capacity 83 times, from 60MW in 2013 to 4,986MW in 2019.

In its report Future of Solar Photovoltaic the International Energy Agency (IEA) states that the solar industry is changing dramatically due to the innovations that are taking place along the entire value chain. Innovations as new materials, module manufacturing, applications, operation and maintenance, and decommissioning management of solar panels will stimulate the solar energy sector.

Mexico presents favorable conditions for companies that are innovating in solar technologies and applications. Currently there are Dutch companies active in Mexico in, amongst other niches, solar thin-film technologies, bifacial solar panels, solar shingles and glass-glass solar panels.

The new energy market and its exponential growth opened the door to accelerate the energy transition and the use of innovations directly with new business opportunities that the sector represents.

According to IEA growth is to be expected in the following applications:

- Solar Floating PV: Deployed in areas where space is limited and taking advantage of the reflection off water, the use of this application is being stimulated in several countries around the world. To date Mexico has not seen projects in Solar Floating PV. This can present a business opportunity in the Gulf of Mexico area. For example, in energy production for offshore oil platforms, or on Islands such as Cozumel, where electricity node prices are the highest in the entire country.

- Building-Integrated PV Panels: Cities as Mexico City, Guadalajara, and Monterrey are a unique opportunity for the application of innovative technologies due to high electricity tariffs, the limited space, the continuous energy demand, and ongoing construction of new buildings and houses. A proof of this is the new Solar City Program of Mexico City that has as objective to increase the use of solar technologies. Dutch technologies as solar roof tiles, solar shingles (made out of clay), and solar windows, are already found in the market, and could play a significant role in Mexico's distributed generation sector.

- Solar Carports: An application that can be found in Mexico. It is expected that, with the increasing number of electric vehicles, parking lots will adopt solar PV panels. The opportunity lies with the use of more efficient solar panels, such as glass-glass PV, to produce more electricity per m2.

- Solar PV-T Systems: Although there is demand from industry and residential sectors, this technology to the date is not present in the country, presenting a business opportunity.

- Agro photovoltaic: Recent research studies show proof of the benefit of growing crops beneath ground-mounted solar panels and the positive effects this method has on electricity production, water usage and crop yields. Using land for agriculture and energy production may prove beneficial to local communities.

Dutch companies with innovative solar technologies will find several business opportunities in Mexico, especially in the applications mentioned above.

CHAPTER 2 | HIGHLIGHTS

OPPORTUNITIES

FAVORABLE CONDITIONS TO PRODUCE SOLAR ENERGY

90% of Mexico's territories are located under the solar irradiation belt of the planet providing up to 8 kWh/m^2.

SOLAR FLOATING PV

Mexico has not seen projects in Solar Floating PV. This can present a business opportunity in the Gulf of Mexico area.

BUILDING-INTEGRATED PV PANELS

Mexico's largest cities show potential for integrated PV panels the due to high electricity tariffs, and ongoing construction of new buildings and houses.

SOLAR CARPORTS

The opportunity lies with the use of more efficient solar panels to produce more electricity per m^2.

SOLAR PV-T SYSTEMS

This technology is not present in Mexico, although there is demand from industrial and residential sectors.

AGRO PHOTOVOLTAIC

Using land for agriculture and energy production may prove beneficial to local communities.

CHALLENGES

UNCERTAINTY CAUSED BY CURRENT GOVERNMENT POLICY

Mexico's current energy policy has its focus on fossil fuels.

PRICE

Average price per watt currently stands at US$0.30/W, forming a barrier to entry.

Chapter 3

3. WIND POTENTIAL IN MEXICO

Mexico is positioned favorable for producing wind energy. Oaxaca, Yucatan, and Tamaulipas have registered wind speed above 8 m/s. Oaxaca's wind speeds, averaging 8.5 m/s at 50 meters altitude, are Mexico's highest and are competitive compared to other areas on the American continent. (SENER, 2018)

Wind energy has seen an annual average growth rate of 86% since 2004. 6.8% of the electricity produced in Mexico in 2019 came from wind energy technologies (SENER, 2019). The energy reform of 2013 cleared the path for this renewable energy technology, as the distribution network was only accessible for a few multinational companies in Mexico under the self-supply scheme, making the installation of wind farms risky.

In the current open market companies are able to sign PPAs in bilateral contract schemes, reducing the risk and getting better electricity prices. Subsequently, the number of wind farms has grown exponentially. (Energía a Debate, 2019)

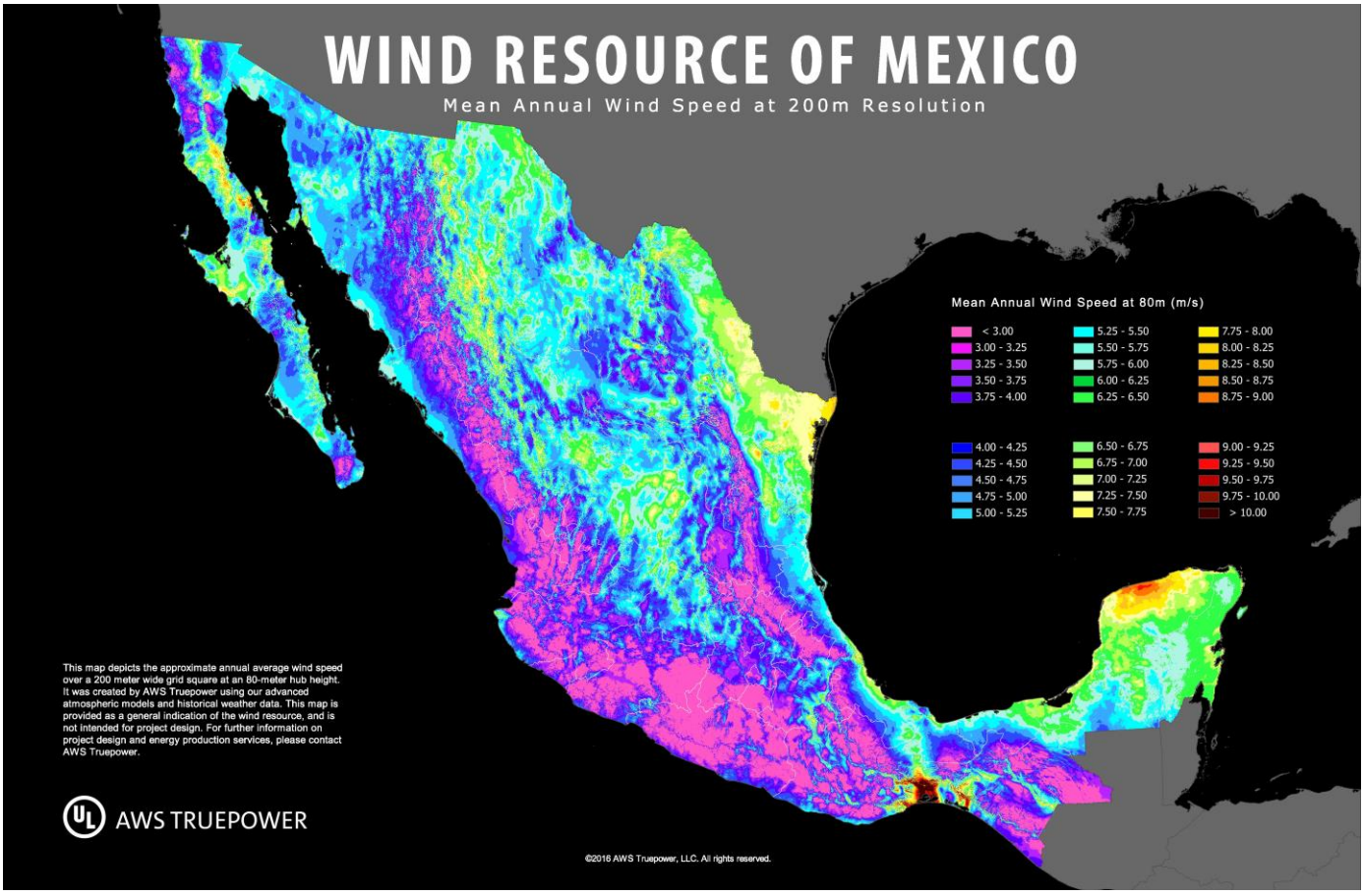


Figure 17: Mexico's average wind speeds (AWS Truepower)

In Mexico the State of Oaxaca possess the best potential for wind energy production, followed by the Yucatan and Baja California Peninsulas. In Oaxaca State facilities for testing

wind turbines are available and high-speed occur almost year-round. Another attractive place for the installation of wind technologies is along the coast of the Gulf of Mexico, where wind speeds average of 5 m/s. Figure 17 shows Mexico's average wind speeds.

In the period 2013-2019 investments in renewable energy in Mexico totaled US$ 8.6 billion, of which US$3 billion, representing 2,121 MW of installed capacity, was funneled to wind energy. (SENER, 2018)

It is expected that by 2021, 3,930 MW of installed capacity will be added to the existing infrastructure, which is 94% more than the installed capacity at the beginning of 2018. The added installed capacity flows from 21 projects (Wilson Center, 2018):

- 5 projects of the first auction (394 MW)
- 10 projects of the second auction (1.038 MW)
- 6 projects of the third auction (689 MW)

The wind park "Reynosa I" located in Tamaulipas is currently the biggest wind park in Latin America. With 123 wind turbines and an installed capacity of 424 MW, the wind park provides electricity for a million people in the North part of Mexico. The wind park had a cost of US$600 million (Mexico News Daily, 2018).

3.1 ONSHORE WIND IN MEXICO

Mexico has an estimated 30 GW of wind potential. Some years ago, the only region attractive for wind generation investment was the Isthmus of Tehuantepec region, located in the state of Oaxaca. In 2019 Isthmus Tehuantepec had an installed capacity of 4.7GW (SENER, 2018).

The wind energy sector in Mexico started in 1994 with the installation of the first wind turbine in Oaxaca. Today, wind projects can be found in 11 states, of which Tamaulipas (1.2GW) is the fastest grower, followed by Coahuila, Yucatan, Puebla and Nuevo León, with each over 950MW of installed capacity and more than 2.5GW under construction (SENER, 2019).

According to SENER there are 73 wind projects in Mexico, of which 41 operational and 32 under construction, as shown in Figure 18. (SENER, 2019)

Among the main drivers of wind energy success in Mexico are technological innovations that drive down production costs, novel turbine models that can leverage different wind profiles, and the start of manufacturing of turbines and wind blades in Mexico.

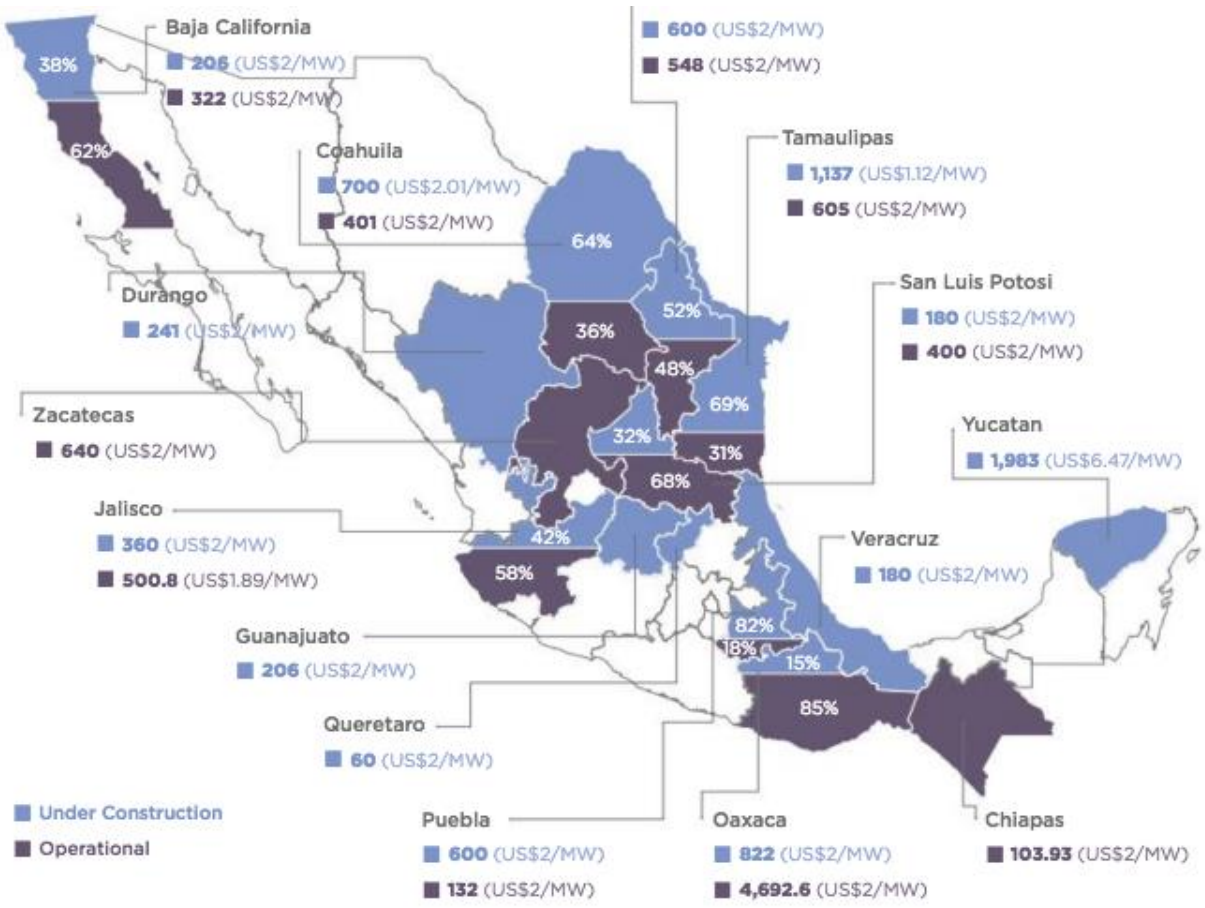


Figure 18. Wind Parks in Mexico. Source: Mexico Business Publishing

In 2019 Vestas and ACCIONA started manufacturing wind blades in the state of Tamaulipas, making wind blades accessible and affordable for the Mexican market. Figure 19 shows an overview of the main wind power players in Mexico.

Main wind power players in Mexico			
#	Company	#	Company
1	ACCIONA Energía	11	GEMEX Energía Renovable
2	Enel Green Power	12	ENGIE
3	EDF Renewable Energy	13	Grupo ACS Grupo Dragón
4	Iberdrola Renewables	14	CFE
5	Naturgy	15	Industrias Peñoles
6	Renovalia Reserve	16	Grupo México
7	EDP Renováveis	17	Zuma Energía
8	Siemens GAMESA	18	COMEXHIDRO
9	Mexico Power Group	19	CIC, POR Green Power
10	IEnova, InterGen		

Figure 19. Source: Mexico Energy Review 2019

The whole pipeline (installed and under construction) of onshore wind energy projects in Mexico is large/utility scale.

Although there is no Mexican company that produces entire wind turbines, there are 112 companies participating across the chain value, adding value to the existing local market (IMP, SENER, 2017). Figure 20 shows how the Mexican wind sector is segmented.

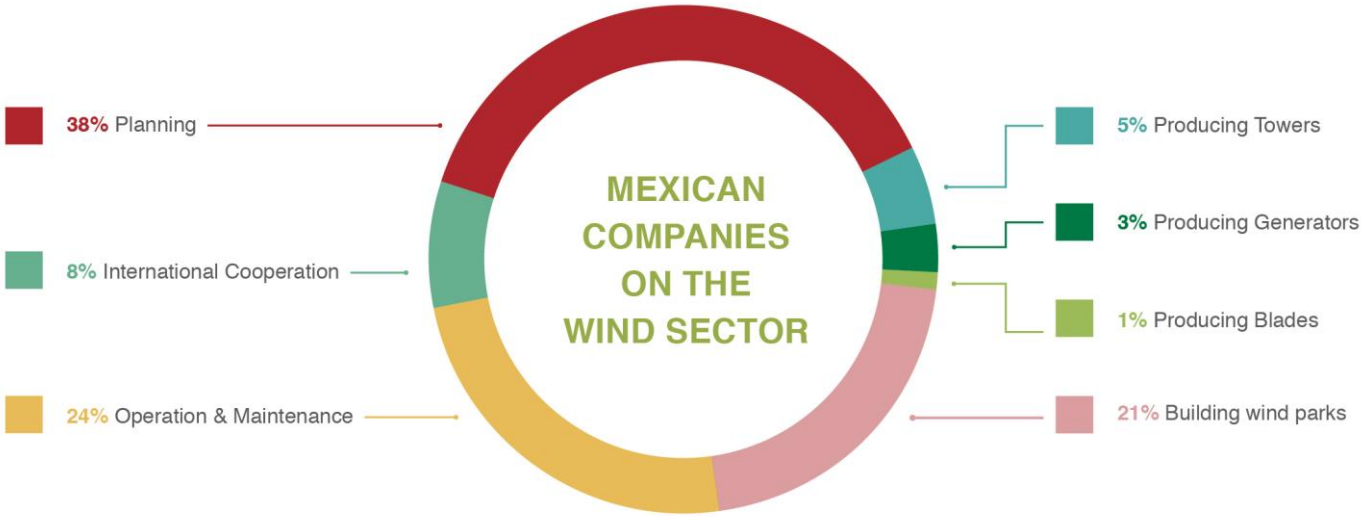


Figure 20. Source: IMP 2017

Currently there are not enough companies to cover the demands of operation and maintenance services for the national and international companies that build wind parks in Mexico. International companies active in Mexico's wind energy sector include Abengoa, Acciona, Alstom, EDF, EDPR, Enel Green Power, Engie, Gamesa, Gas Natural Fenosa, and Iberdrola (IMP, SENER, 2017).

The Mexican Wind Energy Association (AMDEE) to date has 70 members, of which 10 are involved in manufacturing, 29 service providers, and 31 developers.

3.2 OFFSHORE WIND IN MEXICO

Offshore wind has emerged as one of the most promising technologies for producing renewable energy. During 2018 4.3 GW of installed capacity in offshore wind was added around the world, resulting in a total capacity of 23GW at the end of 2018. (Offshore Wind Outlook 2019, IEA, Special Report)

Europe is leader in offshore wind technologies, accounting for 80 percent of the global market. The North Sea is one of the areas witnessing the expansion in use of this technology,

with 2.7 GW installed in 2018. The United Kingdom, Belgium, The Netherlands, Germany, Denmark and China are the leading countries in offshore wind (Offshore Wind Outlook 2019, IEA, Special Report).

One of the main barriers for this technology is the high upfront capital cost. A 250 MW project costs approximately US$1billion. In comparison, Mexico's 424 MW onshore wind park Reynosa I had a cost of US$600 million. (Offshore Wind Outlook 2019, IEA, Special Report)

Although Mexico has potential for installing offshore wind parks, it is not expected to take-off in the near future. The onshore wind potential of Mexico, in combination with high installation costs caused by the lack of port infrastructure, logistics and manufacturing possibilities, form a barrier to entry for offshore wind in Mexico.

The policy of Mexico's current administration regarding renewables could form another barrier to entry. Contracts for offshore oil and gas infrastructure in the Gulf of Mexico would compete with offshore wind permits, placing renewable energy projects in disadvantage.

3.3 DISTRIBUTED GENERATION

Thus far Mexico's wind sector has had its focus on the construction of wind parks and the installation of big wind turbines. However, small wind turbine technology could play an important role in the distributed generation sector. In 2019 only 19 contracts (0.02%) of a total the 112,660 were related with wind technologies (Estadisticas Generacion Distribuida, Julio 2019, CRE)

By law, distributed generation is limited to 500 kW of installed capacity. Advantages to participate in this sector are the limited number of restrictions and permits needed, in combination with the existence of a significant number of clients in the market. (Petroquimex, 2019)

To map wind resources in Mexico suitable for distributed generation, a 10m-wind resource overview is shown in Figure 21.

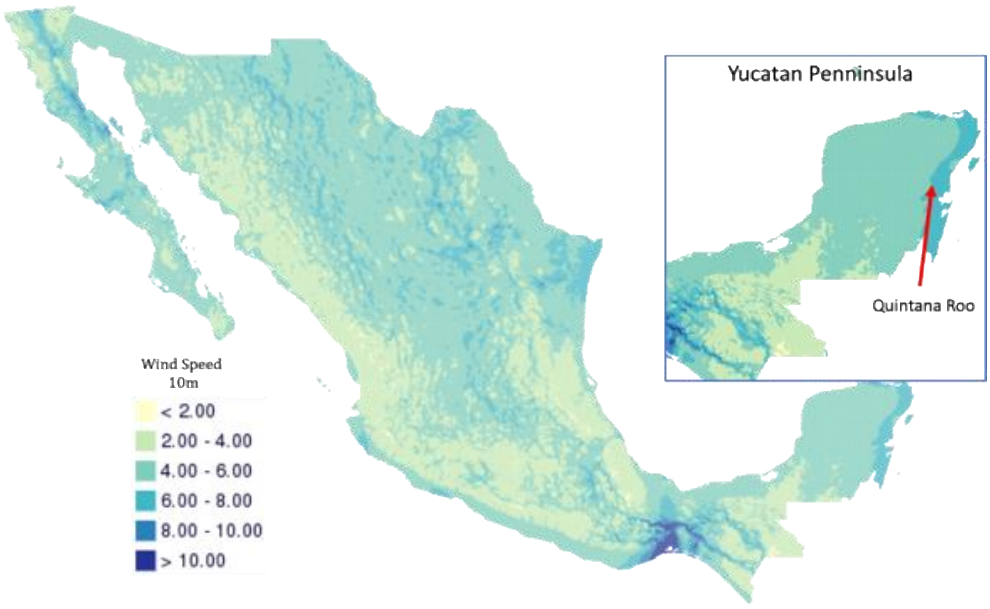


Figure 11.Wind Resource Overview Mexico. Source: (NREL Transforming Energy, s.f.)

Mexico has a coastline of 11,122 km, with approximately 19 million people living in this coastal area, out of a total of 2,458 municipalities in the country, 151 are located on the coast. Mexico is famous for its touristic infrastructure, particularly the coastal cities such as Cancun, Los Cabos, Puerto Vallarta, Acapulco, among others. The tourism industry demands a significant amount of energy, in order to offer comfortable conditions for the tourist.

Electricity tariffs in the Yucatan Peninsula are the highest in the country due to the lack of generation plants in the region, in addition the area is experiencing problems with its electricity supply. On its turn, The Baja California Peninsula is an isolated grid, meaning renewables as small wind technologies can play a different role than in the national grid (SIN).

In some cases, small wind turbines can be more competitive than solar technologies. In certain parts of Mexico wind-speeds are nearly constant, providing for consistent energy production in comparison with solar installations, that typically have 6 hours of production from peak hours.

3.4 EXPERT OPINION

Interviews with two Mexico experts were conducted in order to get an inside perspective on the current market and future of wind energy in Mexico. The interviewees were:

- Pamela Avila, Business Developer of AES Mexico
- Joaquin Pereyra, CEO of VerdeGris

An interview conducted by a third party was used as a source to complete this expert feedback section. This interview was conducted with Leopoldo Rodriguez, President of Mexican Association of Wind Energy (AMDEE) and retrieved from: Leopoldo Rodriguez (2020) 'Clear Rules Needed to Strengthen Mexican Wind Power'. Interviewed by Mirjam Schipper, Mexico Energy Review. Their collective answers are presented below. The remainder of the interview can be found in appendix IV.

Q: What was the impact of the energy reform on Mexico's wind sector industry?

The energy reform was beneficial for the Mexican wind sector, that has seen a rapid growth of wind parks. Mexico has more than 6,000 MW of installed capacity from wind technologies.

During the auctions Mexico was confronted with low electricity prices which created a cost-competitive market. This has led to Mexico participating in the wind sector. Certain blades and towers are built in Mexico as a result of which the costs of this technology are reduced. The energy reform has opened the door for international companies to participate in the energy sector This has brought knowledge to Mexico and helped to facilitate a technology transfer.

Q: What can we expect in the coming years for big-scale wind parks?

Mexico holds significant wind resources. The first resources that come to mind are the high-speed resources in certain states. It is expected that in the coming years new technologies also will be able to harvest the potential of areas with less wind. To achieve this Mexico will need to improve the distribution and transmission infrastructure that at the moment form a bottleneck for industrial growth. Furthermore, Mexico has to provide certainty about the future of renewables to investors and developers and should show a desire to let the market grow.

A possible area of opportunity are offshore wind parks in the Gulf of Mexico, where offshore wind could provide in the current energy demand.

Q: What can we expect for small-scale wind technologies in the coming years?

In the distributed generation sector, we will see small-scale wind parks or isolated installations. The advantage of some new wind turbines is the vertical axis technology, which makes less noise, does not harm local fauna and can be adopted in esthetically pleasing ways. These advantages can increase the participation of wind technologies in the distributed energy sector.

With its wind resources in coastal areas Mexico has a lot of opportunities for wind technologies in distributed energy. In regions along the cost wind technologies can provide more stability to the grid and deliver electricity to remote areas.

The hybrid of small-scale wind turbines and solar panels could form a fitting solution for the distributed generation sector on the Yucatan Peninsula and in Baja California Sur. Both regions have a lot of wind in combination with a high demand for electricity and energy because of the tourism industry. With current prices in these areas distributed generation has the potential to become competitive.

Q: What is your advice to Dutch companies that want to enter the Mexican energy sector?

here are many business opportunities for wind technologies. But the local market can be complex which could complicate making the technologies cost competitive. Dutch companies are advised to contact their embassy Mexico or organizations that can identify the business niches. It is highly recommended to search for local partners with whom enter the Mexican market together.

Interview with Tjerk Suurenbroek, Business Development Manager at The Association of Dutch Suppliers in the Offshore Energy Industry (IRO) and Daniëlle Veldman, CRM Manager at Netherlands Wind Energy Association (NWEA), both representing the Dutch wind energy sector.

Q: What are the strengths of the Dutch wind service industry?

The strength of the Dutch industry is in offshore transport and installation. Dutch companies have a solid track record in the oil and gas and maritime sector and are now using their expertise and large installation vessels to enter the wind energy industry. This expertise is almost unique in the world. The Dutch wind service industry has control over 80 to 90 percent of whole value chain. From engineering, hydrographic research and consultancy, to building foundations, manufacturing transition pieces, installation, operating, and performing maintenance. The only part of the value chain the Dutch industry does not have control over is the fabrication of the turbines. However, we do not have real developers, like the Danes, who have one or two developers.

In the onshore area, the Dutch onshore wind sector industry is not as united as the offshore sector. There are a few knowledgeable companies active in blade design and composites that are active worldwide. However, many Dutch companies active in onshore wind do not have a strong competitive proposition for international markets. To be competitive internationally, it is important to be an absolute specialist in certain areas. Many countries have the capability to do onshore construction and installation with local companies.

Q: What are some of the innovations created by companies you represent?

There is a continuous stream of innovation in offshore wind energy. Many are innovations in the installation and connection processes, such as the use of slip joints to connect transition pieces to foundations without the use of bolts. Many of these new methods reduce the damage of installation on the ecosystem. Dutch companies have come with new ideas on how to use the environment of offshore wind farms for potential aquaculture, such as growing oysters and seaweed. Other developments are focused on using these structures to generate tidal and wave energy. Another example of innovation is the use of drones for inspection. The majority of these innovations are focused on offshore, where there is a greater demand for innovations as the cost for offshore construction is higher and machines and foundations continue to get bigger.

Q: What possibilities do you see abroad for the Dutch wind service industry?

The Dutch wind service industry is already active abroad. Energy transition is a hot topic around the world. Many countries are searching for new possibilities for their energy supply. A lot of them have good conditions for offshore wind energy. At the moment the focus is on approximately 12 countries that have good weather conditions and are already developing offshore wind in their national energy policy, and where are at the same time is imminent tendering and a potentially large number of gigawatts to be installed. On the other hand the focus is on countries that are in an earlier phase of developing a national energy policy and could need help in doing so. The main areas of focus are Asia, the Baltic area and the North Sea, which is currently the forefront of development. Other areas are in France, Poland and at the east coast of the US. Brazil is also upcoming.

In terms of onshore wind power, Mexico already has a significant amount of energy production. This is understandable as the country has a vast amount of suitable space and onshore wind is cheaper to build. Opportunities for Dutch companies are hard to determine as clear competitive edge is missing.

Offshore wind is a less obvious destination for the Dutch service industry as it is still difficult to determine if Mexico will focus on offshore wind. The expectation is that Mexico will focus on onshore wind, solar power and oil and gas for the foreseeable future. Offshore wind would be part of a longer-term trajectory for the country, where it could be built locally for harbors to provide energy supply in shallow waters. An obstacle here is the cost of implementation. Therefore, in the short term it is expected that the Dutch service industry will focus on a small group of countries with a lot of potential rather than exploring new markets with a doubtful outcome.

Q: What is your perspective on the future of wind energy in the Netherlands?

The expectation is that a great deal of extra offshore capacity will be build in the Netherlands. An important aspect to take into consideration is that as installation costs drop, government support and incentives to the sector do not stop. If the industry ceases to be profitable, investors will move to countries with stronger subsidies. The government therefore has a responsibility to make it easier to invest and stay in the offshore industry and make it possible to earn a solid margin.

Another important element is that of knowledge sharing. Countries should be cooperating on topics. I think wind energy will be booming, even though there are still many issues to be resolved. Sharing knowledge is very important. It is a shame that many countries are creating their own energy plans in isolation, even though we could be working together on topics such as bankability and innovation. We should be cooperating on a global stage and share the knowledge on how to implement the system. Recently, the International Renewable Energy Association (IRENA), released a report which predicted that by 2050, annual global investment in offshore wind energy would be US$90 billion. If the Netherlands were to, for example, take 10 percent of the market share, it would contribute US$9 billion to our GDP. This is almost 1 percent of our current GDP. It all depends on the strategies we choose to pursue. Our approach is to be visible, to unite the Dutch supply chain, and to cooperate.

3.5 BUSINESS OPPORTUNITIES

As a result of the energy reform and because of the wind resources, the installations of wind technologies in Mexico have grown with an impressive annual rate of 86%.

The business opportunities of the wind energy sector can be identified in two main categories:

- Service companies for the already installed turbines.
- Small wind turbine technologies for the distributed generation sector.

The first business opportunity is related with services for the 41 wind parks that are operating in Mexico at the moment, and the 32 parks that are under construction. Maintenance services and spare parts for wind turbines are in important opportunity. Many of the services and spare parts are now contracted in the US and Europe, stopping the production of electricity for days.

The best business opportunity in the Mexican wind sector is related with the distributed generation sector. The wind resources that Mexico has along the coast and in some regions

of the country offer a unique opportunity for efficient technologies that can compete with solar technologies.

These opportunities are related with niches as the tourism industry, industrial parks, and big Mexican cities.

The tourism industry is related with hotels located onshore of the main tourist destination as Cancun, Riviera Maya, Cozumel, Los Cabos, Puerto Vallarta, Acapulco and some others. The high electricity tariffs, some locations out of the grid and the huge energy demand that the hotels have, made this niche one of the most attractive BO for small and efficient wind turbines.

Industrial parks are another attractive business opportunity due to the fact that they are often located in remote areas. This results in a significantly higher electricity cost. On top of this sometimes there is no electricity available. Small wind technology applications could be the solution for these parks.

Another possible niche is that of installing wind turbines in cities. The number of tall buildings has been increasing significantly and skyscrapers for residential purposes are a trend in many of Mexico's cities. In cities as Mexico City, Guadalajara and Monterrey in many cases there is not enough space to install solar panels to meet the energy demand for these buildings. Wind turbines could form the solution in these cases.

CHAPTER 3 | HIGHLIGHTS

OPPORTUNITIES

DISTRIBUTED GENERATION

In niches as tourism industry, industrial parks, and big Mexican cities.

TURBINE MAINTENANCE SERVICES

Maintenance services and spare parts for Mexico's existing 32 wind parks.

COMPETITIVE WIND SPEEDS

Mexico has regions with wind speeds above 8 m/s.

ONSHORE WIND POTENTIAL

Mexico has an estimated 30 GW of wind potential.

CHALLENGES

GOVERNMENT POLICY TOWARDS OFFSHORE WIND

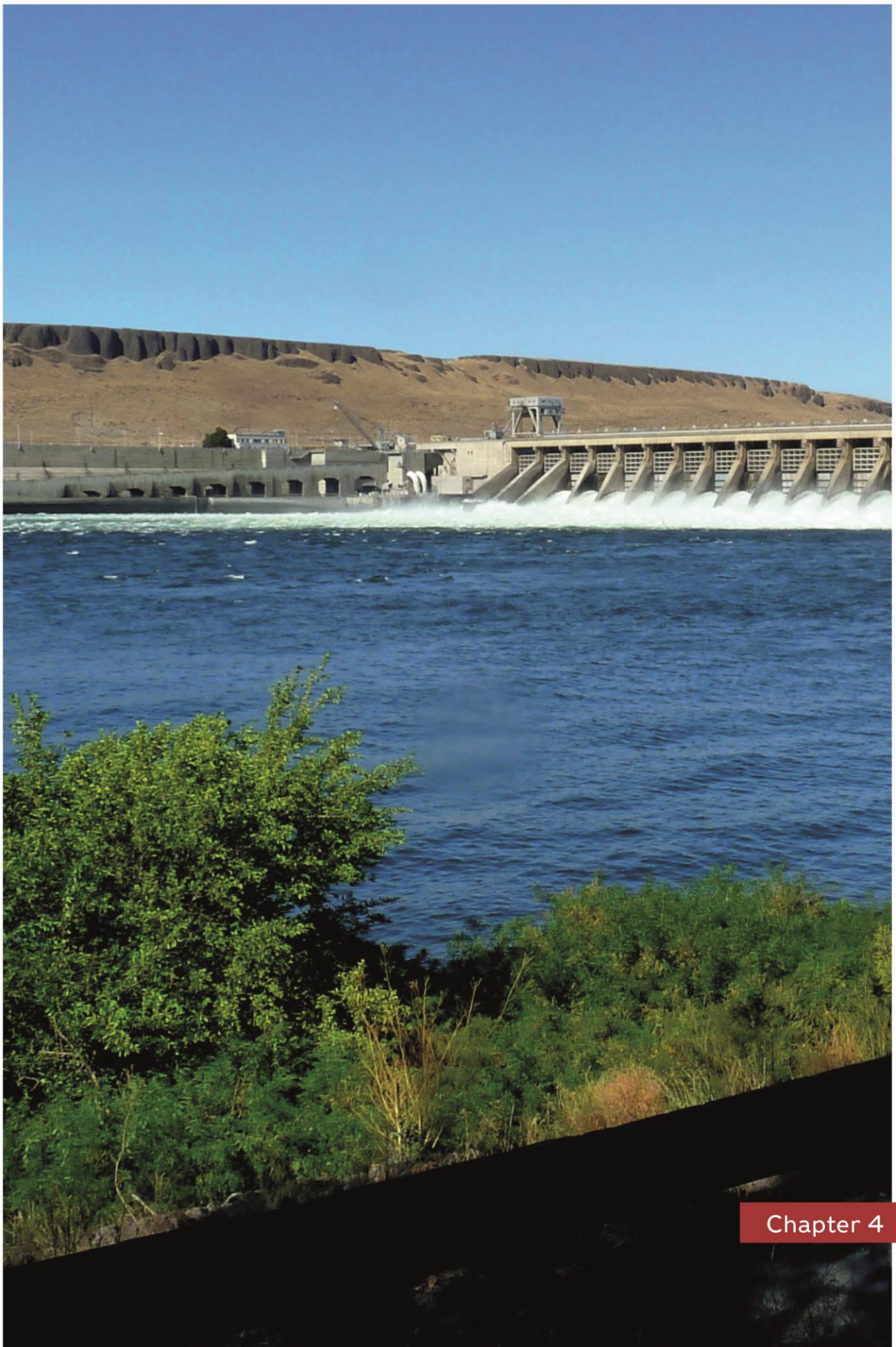
Offshore oil and gas infrastructure favored over offshore wind permits.

BARRIER TO ENTRY FOR OFFSHORE WIND

There is a lack of port infrastructure, logistics and manufacturing possibilities in Mexico.

ONSHORE WIND

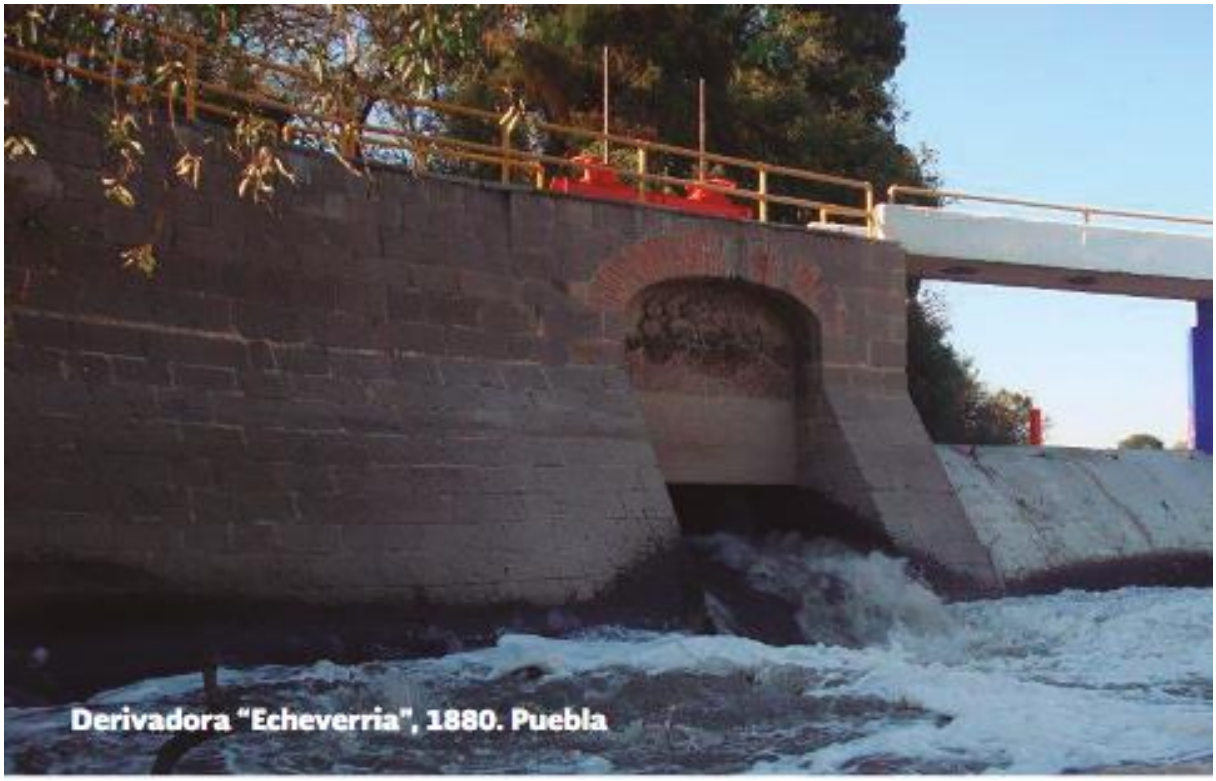
Dutch service industry appears to lack competitive advantage in Mexico's onshore wind sector.



Chapter 4

4. HYDRO ENERGY

Mexico has a significant amount of resources namely the rivers, lakes and inland waters and the coast and sea waters. Also, Mexico has a long history regarding the use of its hydric resources to produce electricity, exemplified by the Derivadora Echeverría dam that was built in 1880 with an installed capacity of 2.8MW (IMTA, 2017).



4.1 HYDROPOWER IN MEXICO

Hydropower is the leading technology for producing 'clean' energy in Mexico. In 2018, 18% of the installed capacity to produce electricity was derived from hydroelectric plants (12,609.54 MW). (SENER, 2019). It is expected that for the year 2032, Mexico will increase its installed capacity in hydropower by adding 2,032 MW with 47 projects in the pipeline industry. This means an increase of 3% of the installed capacity. The participation of hydro energy will decrease to 11% of the total installed capacity of the country. This reduction is caused by the significant grow from the other renewable technologies such as solar and wind. (PRODESEN 2018-2032)

4.1.1 CURRENT DAMS & FUTURE PLANS

Mexico has 101 hydroelectric plants with an installed capacity of 12,609.54 MW. The majority of the infrastructure belongs to CFE, but there are some dams that belong to the private sector (IMTA, 2017).

Of the 101 hydropower plants, 54 have been functioning for more than 50 years, making these plants eligible for updates and improvements. The advantage of updating hydropower plants is the limited investment required to increase installed capacity (IMTA, 2017).

Mexico's government has identified 362 hydraulic infrastructures that have the potential to be updated to produce 484.41MW of additional electricity.
The current infrastructure was built with other purposes, but with the similar idea of boosting the renewable energy production while saving money. CFE has considered to take the next steps. It is important to mention that there is not any official step taken so far, but the potential is already identified. (IMTA, 2017)

4.1.2 ENVIRONMENTAL AND SOCIAL BARRIERS

The construction of dams faces environmental and social barriers. Local communities oftentimes are unwilling to sacrifice land or relocate for the construction of a new dam. The environmental impact, as for instance deforestation and fauna being pushed out of certain zones, has been severely criticized by many NGOs.

Small scale hydropower represented 1% (710.8 MW) of installed capacity in 2016. Mexico has the potential to expand small-scale production to the rivers of the Pacific rim and to the states of Veracruz, Oaxaca and Chiapas. By using technologies as "run of the river" or mini dams, the social and environmental barriers can be minimized (Wilson Center, 2018).

A very important aspect to consider for both small- and large-scale hydropower is the changing rainfall pattern due to climate change. These changes in the supply of water to the system can jeopardize future hydro energy infrastructures.

The Mexican Institute of Water Technology (IMTA), an institute that focuses on water technologies, identified 21 opportunities for new solutions in hydropower. On top of that, IMTA offers three clever solutions using existing infrastructure. These solutions are the following: (IMTA, 2018)

Energy Storage: By pumping water back to dams using renewable energy, dams can be used as an energy storage facility. This solution can take an important role in balancing the grid, or function as a backup in the case of natural disasters as earthquakes.

Solar-Hydro option 1: IMTA experts identified 1,600 dam curtains where solar panels can be installed, adding 1700MW of installed capacity. The connections to the grid are already in place at the hydropower plant, reducing the investment needed to install solar panels.

Solar-Hydro option 2: IMTA identified 180 dams with sufficient capacity to install floating solar systems. It is forecasted that this floating solar can add 18,422 MW of install capacity to the systems. Recent floating solar technologies and the use of efficient bifacial solar panels could prove to be a niche (IMTA, 2018).

4.2 OCEAN TECHNOLOGIES

Ocean energy technologies hold potential for renewable energy production. Currently Mexico has marine pilot projects for power generation ranging from 10 kW to 1MW, which, however, have significant development costs (IEA, 2019). To date, there is no leading technology and economies of scale have not occurred either. However, there is no doubt that these technologies will play an important role in the future.

With the energy reform of 2013, multidisciplinary groups formed by knowledge institutions, government institutions and private sector (CEMIEs) were formed to analyze the potential for each type of technology (solar, wing, geothermal, bio, ocean) and create a roadmap to develop the national industry and capacities needed for each type of technology.

Mexico has 3,149,920 km2 of exclusive economic zone in seawaters and 11,122 km of coastlines. Various studies have been made to forecast potential locations and the types of technology that are suitable in the different regions of the country.

The Mexican Centre for Innovation in Ocean Energy (CEMIE-Oceáno) has as objective to research the potential that Mexico has for each of the different ocean energy technologies and install pilot projects to start the development of this energy niche (IMTA, 2018).

By 2030, Mexico's goal is to have an installed capacity between 500 - 1,000 MW, stemming from different pilot projects. This goal was set by the previous administration. (SENER, 2017)

4.2.1 WAVES

Wave technology can be a competitive technology as it has the potential to compete with fossil fuels and renewable technologies. The availability and potential of this type of resource is very attractive for the entire world. A study by MDPI demonstrates proof that the Pacific Coast, the Riviera Maya, and the coast in Baja California are suitable areas for this technology. Figure 22 depicts the Pacific Coast has the potential to produce 2-5kW/m, for 80 to 100 % of the time. To produce 10kW/m, the electricity production time drops to 70 %.

These results are promising for small wave technologies that could supply energy to the Pacific Coast, where tourist cities with high-energy demand, such as Puerto Vallarta, Los Cabos and Acapulco are located.

Figure 22 shows the results of wave power potential in Mexico, expressed in percentages for the ten-year period (2008-2018).

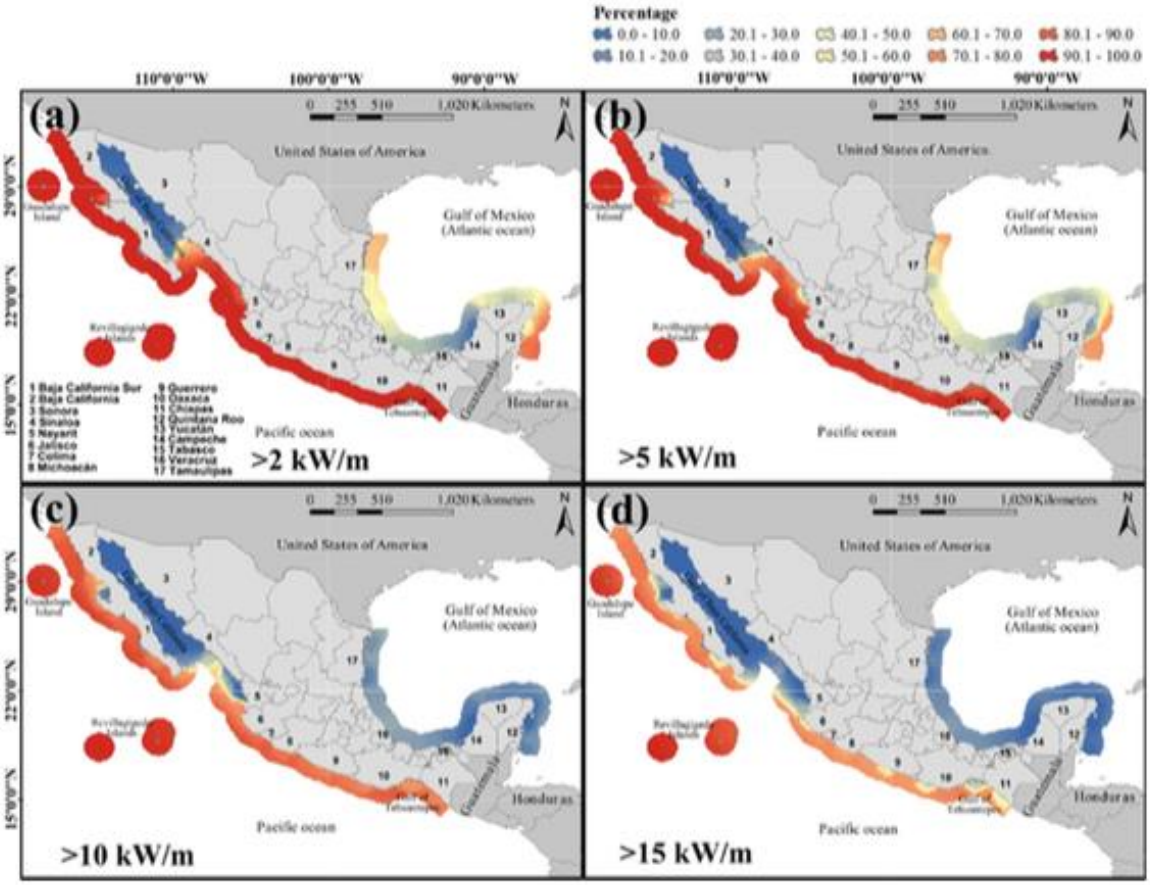


Figure 22. Wave Power Potential Mexico Source: Potential Pacific Coast

4.2.2 OCEAN CURRENTS

Ocean currents are continuous flows that have a specific and predictable direction. In this analysis a cut in velocity of 0.4m/s was considered. As can be seen in Figure 23 only the Riviera Maya coast in Quintana Roo is suitable for this type of technology. Specifically, the corridor between the Island of Cozumel and the Riviera Maya coast is the most attractive location for this technology. In this region energy can be produced 80 to 100 percent of the time.

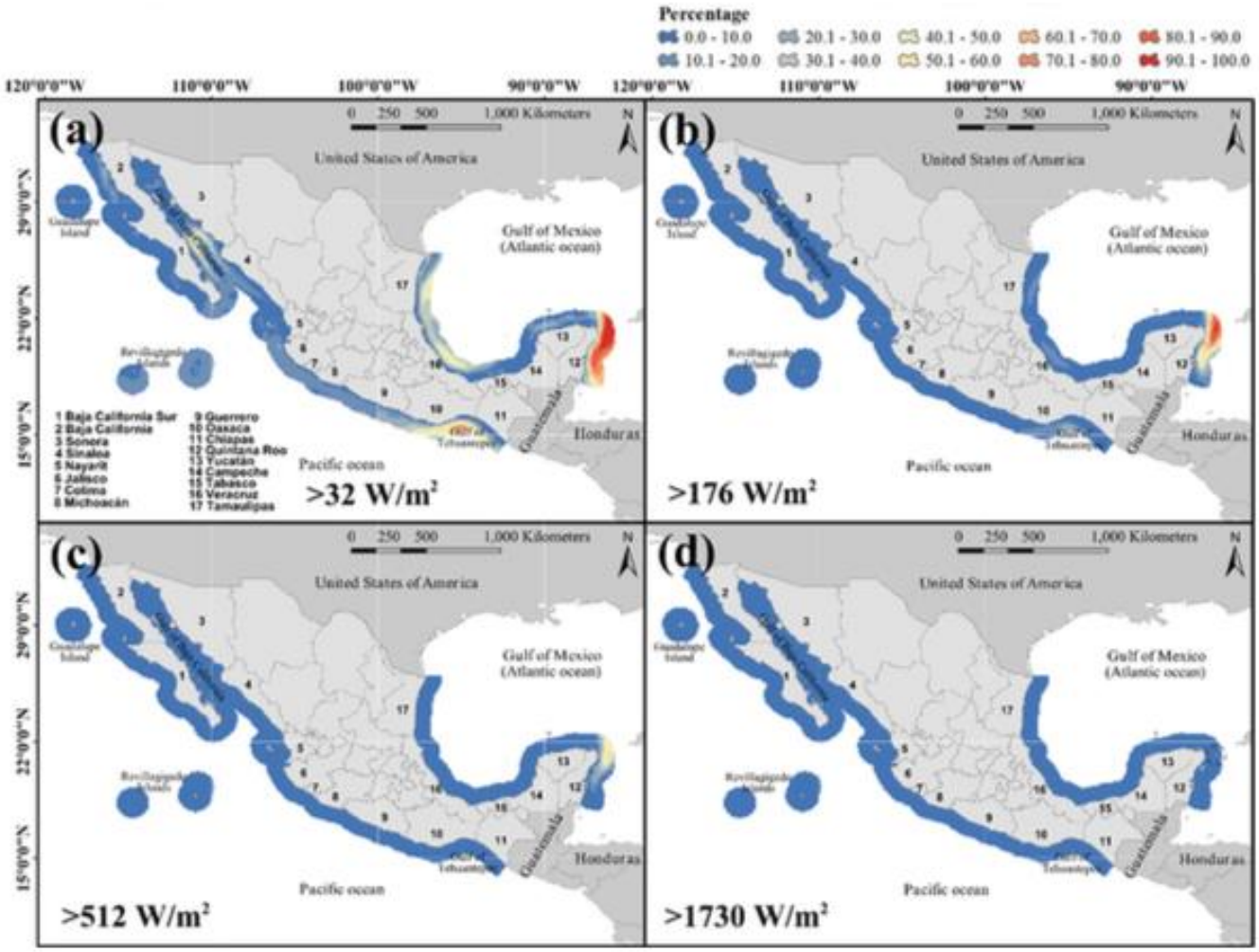


Figure 23 Theoretical ocean currents power availability in Mexico, considering five-year data. Source: (jassiel V. Hernández-Fontes, 2019)

4.2.3 THERMAL GRADIENTS

This energy is generated from the heat interchange between fluids at different temperatures. For this analysis the data that was taken into consideration is 1,000 m depth and a distance to the shore of less than 100km. The most suitable regions for this type of technology are along the Pacific coast, the Caribbean Rivera Maya and along the Gulf of Mexico. Figure 24 shows the theoretical thermal gradient power availability in Mexico for a five-year period (2013-2018).

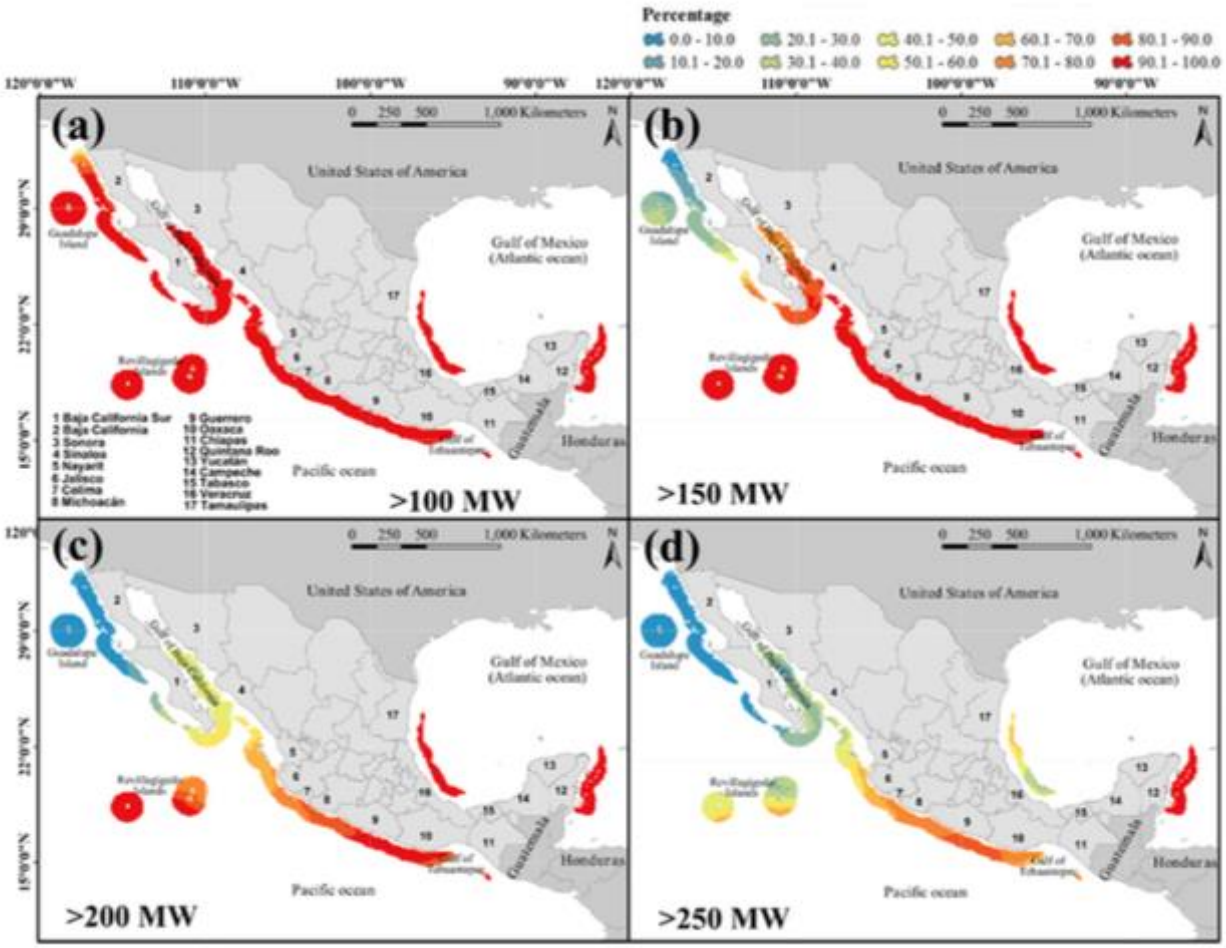


Figure 24 Theoretical thermal gradient power availability in Mexico. Source: (Jassiel V. Hernández-Fontes, 2019)

4.2.4 SALINITY GRADIENTS

This energy is produced by the interaction of a flow with low salinity concentration, such as rivers, with a fluid with higher salinity concentration, such as seawater. For this technology, there is a leading zone which is the river Usumacinta with a potential power generation of approximately 4.1 GW, while the other locations are under this GW threshold. The river mouths with potential are in the Gulf of Mexico, Tamaulipas (+- 232.7 MW), Veracruz, (+-

04.9 MW, +-169.7 MW) and Tabasco (+-126.1 MW) (Jassiel V. Hernandez-Fontes, 2019). Figure 15 shows the annual averaged power from the 29 studied river locations in Mexico.

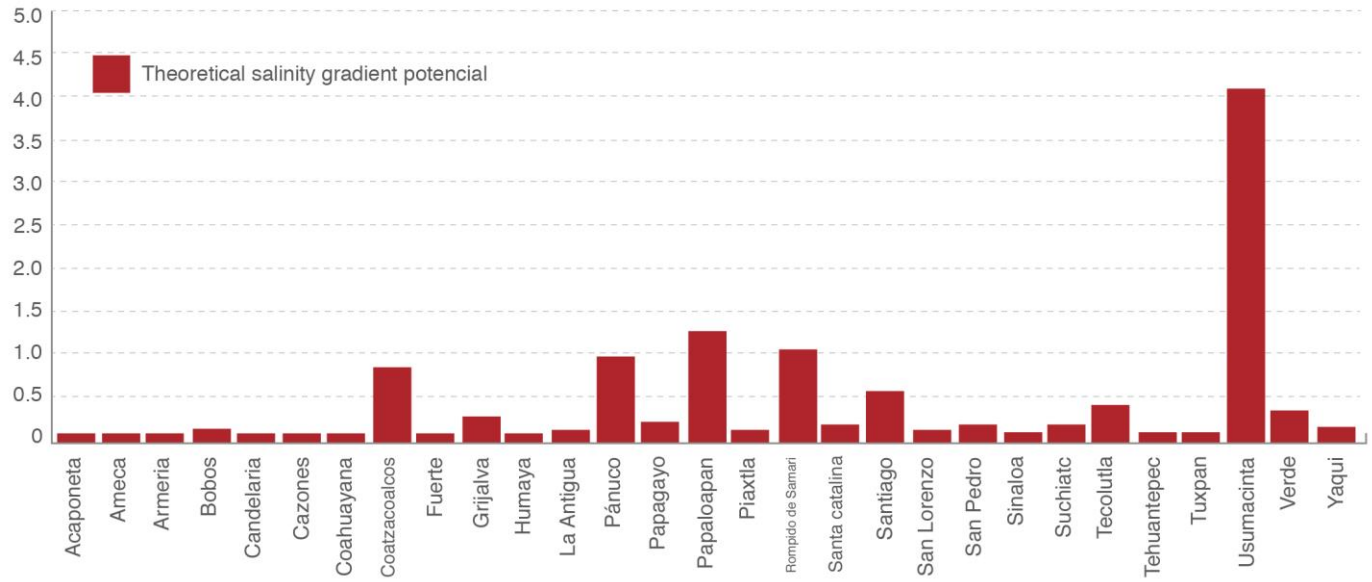


Figure 25 Annual Averaged Power Studied From 29 River Locations in Mexico. Source: (Jassiel V. Hernández-Fontes, 2019))

As the river studies only measure theoretical potential, a deeper analysis is required to match technologies to suitable locations.

A planned project in Mexico is that of Eco Wave Power in Manzanillo. The project, with an installed capacity of 4.8MW, is expected to be launched in the coming years and will be the largest of its kind in Mexico and Latin America (TETHYS, s.f.). For all future projects it will be very important to consider the environmental, social and legal consequences as well as the effects of the installation of these type of technologies for the coastal cities.

4.3 EXPERT OPINION

Mexican hydro energy expert Eduardo Ortegon, CEO of Flow, answers four questions about the future of the Mexican hydro sector and the continuity of the energy reform.

Q: What was the impact of the energy reform on Mexico's hydro energy sector industry?

The energy reform proved to be an opportunity for small companies and investors to participate in the energy sector. The partipation in the hydro industry is mainly found in the distributed generation sector.

Q: What are the opportunities in the hydro energy sector in Mexico?

The hydro sector offers potential in the small-scale sector. In the north and south of Mexico there are natural hydro resources with significant height differences. Distributed generation is the solution to harvest this potential.

There are also chances in terms of energy storage. Mexico's current infrastructure consists of dams and mini dams that have the potential to be used as energy storage. It makes sense to use the existing CFE-infrastructure for energy production and energy storage at peak hours because sometimes it does not operate at full capacity. With this same logic mini-dams and other hydraulic infrastructures can be used as energy storage systems.

Q: What can we expect from the ocean technologies sector in the coming years?

There are important business cases for using ocean technologies. Mexico's highest electricity tariffs are found in areas near the shore. For example, in the south of Baja California, where electricity is currently produced using diesel, and in Yucatan. The use of this technology is not common in Mexico but definitively presents an important business case.

Q: What is your recommendation to Dutch companies that want to enter the Mexican energy sector?

It is recommended to look for a local partner. A Dutch company can benefit from the lessons learned previously by the local partner. To open doors in Mexico, it is very important to have a network. A local partner will save time and money to enter the Mexican energy market.

4.4 BUSINESS OPPORTUNITIES

For the hydropower sector in Mexico there are two different options; on the one hand the already exploited conventional hydropower, and on the other the clear path for ocean technologies. Nevertheless, there are important business opportunities for both niches, where Dutch expertise can be a key component.

Energy Storage

The BO of energy storage is already a promising business niche. Mexico's renewable installed capacity is growing each year. On top of that, the grid balancing problems and the need to storage energy for when its needed, not when it is produced, create possibilities. The reuse of existing water infrastructures such as dams, mini-dams, or the creation of new infrastructure such as water canals, form an opportunity for energy storage solutions.

Floating solar panels

A second clear BO is the use of floating solar panels, a niche in which Dutch technologies are global forerunners. There is a potential for 18 GW of installed capacity, which in this case is likely to be contracted by CFE.

Small-scale hydropower in the distributed energy generation sector could form an important BO. Regions on the Pacific coast and states as Veracruz, Oaxaca and Chiapas show potential for the installation of technologies such as “run of the river” and mini dams.

Research and pilots

On the other hand, the BO opportunities for ocean technologies are related with business-oriented research and pilot projects for new technologies between Dutch and Mexican research institutions.

For current ocean technologies, the zone of the Caribbean is a suitable location to install pilot projects. For wave technologies, the entire coast of the Pacific offer potential for small-scale energy technologies below 15kW/m, with power production availability between 80 percent and 100 percent of the time.

For thermal and salinity gradient technologies more research is required, presenting another BO for Dutch applied research.

CHAPTER 4 | HIGHLIGHTS

OPPORTUNITIES

ENERGY STORAGE

The reuse of existing hydro infrastructure forms an opportunity for energy storage solutions.

FLOATING SOLAR PANELS

Mexico has potential for 18 GW of installed capacity in floating solar panels, which is likely to be contracted by CFE.

RESEARCH AND PILOTS

Opportunities exist for business-oriented research and pilot projects for new technologies between Dutch and Mexican research institutions.

CHALLENGES

HIGH GOVERNMENT INVOLVEMENT IN PROJECT

Contracts will need be signed with CFE, which could be a challenge.

Chapter 5

5. WASTE TO ENERGY

Mexico is a high waste producing country. Each Mexican citizen produces 1.16 Kg of waste per day, of which only 4.5% is being recycled. 87% of the waste is dumped at illegal landfills or open sky landfills and only 13% of the waste is managed in regulated landfills (INEGI).

This problem is strongly related to urban waste created by the 125 million inhabitants of Mexico. Despite government efforts, infrastructure and in many cases the economic situation of municipalities, remain the biggest challenges to overcome.

As a result of the human activity, waste is created in different forms. Waste created in urban areas mainly originates from products that citizens use in their daily life. Another important stream of waste is created in industrial zones. Although this type of waste is significantly less voluminous than urban waste, hazardous chemicals in industrial waste can cause significant harm to the environment.

The main document that frames the entire waste scenario is called the General Law for the Integral Prevention and Management of Waste (LGPGIR) according to the initials in Spanish. This law classifies the waste in three main categories: urban waste, special management waste and hazardous waste.

5.1 URBAN WASTE

The waste problem in Mexico and the high percentage of illegal landfills is primarily an urban waste problem. Given cities such as Mexico City, with a suburban area of more than 20 million inhabitants, and small isolated areas where there are less than a thousand inhabitants, the distributions, resources and infrastructure vary a lot.

As in many countries and cities, the basic action is to remove the waste beyond the boundaries of the cities. However, if there is a lack of infrastructure to support the increasing creation of waste, this will create a problem as many cities in Mexico do not have sufficient legal landfills to manage the amount of waste (Navarro, 2020).

Many actions have been proposed in recent years to tackle this problem. Among them, the reuse or recycling of many materials, higher citizenship participation and the use of waste as a source of energy as may be possible with biogas technology.

Mexico has made significant progress since the year 2000. Public-private participation made it possible for three cities to produce electricity with biogas technology. In addition, recycling in Mexico has surged over the past decade, positioning Mexico as the leader in Latin America in the recycling of some common use plastics such as PET (La Verdad, 2019).

The potential of more participation and creation of a better infrastructure for waste management in Mexico is still in a niche.

5.1.1 WASTE MANAGEMENT RESPONSIBILITY

In Mexico urban waste management is the responsibility of municipalities. However, most of the municipalities face serious economic problems and they depend entirely on the budget that the federal government grants to the state and the participation that the state grants to the municipality. At the same time, the parties responsible for waste management in municipalities change through local political cycles. It is not infrequent that the mayor's office appoints a person as a personal favor. This phenomenon hinders the appointment of a responsible authority that seeks to take serious action and complicates the ability to create a long-term effective strategy (Raphael, 2017).

With the creation of recent regulations and laws, especially the regulation NOM-161-SEMARNAT-2011, stipulating the criteria and process for a municipality to design and create their Integral Management Waste Recollection plan, private sector participation now belongs to the possibilities.

5.1.2 URBAN WASTE COMPOSITION

The Mexican urban waste mix can be divided into organic and inorganic waste. Organic waste represents approximately 52% of the total waste produced. In large cities it is common that the recollection is nearly 92% of the waste generated, whereas in rural areas recollection can be as low as 13%. Resolution of waste problems in Mexican municipalities and the possibility to use waste as a public resource can transform in an opportunity (SEMARNAT, 2012).

Figure 26. Mexican Urban Waste Composition. Source: (SEMARNAT, 2012)

5.2 SPECIAL MANAGEMENT WASTE

One of the main criteria of the Special Management Waste (RME) is to manage volume created by specific actors in municipalities. This has advantages for the reuse, recycling and proper management of the waste produced. Special Management Waste is treated in a different manner than urban waste.

Generators of Special Management Waste include malls, hospitals, clinics, warehouses, shops, restaurants, schools, factories (non-hazardous waste) and other participants that produce more volume than a common household. These need to be registered as Special Management Waste Generators on the municipality and the State level. The enrolment process itself provides parties with guidance on waste creation policies.

RME comes with a certain certification process. It is the responsibility of the company that produces the waste to manage this certification and to hire the right services for recollection and final disposal of their waste. A company that is certified by the municipality or the state must execute recollection. If the certificates do not have a final disposal, the local authorities grant fines and penalties to all the actors involved in the process.

According to LGPGIR law it is the responsibility of the municipalities and the state to have an Integral Waste Management plan, and to provide the infrastructure that is necessary for the recollection, recycling, reuse and final disposal of waste.

Annually 84 million tons of RME waste is produced nationwide. This waste is divided into 8 categories (SEDEMA):

1. Construction Waste: Waste stemming from construction materials.

2. Medical Waste: Waste derived from medical activity, related to hospitals, clinics, veterinarians, etc. Bio-infectious waste should be treated as hazardous waste.

3. Agricultural Waste: includes the waste created by fishing, poultry, livestock, forestry and agricultural activities.

4. Transportation Services Waste: Waste produced in ports, airports, train stations and bus stations, amongst others. Examples are left-over residues of oil and rags with grease.

5. Water Treatment Plants Waste: Commonly referred to as wastewater sludge.

6. Commercial Waste: Waste from stores, shopping malls and waste generated in quantities larger than standard household volumes.

7. Rocks: the waste produced on rock mining sites that will be used for construction sites.

8. Electronic Waste: all electronic devices.

A 2012 study performed by the National Institute of Ecology and Climate Change, showed that in terms of special waste, livestock produces most waste; 66.700 tons of waste. Paper and cardboard is the second-largest generator with 6,820 tons of waste.

5.3 HAZARDOUS WASTE

Hazardous waste is waste that could possibly harm public health and the environment, if not managed properly. This waste generally originates from industrial waste, where the use of chemicals is widespread. Next to this, Mexico's oil and gas industry is a large producer of hazardous waste, both on the extraction level as well as in the refining process of oil products.

CRETIB criteria

According to the Mexican Law and the regulation NOM-052-SEMARNAT, which indicates the identification and classification of industrial waste, something is considered hazardous waste if it can be related with any of the following CRETIB criteria:

Corrosiveness ***(C)***
Reactivity ***(R)***
Explosiveness ***(E)***
Toxicity ***(T)***
Inflammability ***(I)***
Biological Infectious ***(B)***

Figure 27 CRETIB criteria

The regulation based on this criterion, has produced various lists of possible products that are related with the different industries. All the definitions stated in the NOM-052-SEMARNAT allow for the verification of new products and categorizing them using this norm.

Handling hazardous waste

The General Law for the Integral Prevention and Management of Waste (LGPGIR) obligates companies that produce and handle hazardous residues, to treat these residues in a safe and environmentally friendly manner. It is the duty of Mexico's Federal Prosecutor of the Environment to enforce responsible hazardous residue management.

Regulation of hazardous waste

Hazardous waste and the registration of companies fall under national or federal authority, not under municipal or state jurisdiction. The same goes for waste producers, transportation, recollection and the final deposal.

Mexico's Ministry of Environment and Natural Resources (SEMARNAT) is responsible for designing new plans, ensures that all parties concerned comply with the law, and gives out permits and certifications for this type of waste.

A study conducted by the SEMARNAT between the years 2004-2011 revealed that 68,733 companies were registered as a producer of hazardous waste, producing 1.92 million tons over the same period (SEMARNAT, 2015).

Figure 28. Source: (SEMARNAT, 2015).

As demonstrated in Figure 28, the metallurgical industry produces the highest amount of hazardous waste. Another important finding in the study, was that 30% of this hazardous waste is located in the Mexico City area and the states surrounding it. The states with the lowest numbers of hazardous waste created are Chiapas, Tlaxcala and Baja California Sur, with a combined total produce of 0.3% of the total generation.

5.4 NATIONAL & INTERNATIONAL WASTE REGULATION

Mexico has made an effort to reduce illegal and uncontrolled landfills, by focusing on creating infrastructure for the reuse of materials, by exploiting waste residues and by increasing the appropriate final disposal of waste, on proper sites.

There are numerous international agreements on waste management. Over the past three decades, Mexico voluntarily signed the following four:

Year	Name	Objective
1992	Treaty of Basel	Control the movement of residues between borders, and use environmentally friendly practices.
2004	Treaty of Rotterdam	Enhance the international responsibility with regards to hazardous chemical substances, and protect the environment and public health from them.
2004	Treaty of Stockholm	Protect human health and the environment from persistent organic pollutants.
2006	SAICM	Minimize the risk caused by the use and production of chemical compounds for the year 2020.

The basic regulation that applies for all types of residues in Mexico can be resumed in two general laws and 20 norms. Topics include the design, maintenance, and operation for landfills, containers, and sites for handling urban waste, special management waste, and hazardous waste. Appendix V provides an overview of these rules. Most notable is the regulation for clear separation of the hazardous waste, and the municipal guides for urban waste as well as the rules for the special management of waste. Mexico's 32 states and their municipalities have norms and laws to shape their local waste management. The articles of federal law, however, are leading.

5.5 BIOGAS

There are several ways that waste can be transformed into energy. Especially, the organic components of waste present a high caloric value, which can be recovered. Usually this is done via the process anaerobic digestion, in which the organic matter is decomposed by

diminishing or subtracting the presence of oxygen. This way, a (bio)gas is formed, with higher concentration of CH4 (methane) and CO2 (carbon dioxide), while containing also small concentrations of other gases like nitrogen and hydrogen sulphide.

Biogas can be used either:
- to produce electricity and/or
- to produce heat
- it can also be upgraded to biomethane, which can
    - fuel thermoelectric utility plants (today, 60% of the electricity produced in Mexico is by natural gas, 30% of this demand is imported from the US)
    - be injected in the natural gas grid or
    - be used as 'green gas' for cars, tractors or trucks.

Leftovers (i.e. the digestate as residue from the digestion process) are usually rich in nitrogen and phosphorus and therefore can be transformed into organic fertilizers.

Apart from anaerobic digestion, there are also other technologies to transform organic matter into energy, such as pyrolysis, gasification, biorefinery etc.

Main sources of organic matter are:
- agricultural residues
- municipal solid waste (usually, 50% of MSW is organic)
- animal manure
- residues from wastewater treatment plants (WWTP's).

Another way to obtain energy from waste is to incinerate parts that are not used for recycling or which are not going to landfills. However, for the scope of this research we will concentrate on the identification of organic waste streams.

Next to offering an alternative energy solution, the transformation of organic waste also reduces the volumes of generated waste produced. Besides, capturing biogas from landfills will contribute significantly to the reduction of greenhouse gas emissions, as methane (CH4) – which is usually between 55% and 60% of the biogas – is 21 times more harmful than carbon dioxide (CO2). At farms, biogas can help to reduce contamination of soils due to saturation of manure as digestates, either or not transformed into formulated organic fertilizer, and can be transported more economically to places with less supply options. As such, biogas can be regarded as an alternative source of energy supply. It can also relieve the volume and quality of the waste flows. Biogas can create economic value and boost circular economy and sustainable schemes.

5.5.1 MEXICAN MARKET AND POTENTIAL

For over 10 years, the development of technology to create biogas and biomass has been lingering in the country. More recently, the market seems to become more mature, as in the period from 2016 to 2018, the installed capacity of biogas production increased from 83.17 MW to 217.21 MW (SENER, 2018).

More than a decade ago Mexico had less than 20 bio-digestors. In 2018, this number had increased to 87, partly with the participation of Dutch companies. Particularly, opportunities can be found in the following sectors:

1. Agro-sector

Mexico has a strong agriculture sector as most of the products like vegetables and cereals are exported mainly to the U.S. This is the same situation for the pork and beef production. Only for pork manure, the potential is estimated at around 650 million m3 of biogas per year. The main states where this industry can be found are Guanajuato, Jalisco, Puebla, Sonora, Veracruz and Yucatan.

2. Fruit production

Mexican fruit production is not competitive enough for the international markets and therefore, it is just sold and distributed inside the country. A great part of this produce is considered as waste or residuals if it does not fulfil some healthy or sanitary conditions. As the breaking point of being considered as waste is measured by the levels of sugar, it represents great opportunity for biogas production.

3. Nopal

Perhaps the most important agricultural product in Mexico is the nopal (Cactus) that can be easily produced and harvested. This creates a promising business case for many farmers that trouble with food production to create an extra income by biogas production or fulfilling their electricity and heat demand.

4. Milk production

The milk industry has an enormous potential for cow manure. There are two states that have 77% of the milk production: Jalisco and Durango. In this industry around 472,000 cows are milked daily. Other locations of this industry are found in Coahuila, Guanajuato, Chihuahua, Hidalgo and Mexico City.

5. Waste treatment

This is something that can be the low hanging fruit opportunity as there is a norm (NOM083 from 1987) that forces municipalities to have the proper technology and methodology to treat their waste stream in a manner that is conscious of the environmental conditions.
Metropolitan cities as Monterrey and Mexico City are taking action to address this area, both cities with good results. The problem is worse in the smaller municipalities, where a lack of

infrastructure or financial capacity to take action are common. Nonetheless, the potential of waste treatment plant derived biogas is circa 5,000 million m3/year. The states that have the biggest potential for waste treatment plant installation are Guanajuato, Hidalgo, Nuevo Leon, Puebla and Tamaulipas (SEMARNAT, 2012).

6. Water treatment

There are 2,816 water treatment plants, in total it is estimated that in Mexico current treatment is at 82,000 l/s. According to one source, the potential of electric energy production using biogas produced from water treatment, is near to 3,600 MW. This information points towards a market with business potential to act on.

This study identified some Mexican companies and projects that are active in the Bio-gas area and related services. These can be found in appendix VI. This list demonstrates that the interest and activity in the market. The natural gas industry is still in development and receives wider acceptance. Possibilities of creating ventures with companies either on the supply to be transformed in organic fertilizers side (agricultural residues, waste etc.), either on the demand side (gas distribution, utility companies, own users) are promising.

5.6 EXPERT OPINION

Four Mexican experts were asked four questions about the current and future state of the waste to energy market in Mexico. The collective answers of the interviewees are presented here. The interviewees were:

- Francisco Velasco, Founder of Waste Cero
- David Herranz, Deputy Director Technical Management and Performance of Veolia
- Juliana Gutierrez, CEO of Energica
- Berardo Mejia Urdapilleta, CEO of BioEtOH

Q: What was the impact of the energy reform on Mexico's waste to energy sector industry?

In the waste sector there are few examples of changes after the implementation of the energy reform. The City of Monterrey, for exemple, produces electricity from its organic urban waste that it uses it for its metro system. Another change is the increasing interest of the private sector to participate in the industry, as the waste problem is not only an issue of the government or of large cities.

However, in general the waste sector has not seen any changes after the energy reform was enacted. It is expected that in the coming years this may change and that the waste to energy sector will receive an impulse.

Increased environmental regulations are the solution to boost the waste to energy sector. Municipalities and companies would have to increase their efforts in transforming waste into energy. Regulations need to be aimed at diminishing GHG emissions and not at electricity sales.

Q: What are the main barriers for municipalities to start implementing waste to energy processes?

The first step is to create awareness of the waste problem since waste is produced by people and the actions and decisions they take. The community can be of significant help by separating waste and actively recycle.

Community cooperation through waste separation combined with effective regulation on recollection will make the process easier for municipalities to transform waste into energy.

The high cost of recollection, transportation and waste transformation is another important barrier from the point of view of municipalities. For them it is at this moment not an attractive business model to invest in an entire infrastructure that is needed to sell or use the electricity generated from waste. For the moment this business model is only feasible in large cities as Mexico City or Monterrey.

Q: What trends in technologies will we see in the coming years?

We hope to see technologies that transform waste into energy or other products on site. The advantage is that the site will transport energy or products instead of moving waste to an onward location. However the mindset of community and authorities have to change to have this type of technologies implemented.

Another expected technology is that of shared biodigesters. It is expected that the infrastructure for this technology will be used by small municipalities and that larger facilities are to be build in big cities.

The private sector will be leading the way in the transformation of waste into other products and in the efforts to minimize GHG emissions. It is expected that the private sector will be driving the transition because of economic motives and, in the case of Mexico, because foreign companies will be bringing their international best practices to the market.

Q: What is your advice to Dutch companies that want to enter the Mexican energy sector?

The first recommendation would be to contact local industry associations that have contacts with both the private sector as well as with local governments.

Mexico has many business opportunities in this sector. It is important to identify niches and, for example, introduce on site solutions for waste problems to increase cost efficiency.

On the other hand, it is valuable to look into solutions that the Mexican industry is developing. These solutions are further along the learning curve for Mexico's waste to energy sector. When developed in partnership with an international company these Mexican solutions have to potential to serve numerous other market segments

5.7 BUSINESS OPPORTUNITIES

The following business opportunities in the waste to energy sector in Mexico are identified:

Small-Scale Biogas Facilities: Opportunities lie with generators of Special Management Waste (SMW), which include hotel chains, factories and schools. Small scale biogas could offer the solution to these generators in converting their waste into a solution that can produce energy in their facilities.

Biogas to Biomethane: There is an opportunity of producing biogas and upgrading this to biomethane to compete with natural gas. Considering that CFE produces its electricity using natural gas and most of its gas is imported from the United States and regions as the Yucatan Peninsula are short on natural gas, biomethane could play an important role.

Biogas as Energy Storage Facility: Storage of biogas to contribute to energy production in peak hours when electricity node prices are at the highest point. This application can produce energy to the Mexican grid and to sectors in regional areas such as the agro sector.

Waste to New Products: New products can be manufactured from waste in a circular economy market. This presents a concrete business case in Mexico.

CHAPTER 5 | HIGHLIGHTS

OPPORTUNITIES

SMALL-SCALE BIOGAS FACILITIES

Opportunities lie with generators of Special Management Waste (SMW). Small scale biogas could offer the solution to these generators in converting their waste to energy.

BIOGAS TO BIOMETHANE:

There is an opportunity of producing biogas and upgrading this to biomethane to compete with natural gas.

BIOGAS AS ENERGY STORAGE FACILITY

Storage of biogas to contribute to energy production in peak hours when electricity node prices are at the highest point.

WASTE TO NEW PRODUCTS:

New products can be manufactured from waste in a circular economy market. This presents a concrete business case in Mexico.

CHALLENGES

HIGH BARRIER FOR ENTRY

Local ownership, social factors and a lack of perceiving waste as public resource make centralized waste management in Mexico challenging.

Chapter 6

6. TRANSPORT SECTOR (EV)

The transport sector is responsible of the 25% of the CO_2 emissions of the world. (IEA, s.f.)
The urgency of reducing CO_2 emissions is an international top priority.

Electric vehicles are a solution for the transport sector to reduce significantly the CO_2 emissions. It is forecast that for the year 2030 the use of EV will offset about 220 Mt CO_2-eq. (IEA, 2019)
In 2018, the global electric car fleet reached 5.1 million; 2 million units were added just in 2018, showing the exponential growth of the sector. China is the leading market followed by Europe and the United States. (IEA, 2019)

Although the adoption of electric vehicles is growing, there are still many barriers to overcome to achieve a massive adoption of this type of technology. Some of the barriers are the cost of the vehicle that are still the double in comparison with the combustion engine vehicles, the accessibility to charging points, the waiting time for each reload of the battery and the distance that the vehicles can travel with the normal charge. (IEA, 2019)

Due to all the barriers mentioned above, the only manner that the countries have managed to promote the adoption of these vehicles is with a strong governmental program associated with subsidies and other benefits as special parking places and tax exemptions.

Charging infrastructure and innovation in the battery systems is key to achieve the results that the entire world is expecting. (IEA, 2019)

6.1 SUSTAINABLE PUBLIC TRANSPORT

Mexico presented its program of emission reduction for 2050, during the COP 22 in 2016. As a result of being one of the countries that signed the Paris agreement at the COP 21 in 2015, Mexico has committed to reduce 25% of his GHG emissions for the year 2030 and 50% for the year 2050. (SEMARNAT, 2017)
During the first quarter of 2020, the Ministry of the Environment and Natural Resources (SEMARNAT) will publish the "National Strategy for Electric Mobility" (ENME) (Alianza Flotillera, 2019).

This national strategy for electric mobility has been under development since 2018. National and international efforts have been made to design a proper solution that is adequate to the Mexican conditions. The main goal is to reduce the emission of CO2 with 5 MtCO2-eq in the year 2030, and to have an electric car fleet of 500 thousand light vehicles, and 7 thousand public transport electric vehicles. (SEMARNAT, 2018)

The reduction of emissions, the improvement of the air-quality in the cities and the improvement of the public transport infrastructure are not new for Mexican Cities. They

were the main goals for the implementation of BRT (Bus Rapid Transit) systems in Mexico. It is important to mention that to the date only 3 Mexican cities have a metro system Guadalajara, Monterrey, and Mexico City. (Zamora, ¿Qué ciudades tienen red de Metro en México?, 2019)

The first BRT system was implemented in the year 2003 in the City of Leon in the state of Guanajuato. In 2015 19 BRT systems were functioning in 8 different cities (El Poder del Consumidor, 2015). BRT systems were a first step to reduce GHG emissions in the main Mexican cities and to start the transition towards a sustainable public transportation. A passenger in a BRT system will just emit 9 g/km of CO2-eq emissions in comparison with the 261-g/km emissions of a combustion engine vehicle (SEMARNAT, 2018).

In Mexico City, 34.56 million trips are done daily. The public transportation is responsible for 15.57 million of trips, while the private transportation (own vehicle) represents 6.6 million of trips; in average each car trip has 1.5 users. The GHG emission is not a minor issue. (INEGI, 2018)

Mexico City, has designed the electro-mobility strategy 2018-2030 with the vision of a zero GHG emissions mobility, using electricity as fuel produced by renewable energy technologies. (C40 Cities Finance Facility, Carbon Trust, 2018)

The short-term goals in the electro-mobility strategy Mexico City are to make 20% of public transportation electric to make 15% of new car sales EV, to make 80% of the taxis being EVs, to make 30% of the utilitarian vehicles being EV or hybrid, to make 30% of the bicycles electric, and to have 1,500 electric charging stations in the year 2024. (C40 Cities Finance Facility, Carbon Trust, 2018)

To date there is no city in Mexico that is using electric buses as a public transportation system. Mexico City is the only city that has recovered the old infrastructure of trolleybuses; buses that work with electricity but are attached to a cable. (Espinosa, Apuestan por el transporte electrico para la CDMX, 2019)

Mexico City has already implemented a program for the substitution of taxis for new hybrid or electric vehicle taxis, giving a low rate finance scheme and a subsidy from the city to lower the cost of getting a new vehicle. The program did not reach the goals, but the lessons learned are that the new vehicles were too expensive and that this, in combination with the lack of an infrastructure, was a barrier that prevented the participation of the taxi drivers. (Frida Mendoza M. M., 2018)

6.2 EVS IN MEXICO

Similar to other countries, Mexico faces some barriers to the adoption of EV, being the price of the vehicles the most important barrier to overcome, and second the insufficient charging infrastructure in the country.

In order to promote the use of EVs the Mexican government has implement some incentives as the exemption of taxes, special plates, a discount on the toll fee, and the installation of charging points. In the ENME (national mobility strategy) 16 new incentives are going to be launched, giving a strong impulse in the EV public transport. (SEMARNAT, 2018)

These incentives, and the "Hoy No Circula" programs have impulse the adoption of low emission vehicles (EV, Hybrid Plug-in, Hybrid) in Mexico since 2016. The "Hoy No Circula" program prohibit that the vehicles that emit more GHG emissions transit in the city during an environmental crisis related with the air-quality.

In the period 2016-2019 almost 1,000 EVs were sold in Mexico, in comparison with the 51,144 hybrid cars. Figure 29 shows an overview of these EV sales. Information from Tesla is not included in this figure, as the company does not report its sales figures. It is estimated that more than 3000 EVs are on Mexico's streets. Because this information is not accurate, this report will focus only on official data (Cabeza Santillana, 2020).

Units sold per year	2016	2017	2018	2019
EV	254	237	201	231
Hybrd plugin	521	968	1584	1081
Hybrid	7490	9349	16022	18283

Figure 29. Overview of Electric Cars in Mexico. Source: (INEGI, 2020)

The states with most EVs in Mexico are Mexico City (357), Jalisco (118), Chiapas (54), Nuevo Leon (49), and Mexico (41). The states without EV in Mexico are Baja California Sur, Campeche, and Tabasco. (INEGI, 2020) The table with all the EVs per state can be found in Appendix VII.

The EVs currently available in Mexico are expressed in figure 30:

Brand	Model
Audi	e-tron
BMW	I3
BMW	I8
Chevrolet	Bolt EV
Jaguar	I-Pace
Nissan	Leaf
Renault	Twizy
Tesla	Model 3
Tesla	Model S
Tesla	Model X
Zacua	MX2
Zacua	MX3

Figure 30. Source: (Bureau, Motorpasion Mexico, 2019)

Mexico is the sixth car manufacturers in the world, with 22 manufacturing plants in 14 States of Mexico (Expansion, 2019). The automotive brands that manufacture in Mexico are: Audi, BAIC, BMW, Ford, GM, Nissan, Honda, JAC, Kia, Mazda, Toyota, Volkswagen and the Mexican brands Vuhl and Zacua. (EXCELSIOR, 2019)

Zacua is the Mexican automotive firm that is producing the first Mexican EV, with the models MX2, and MX3. Both models have the same dimensions, with space for only two passengers. The firm launched the two models in 2016; at the end of 2019 the firm has around 150 cars. The range of the car is 160km and it takes 8 hours to fully charge the batteries. The price of each both models is $600,000 Mexican pesos (28,600 euros).

(photo taken by Fernando Flores, in ZACUA sales floor)

6.3 CHARGING EV INFRASTRUCTURE IN MEXICO

One of the incentives that CFE is offering for the EV is the installation of the charging station in a separate electricity contract than the house or office; this separate contract has a low kWh fee.

The charging infrastructure is an important barrier that the Mexican cities and municipalities have to overcome. This is why car manufacturers BMW and NISSAN have joint efforts and together have invested 100 million Mexican pesos, around US$5 million, to install 661 charging locations, in strategic places such as shopping malls, hotels, universities, parks, main streets and some important highways in the country. For the time being these charging points are free. Anyone that has an EV may charge their batteries for free while they are shopping the groceries, or seeing a movie at the cinema. Info on this loading station can be consulted at www.chargenow.mx (Chargenow, s.f.)

Together the CFE and initiatives as Charge Now have installed more than 2,500 charging points in Mexico (Cabeza, 2020).

In November 2018, the CRE (energy regulator) released an agreement that allows the sale of electricity between private parties in order to promote the sales of electricity for EVs through charging stations. This agreement opens the door for everyone to sell the electricity as a fuel for EVs, just like gas stations sell gas today (CRE, 2018).

Anyone in the private sector who has renewable energy power plants, as well as a household with more solar panels than it needs, can participate in this transaction without a specific permit of the CRE. (CRE, 2018)

For now, the charging stations are free, the shopping malls and other locations (what locations?) are paying for the electricity that the EVs are consuming. At the moment this strategy is used to attract the users of electric vehicles to spend time and money inside the infrastructure (Comment JR: Don't understand what you do want to say here) than paying for the electricity. When the number of EVs in Mexico has grown the free charging stations will start to charge money for the electricity.

6.4 EXPERT OPINION

In total five separate interviews were held. The answers are grouped together and presented in three different parts. Two electric vehicle experts were asked three questions about their views on the future of the Mexican EV sector and the continuity of the energy reform.

The interviewees are as follows. Their collective answers are presented below.

- Francisco Cabeza Santillana, Electric Mobility Manager of Engie
- Leopoldo Ruiz Huerta, Automotive Product Specialist

Q: What is the current state of the electric mobility market and what is the outlook?

To understand the transition to electric mobility in Mexico it is important to understand the entire ecosystem of Mexico. The transition to electric mobility will start when important actors in sectors such as private and public transportation adopt the technology and when the status quo around electric vehicles is challenged.
Globally, the phenomenon of electric mobility transition is already taking place. The pace of transition in Mexico will depend on the transportation ecosystem.

Q: What are the main barriers for the electric transition?

An important barrier to overcome is the high cost of electric vehicles. It is expected that the adoption of this technology will increase rapidly, similar to the adaption by the consumer of other technologies, such as flat screen TVs and mobile phones.
Another barrier is related to status quo; consumers want to have the same driving range in an electric vehicle as they would have in a conventional combustion engine vehicle. In Mexico this limited driving range is potentially a problem as distances between cities tend to be extensive.

Also, improvements in Mexico's smart metering charging points need to be made. The charging points are mapped but real-time information on if a charging point is functioning is absent.
The main advantage is that 98% of the population has access to electricity in Mexico, giving a clear advantage for the adoption of this technology. Access to electricity means the charging infrastructure can be easily adapted according to the local needs.

Q: Can renewables become an important part of the energy supply for charging station infrastructure?

Mexico has introduced basic regulation for charging stations to stimulate the sales of electric vehicles, although no company has introduced charging stations running on renewable energy so far.
In the near future, when electric vehicles are commonplace and charging points are more advanced through applications such as DC Fast Charging. Renewable energy can play an

important role in the sector. It is foreseen that this type of charging point will be implemented in the gas stations of the future. The business model will be based on electricity prices and thus is correlated with the electricity market.

Q: What would be your advice to Dutch companies that want to enter the Mexican energy sector?

The recommendation for Dutch companies is to study the market in Mexico and participate in the charging infrastructure sector and in niches such as utility and delivery vehicles, public transport, in order to accelerate the transition of electric mobility.

A second interview was conducted with Alberto de la Fuente, President and Director General of Shell Mexico, in which de la Fuente was asked about his views on the future of electric vehicles in Mexico and the role of Shell in charging stations.

Q: How do you see the future of electric vehicles in Mexico? And what would the role of Shell be?

Although overall sales of vehicles have fallen in recent years, the hybrid and electric car sector has shown a steady increase. Mexico is one of many countries with this hike, but it still has challenges to overcome.

According to the Mexican Association of the Automotive Industry (AMIA), during July 2019 the sale of hybrid and electric vehicles reached 2 thousand 68 units, or 66.9% more than in the same month of 2018.

Despite this growth, sales of such vehicles still represent a very low percentage of the total marketing of light vehicles in the country. Between January and July 2019, 12,408 vehicles with such environmental technology were sold, representing just 1.66% of total sales of light vehicles made during that period in Mexico (AMIA).

While it is true that hybrid and electric car prices have fallen in recent years, and will continue to fall in the future, their cost remains high relative to combustion vehicles.

In Mexico, the price of the cheapest hybrid is at least 100 thousand pesos higher than that of a petrol-powered car of similar dimensions and characteristics, while in terms of performance, that of electric cars is still much lower than that of combustion vehicles.

This situation makes it still complicated and unmotivating for the average consumer to acquire such a unit in Mexico but this will change over time.

There is no doubt that in the future we will continue to see reductions in the costs of clean technologies, but to reach the target faster – which is to reduce the emission of pollutants, through the use of hybrid and electric vehicles – will depend to a large extent on the coordinated efforts of the government and the domestic automotive industry.

Q: In terms of charging stations, what role do you foresee for Shell? And will charging stations be introduced in Shell's gas stations?

Mexico is no doubt a key market for Shell. We currently have over 200 stations in 14 states of the country and we have a very aggressive growth strategy to become a key player in the retail business that includes investments for one billion dollars over the next ten years if market conditions remain the same.

This ambition includes setting up electric charging stations, the first of which we expect to open this year. Having said that, the market of electric vehicles is still quite new in Mexico, but we intend to grow with that market and provide consumers with attractive alternatives for charging their vehicles as more and more cars switch to electric technologies to satisfy mobility needs.

As a company, we are investing between $1 billion and $2 billion annually on our New Energies division, which includes investments in electricity, clean energy, electric vehicle charging and alternative fuels. We have made several purchases of EV charging companies over the last few years in Singapore and the UK, acquired a customer-facing electricity and gas provider in the U.K., and installing numerous charging stations in Europe, UK and Asia under the Shell Recharge brand.

The third and final element of this sub-chapter is an interview with Michel van Lindert Managing Director of the Dutch Organisation for Electric Mobility (DOET). The aim of this interview is to understand the developments in electric mobility in the Netherlands. The lessons learned in the Netherlands could serve as guidelines for entry into the Mexican market.

Q: How has the electric mobility sector evolved over the last ten years in the Netherlands?
Currently, the Netherlands has about 200,000 electric vehicles of both the battery and plug-in hybrid type. There are over 50,000 public charging points, of which the majority are found in the four main cities: Amsterdam, Rotterdam, The Hague and Utrecht. This infrastructure was all developed in the last ten years.

We are now frontrunners together with Norway and achieved this primarily through public-private partnerships between companies, the national government and local government. Of the total electric vehicles on the road, 90 percent are company cars. Companies are incentivized through a scheme which allows the company car holder to claim a reduction on their income tax.

DOET is currently in consultations with the Dutch government to create more incentives for the private market for battery electric vehicles. Hopefully we will be able to announce an incentive, or several incentives by June 2020 in order to get this market going. The most likely incentive will be subsidies for new cars, as well as second-hand cars. We foresee that there will be subsidy to buy the car, also known as a prime. This would be around four to five thousand euros, which would still leave a price gap between the internal combustion engine vehicle and electronic vehicle but would make a significant difference.

Q: Are subsidies a necessary tool to drive the transition to electric vehicles?

Initially, it is necessary to have subsidies as there is still a considerable gap between the price of electric vehicles (EVs), and internal combustion engine vehicles (ICE vehicles). The average cost of a small EV is nearly double the price of a small ICE vehicle. However, there are advantages to the electric vehicle when we look at the total running cost. The total cost of ownership is much lower than a diesel or gasoline car, due to low maintenance and fuel cost.

Apart from a lack of awareness of overall cost implications, there are other common concerns which persist about electric vehicles, such as range anxiety, battery life cycle, charging infrastructure and fluctuating charging fees.

Q: What progress have you seen in terms of other electric vehicle types?

Lately, many supermarkets have started using light electric vehicles for cargo transport, also known as light electric cargo vehicles. They have been in use by the Dutch postal services for a while.

In the e-bus segment we have two manufacturers in the Netherlands. The largest is Van der Leegte (VDL Group), based in Eindhoven. They export buses and sell buses to Dutch municipalities. Then there is another company, Ebusco, which is relatively young, but has made interesting progress in building a bus of composite material. This material allows the buses to be much lighter, giving the bus the opportunity to load more passengers as the weight of batteries becomes less of an obstacle. The number of passengers is very significant in a successful business case. The government has set the target that by 2025, all Dutch buses operated in cities should be electric. Longer distance routes, running through rural areas, is still likely to remain combustion engine based.

It should also be worth noting that hydrogen run vehicles, fed with water, are a runner-up in the Netherlands. They could be a solution for buses, and for trucks. However, hydrogen is not as efficient as electricity. For long distance transport, for example intercontinental truck transport, they can be attractive. You cannot transport cargo from the Netherlands to Barcelona with a 40-ton electric truck. Up to 3.5 thousand kilos, electricity will remain the best option, particularly for public transport in cities. Trucks up to 12 tons will use electric

power for national transport. International transport is more likely to use hydrogen, as the system does not require very heavy batteries.

Q: Where do you see the most innovation in the electric vehicle sector?
The main focus of innovation, amongst our members, is on the charging infrastructure. EVs used to be charged with charging points. Now we see a phenomenon emerging called smart charging. The grid operators play with the charging times between different users. The price of charging will differ for very busy hours and less busy hours.

In the future many electric vehicle owners will charge their vehicle at work. This means they return home with a lot of capacity, which can be used to charge the cells, and even be taken out of the vehicle to charge homes. If the houses have solar panel capacity, this energy could be used to charge the vehicles, reducing emission to effectively zero. This solar system is already in use in Utrecht, where is it operated by We drive solar. It was opened mid-2019. The two-way charging capacity is known as bidirectional charging.

Q: Are we seeing a gradual shift to a circular economy approach with respect to the use of energy in transportation?
Although we are good in deploying the e-market in the Netherlands, such as electric vehicles and charging points, we are behind in our wind and solar energy capacity. There is limited space for wind energy installation on land, which has led to a greater push of offshore wind energy on the North Sea. However, not everyone is in favor of this as it involves higher costs. There is a discussion about potentially going back to nuclear energy as a source. Most of the green energy the Netherlands, which is primarily wind energy, is currently imported from Scandinavian countries, purchased through a trade system. Our own share of green energy production has to be increased.

Q: In terms of export, where do you see opportunities for the companies you represent?
Most potential lies in innovation amongst charging point operators and mobile service providers. Three of our members, active in this area, are in the absolute top companies worldwide. We also have consultancy companies which started around ten years ago, and now have vast knowledge on how to collaborate and implement effective strategies for electric vehicle markets.

In order to persuade companies to come to Mexico, you need very solid information in a clear report on the chances of their products and services in the respective market. For example, it could include information on how much the Mexican government is planning to invest in the sector over the next few years.

6.5 BUSINESS OPPORTUNITIES

Mexico is part of the transition into the electro-mobility; this transition is slow compared to countries like China or European countries. There are three main business opportunities for Dutch companies to participate in the sector:

Charging Infrastructure
The lack of charging points is one of the main barriers for the adoption of more EVs in Mexico. The agreement of the CRE makes selling electricity as fuel for these vehicles possible. The installation of charging stations in combination with sustainable energy technologies is a clear business opportunity. The production of electricity on site, the increase in demand in the big cities in Mexico in the coming years, combined with the available natural resources in the country such as solar energy, makes the installation of this “electro-stations” in Mexico very attractive.

Public EV transportation
The lessons that Dutch companies have already learned during the implementation of electric buses, could also provide an important business opportunity to acquire a public transportation concession for Mexican cities.

CHAPTER 6 | HIGHLIGHTS

OPPORTUNITIES

CHARGING POINT INFRASTRUCTURE

Opportunities exist in smart charging infrastructure combined with distributed solar generation.

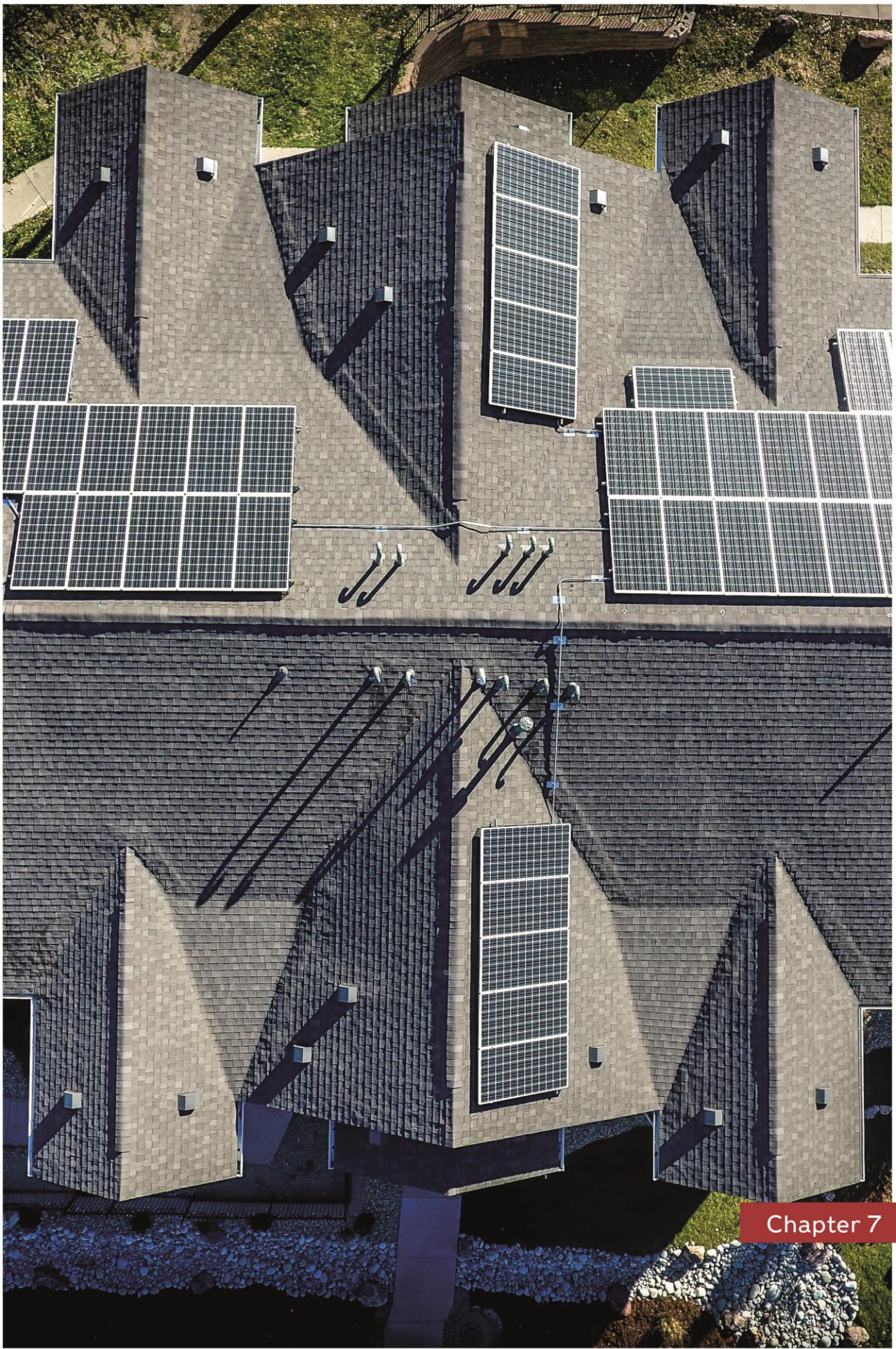
PUBLIC EV TRANSPORT

Dutch knowledge on the implementation of electric buses could be an opportunity.

CHALLENGES

USUAL BARRIERS FOR ENTRY

Cost of purchase, accessibility of charging points and public opinion are barriers for entry.



Chapter 7

7. GREEN BUILDINGS

To date, 55% of the world population lives in cities. This number is expected to increase to 68% by the year 2050 (United Nations, 2018). The importance of bringing sustainable solutions to the cities is not a minor challenge.

It is expected that the total floor area will double by the year 2060; this represents an additional 230 billion of m2. The middle-income countries will see a growth in the residential buildings mainly. (IFC, 2019)

The building and construction sector are responsible for 36% of the final energy use and for 39% of energy and process-related CO2 emissions (GlobalABC, 2018). Therefore, the Green Buildings niche offers a unique opportunity to reduce their energy consumption and GHG emissions, and more important, to improve the living conditions for their habitants.

The transition to Green Buildings will play a significant role in the reduction of GHG emissions and in the preparation of resilient buildings that can withstand the challenges that climate change brings with it. Green buildings also will help to increase the standard of living conditions. (Pierdo Comunicación, 2018)

The most common international rating systems are LEED, BREEAM, DNGB, EDGE, and Green Star. LEED is the most popular method of certification. It is being used in 167 countries and was used to certify 96,275 buildings around the globe at the end of 2018. (Stanley, 2019)

7.1 GREEN BUILDINGS IN MEXICO

In Mexico 74.2% (92.7 million inhabitants) of the population lives in 401 Mexican cities. 13 of these cities are considered metropolitan areas and have more than 1 million inhabitants. (SEDATU, 2018)

- Mexico City (20.89 million)
- Guadalajara, (4.89 million)
- Monterrey (4.69 million)
- Puebla-Tlaxcala (2.94 million)
- Toluca (2.20 million)
- Tijuana (1.84 million)
- Leon (1.77 million)
- Juarez (1.39 million)
- La Laguna (1.34 million)
- Queretaro (1.32 million)

- San Luis Potosí (1.16 million)
- Mérida (1.14 million)
- Aguascalientes (1.04 million)

Due to this high percentage of Mexicans living in cities, the only way to face the challenges of properly managing the energy supply, resources as water and food and transportation will be Green Buildings and Smart Cities solutions. The residential building is the niche within the construction sector that will grow in the following years. (IFC, 2019)

Mexico is not staying behind in sustainable construction; the country has already implemented policies, regulations, and adopted new technologies making a reference to some of the best practices of Green Buildings (GlobalABC, 2018). Mexico got its first LEED building certification in 2005 in Ciudad Juarez (Mata, 2016). With 370 certified projects Mexico occupies the eighth position in the global top 10 of countries with LEED certifications. (8.41 million m2). (Chaverra, 2019)

The most emblematic LEED buildings in Mexico are (Ventura, 2019):
- Torre Virreyes (135,901 m2, Mexico City)
- Torre BBVA (92,903 m2, Mexico City)
- Torre Reforma (54,572 m2, Mexico City)
- Punta Reforma (50,194 m2, Mexico City)
- Torre HSBC (46,354 m2, Mexico City)

Mexico City is not the only place with LEED-certificated buildings. These can also be found in important cities such as Monterrey, Puebla and Queretaro. Furthermore, LEED certification is not exclusively for new buildings. It can also be granted to old buildings, as long as they meet the requirements. An example is the "Antiguo Palacio Virreinal in Mexico City, that was granted the golden LEED-certificate, after it made a few changes. (GBCI Mexico, 2016)

Photo: The Antiguo Palacio Virreinal, currently City Hall, the seat of Mexico City ´s government. Source: (Revitaliza Consultores, 2015)

Using new efficient energy technologies will reduce the energy intensity of new buildings per floor. Lighting- and space heating technologies have reduced their energy intensity use significantly since 2010, while space cooling technologies have increased their energy consumption, according to the 2019 Global Status Report for Buildings and Construction" (GlobalABC, 2020, figure 31).

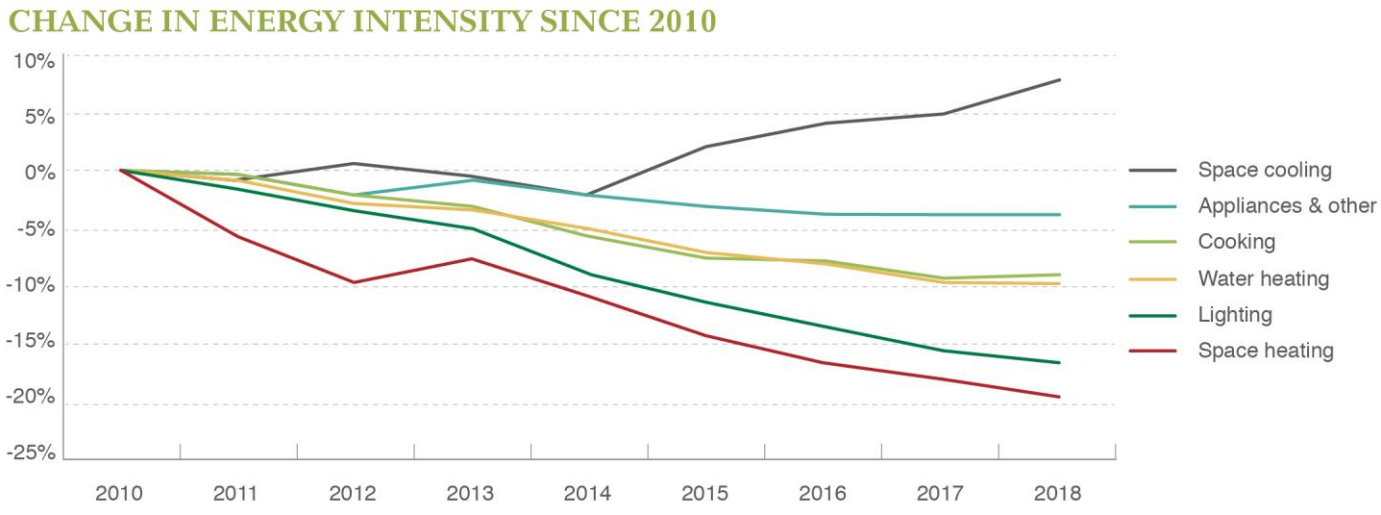


Figure 31. Source: (GlobalABC, 2020)

Despite the international effort of promoting the use of new technologies and of the construction of Green Buildings, an IEA-report on green buildings shows that this sector is not on track to meet the targets of reducing GHG emissions. Only lighting technology does. Cooling, heating, buildings envelopes, heat pumps and appliances worldwide do not meet the targets. (IEA, 2019)

Mexico signed the Paris Climate Agreement in 2015. At the international climate conference COP 24 in Poland in 2018, Mexico presented it´s proposal National Determined Contributions (NDC), a plan to reduce GHG emissions. Unfortunately buildings are not specifically mentioned in Mexico's proposal. (GlobalABC, 2020)

There are 2,637 government office buildings in Mexico that consume 355 GWh per year. In a 2018-study of the Internatioinal Development Bank (IDB) 1,350 office buildings were identified that could reduce 40.5% of the electricity consumption which can be translated into 115 GWh per year creating savings of US$10.2 million (IBD, 2019).

The BID-budget to change AC and Lighting systems in 1,350 government office buildings is 30 million dollars. The objective is to reduce the energy consumption with 40,5%. As a result of this 35,734 tons of CO2e/per year , in emissions will be avoided. Due to the Mexican weather characteristics the systems that consume most electricity were AC (48%) and lighting (24%) systems. (IBD, 2019)

In 2018 the International Finance Corporation (IFC) Mexico City was selected as a case study for Climate Investment Opportunities in Cities. In this study the opportunities for climate smart investments were estimated at US$37,500 million. (Villanueva G. H., 2019)

- Green Buildings (US$18,000 million)
- EV (US$7,000 million)
- Water (US$6,000million)
- Renewable Energy (US$3,000 million)
- Public Transport (US$2,000 million)
- Waste treatment (US$1,500 million)

Mexico forms part of the GOBALABC, which is a voluntary partnership of national and local governments, international organizations, business, associations, networks and think tanks committed to an efficient and resilient Zero-emissions buildings and construction sector. (GlobalABC, 2020)

As result of this international participation Mexico has created ALENER, the Mexican Alliance for energy efficiency. In this consultative body Mexican government institutions and the private sector try to align their thoughts and ideas about energy efficiency in Mexican Buildings. (ALENER, s.f.)

The University for the Environment (UMA) in Mexico has an international project of sustainable building design. UMA produces its own food, zero wastewater, natural ventilation systems for the classrooms while solar thermal collectors supply 100% of hot water. (Plazas, 2019)

Photo: University for the Environment (UMA). Source: (Plazas, 2019)

Mexico has created a fund to face the climate change ("Fondo Especial para el Cambio Climático"). The objective of this fund is to support projects for technology and knowledge transfer for new sustainable technologies. Part of this fund was used for projects of social housing stimulate the adoption of solar collectors and the change of lighting systems. (GlobalABC, 2018)

Another important step that Mexico has taken to finance this type of projects is the emission of Green Bonds that are available at the Mexican stock exchange. Green Bonds can be used to fund sustainable energy technologies, Green buildings, energy efficiency sustainable transportation, agriculture, bioenergy, reforestation etc. Mexico was the first Latin American country to offer this financial instrument. (BMV, 2018)

At the UN Climate Summit in September 2014 in New York City 2014 Mexico joint the Building Efficiency Accelerator (BEA). The goal of this public-private collaboration is to adopt and implement a building energy code i.e. to boost the implementation of best practices and policies for sustainable buildings. The BEA is led by the World Green Building Council (World-GBC) and the World Resources Institute (WRI). In Mexico it is executed by SUME and WRI Mexico. (SUME, 2019)

The BEA is active in 60 Mexican cities and gives advice and technical support to states and municipalities on how to improve the existing regulation. 60% of the buildings that will be

there in 2030 still have to be built; making smart sustainable decisions will therefore determine the living conditions of the coming years. (Flores, 2019)

With the construction of 600 houses funded by the Latin American Investment Fund, Mexico has already taken some actions to construct passive houses. One example is the passive house in Morelia, Michoacán, the construction of which was focused on the building envelope and shadowing systems with the objective to reduce the energy cooling consumption. (GlobalABC, 2018)

Green Roofs

In 2007 Mexico City launched its Green Roofs Program 'Azoteas Verdes' for the creation of green roofs on public buildings, hospitals and schools. The program reached 35,000 m2 of green roofs installed in the city, which equals 0.44% of Mexico City's surface (Comercializadora Hortícola, 2020).

Mexico City is the only city in Mexico with green roof regulation. Under the norm NADF-013-RNAT-2007 a tax reduction of 10 percent is included for buildings that comply with this regulation (Excelsior, 2016).

The private sector holds the largest potential for green roofs. Currently 20 companies are installing green roofs in Mexico City. These companies combined have installed more than 1,000.000 m2 since 2007. With an average cost of a green roof per m2 of $3,000 Mexican Peso, the estimated investment in the market was approximately US$172 million in the period 2007-2017. Most installations were performed for commercial buildings that were in the process of obtaining their LEED certification (El Financiero, 2018).

The green roofs market is fueled by an increasing number of LEED certifications and by the corresponding increase in property value these certifications bring about. On average a LEED certified building raises its value in the real estate market by 15% (Obras Expansion, 2013)

7.2 LAWS AND REGULATIONS

Mexico has developed its building energy codes with the goal to reduce the energy used in buildings or building components. The energy buildings codes are mandatory for part of the construction sector. In collaboration with the private sector the Mexican federal government developed the "Código de Conservación de Energía", a local energy efficient code for buildings, in 2017. (GlobalABC, 2018). More information on different laws and regulations can be found in appendix VIII.

Due to the important growth of the construction of Green Buildings and sustainable urban solutions in the building sector, Mexico has created a regulation framework to enhance these new constructions by adopting lessons learned from the experiences of other

countries and through developing local regulation according to the local environmental conditions.

7.3 EXPERT OPINION

Three Mexican experts were asked about their view of the current and future state of Mexico's green building sector. Their collective answers are presented below.

- Alejandra Cabrera, Executive Director of SUMe
- Francisco Velasco, Founder of Waste Cero
- Miguel Mendoza, CEO of Engineering and Design Process (EDP)

Q: How has the energy reform changed the Green Building sector? Has it contributed to an increase in Green Buildings?

In terms of construction, not much changed under the energy reforms. LEED certified buildings in Mexico promote energy efficiency solutions, which in turn save money on operational costs of buildings. But there is another reason for the increase of LEED certified buildings: the square meter of space is much more valuable than non-certified buildings, hence making for a higher profit margin.

Another reason for the healthy market for LEED certified buildings is that many of the certified Green Buildings are leased as corporative offices for international companies as part of their international strategy to be a sustainable company.

It is important to understand that certified buildings are changing existing business models and that these investments in new technologies and energy efficient components are paying off not only by the savings that the caused, but also through the clients and the contracts that these types of buildings are attracting.

The construction industry is growing at its own pace, but there are some events that can trigger the industry, for the Mexican experience this trigger was not the energy reform, but it was the New Airport of Mexico City that has been canceled. This construction project attracted many new materials, best practices, and different technologies that now are available in the country.

Q: Which are the main barriers that the industry is facing to build certified Green Buildings?

The main barrier is education and awareness of this type of construction practices and technologies that can save money in daily operations. Investing in technology pays off. If

there is more awareness of the benefits of these technologies more constructions will implement Green Building practices.

Another important barrier is the significant investment needed to build this type of certified buildings. There are some initiatives, such as “green credits” available for the domestic and construction industry, but this is not widely known.

It is important to show the success cases, and invite the industry to know and to understand how these technologies are changing the daily operations of buildings, saving money at the same time.

Q: Which technologies do you think contribute to the construction of more certified Green Buildings?

The technologies that are related with energy efficiency, and management of local resources will be the technologies that will impulse this type of buildings.

There are many examples, including changes to the lighting, heating and cooling efficient systems, and the use of new materials in the envelope of the buildings, and energy technologies that produce part of the demanded energy.

Local materials and new construction materials are very important for the construction of this type of buildings. It is important not only to adopt technologies, but also learn from best practices from other international experts.

It is important to understand that climate change is here and invest in resilient buildings that will last for the next at least 60 years. It is time to take smart decisions and try to make efficient buildings that contribute to reducing waste and are energy self-sufficient.

Q: What would you recommend Dutch companies that want to participate in the Mexican energy sector?

The best advice is to contact different associations in Mexico that can provide the companies an understanding of the local market and the Green Building sector of Mexico in particular. These associations will also be a perfect place for networking with both the private sector and local authorities.

An expert representing a Dutch trade organization was asked five questions about the state of the green buildings industry in The Netherlands and opportunities for Dutch internationalization in the sector.

The interview was conducted with Martin Mooij, Head of Certification and Project Manager of DGBC Deltaplan.

Q: What are the current trends and challenges in the industry?

The Netherlands is one of the forerunners when it comes to green buildings. Innovative projects have been realized since the 80s and continue to be developed. However, development needs to be accelerated because of the still-existing threat of climate change. Climate change is a challenge that the industry is currently facing is that. The green buildings sector must act immediately to the effects caused by climate change, and therefore cannot wait for the development of promising new technologies. As a result, the industry uses existing technologies that sometimes result in a surge in costs. The question that needs to be asked is: do we prioritize efficiency or price? To tackle this we need smart solutions, rules and regulations.

Q: What are some of their leading innovations of companies that are affiliated with Dutch Green Building and what are the competitive advantages?

One of the most interesting innovations is the usage of data to improve the energy efficiency in buildings. Compared to other industries there is relatively little data available in the building sector. An example is the Smart Data technique, a promising method companies can adopt to have an automated analysis of their energy consumption in order to reduce their consumption. The Smart Date technique does not require a high investment and a company's energy consumption can be reduced with 20% to 30%. Several Dutch companies are investing in this new technique.

Another interesting innovation, MADASTER by Thomas Rau, is a circular economy project that focusses on material recycling. This project creates material passports that monitor scarcity and availability of materials. An analysis of the available materials in a building is made, so when a certain material is needed and available in the building, it does not have to be granted from another source.

Lastly, another promising and innovative project is one led by Michiel Baars called Smart Liberator. Its objective is to reuse concrete. Concrete is a very popular but also polluting material globally and currently a technology to crush and reuse it is being developed. This is a good example of a technology that could be exported to areas where there are big urban developments or areas where there is a lot of waste available.
The Dutch are also known for their efficient built environment and water protection. In 2020 there have been many floods in the UK. Dutch consultants have been helping with redesigning their water systems to solve the current problems and to prevent major floods in the future.

Q: If you look at the future, do you expect that the Smart Data technique will be developed and applied in private homes as well?

The technique will be developed further, however, to reach this, it is important to first create awareness among people about their energy consumption. The second step is to integrate an automated system that regulates the energy usage.

Q: Do you believe that Dutch heat pump technologies and air conditioners are applicable in Mexico?

The Netherlands produces and uses heath pumps. Air conditioning systems, on the other hand, are mainly imported from China and Japan. Therefore, I think that the small Dutch market could provide heating systems, such as boilers, but no air conditioning systems.

Q: Do you believe that there is an international market for Dutch expertise on Green Buildings?

There are opportunities for Dutch expertise abroad, although there is still plenty to learn in the Netherlands. The Netherlands has expertise in urban planning and transportation systems. Given the fact that 70% of the global population will live in cities in the future, this is where opportunities lie for the Dutch green building sector. Next to this, in Europe Dutch companies are prominent players in lightning.

Q: Do you believe that your industry is rather focused inwards instead of outwards and therefore opportunities abroad are not always exploited?

This is a phenomenon often discussed within the industry. Currently there are plenty of projects just within the Netherlands. Because of that, the capacity to look abroad is absent. Some companies in the Dutch Green Building Council have international relationships in Europe and on other continents. Sometimes, there are opportunities to bring all the companies together and discuss their problems and needs. In such moments, Dutch companies can look for opportunities to help globally.

7.4 BUSINESS OPPORTUNITIES

The business opportunities for Dutch companies in Mexico in the Green Building sector are twofold:

Energy Generation
With buildings accounting for 36% of the total energy use, an important element for the Green Building sector is energy generation. The use of new renewable energy technologies incorporated in the building present a concrete business opportunity.

Energy Efficiency
Opportunities exist in making buildings energy efficient by changing appliances as lighting, heating and cooling efficient systems, and using new materials in the envelope of the buildings. Also, the usage of data to improve a building's energy efficiency is an opportunity.

CHAPTER 7 | HIGHLIGHTS

OPPORTUNITIES	CHALLENGES
ENERGY GENERATION The use of new renewable energy technologies incorporated in buildings present a business opportunity.	**EDUCATION AND AWARENESS OF CERTIFIED GREEN BUILDINGS** The benefits of certified Green Buildings and its cost savings are not always know, leading to scarce investments.
ENERGY EFFICIENCY Opportunities exist in making buildings energy efficient by changing appliances, using new materials in the envelope of the buildings and applying data techniques.	**HIGH INVESTMENT REQUIRED** An important barrier is the significant investment needed to build this type of certified buildings.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, there are numerous opportunities for Dutch companies in the renewable energy sector in Mexico, mainly in niche sectors; generated distribution, solar power innovations, the service industry for wind generation, energy storage through water management and electric public transport and smart charging solutions. Dutch innovation and expertise are highly valued in Mexico and can also contribute to research in still unexplored areas.

Climate change forms a very real threat to our civilization, and it is only when the private and the public sector come together that change can be effective. Industry associations and the companies they represent, need government support in matters related to changes in laws and regulations, cooperation between institutions and industry advice. Frameworks and strategies from local governments and international cooperation are key to a successful energy transition and a clean approach to global economic sustainability and growth.

Interested Dutch companies are advised to partner up with a Mexican company and seek help from local organizations including embassies, chambers of commerce and consultancy firms, to ensure their success on the Mexican market.

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Appendix I: Articles and laws energy reform

The following changed were made in the Mexican Constitution and secondary laws that shape the energy reform.

Art. 25: Establishes the category of a Productive State Company, providing legal ground to CFE to participate in the open electricity market.

Art. 27: Establishes that the Mexican state is the only entity entitled to plan and control the National Electric System (SEN), transmission and distribution of energy. This article depicts there are no concessions granted to private sector players that offer distribution and transmission services. Private companies can only participate in this sector when under a contract with CFE or the Mexican State.

Art. 28: Establishes that the Mexican State is the only entity entitled to plan, control the National Electric System (SEN), transmission and distribution of energy.

Law for Foreign Investment: Promotes foreign investment for projects related with the energy industry and creates a framework for strategic areas in energy.

Law for the Energy Transition: This law regulates the use of sustainable energy technologies, sets the responsibilities and goals of clean energy, and the reduction of GHG emissions in the electric industry.

Electricity Industry Law (LIE): This law depicts the criteria for the generation, transmission, distribution and commercialization, of electric energy. It also establishes the criteria for planning and controlling the National Electric System (SEN) and the rules for the operation of the open electricity market, which are executed by CENACE.

Law of CFE: Is the law that regulates the organization, administration, operations, control, evaluation and accountability of the state company CFE.

General Law of the Climate Change: Aims to develop comprehensive strategies, programs and projects to mitigate the effects of climate change caused by hydrocarbons and electricity sectors and to achieve efficient and sustainable use of fossil and renewable energy resources Mexico.

Law of Geothermal Energy: This law establishes the criteria for the scouting, exploration and use of thermal energy in Mexican Territories. It is important to note that this law sets out the possibility of concession that can be granted to private companies.

Law of the Energy Regulators: Created the National Commission of Hydrocarbons (CNH) and the Commission of Energy Regulation (CRE). Whereas before 2013 both entities were part of the Ministry of Energy (SENER) post energy reform, the commissions were given autonomy to create fair market conditions. The Law of Energy Regulators depicts the responsibility and faculties of both entities.

The following institutions play a role in the Mexican energy reforms:

The Mexican Ministry of Energy (SENER) is empowered to establish, conduct and coordinate the country's energy policy regarding electricity, mainly through:

- Direct the planning process and the development of the SEN Development Program

- Establish the criteria for the granting of Clean Energy Certificates (CELs)
- Monitor the operation of the Wholesale Electricity Market and the CENACE determinations

The **National Energy Control Center (CENACE)** is a decentralized public body responsible for the operational control of the National Electric System (SEN), operating the wholesale electricity market, managing open and non-discriminatory access to the national transmission network and general distribution networks. CENACE's main responsibilities are:

- Operating the national electricity system
- Operating the wholesale electricity market
- Managing open and non-discriminatory access to the national transmission network and general distribution networks

The **Energy Regulatory Commission (CRE)**, is responsible for creating fair market conditions among all the participants of the open electricity market. The main functions of CRE are:

Generation permits;

- Determine the consideration of methodologies applicable to Exempt Generators (distributed energy)
- Issue and apply the tariff regulation to which the transmission and distribution is subject
- The operation of Basic Service Providers (residential)
- The operation of CENACE and Related Services not included in the Market
- The final rates of the Basic Supply that are not determined by Federal Executives

The **National Commission for the Efficient Use of Energy (CONUEE)**, is the technical entity responsible for promoting energy efficiency and has the following tasks:

- Promote the optimal use of energy from its generation to its consumption.
- Promote goals in energy efficiency and the mechanisms to achieve those goals to SENER
- Create energy efficiency norms

Institute of Electrical Research (IIE), provides technological support in the field of electricity to the aforementioned entities, as well as to PEMEX and other public and private entities.

Appendix II: Electric market participants

GENERADOR

1. Frontera México Generación, S. de R.L. de C.V.
2. Comisión Federal de Electricidad, (Corporativo)
3. Generadora FÉNIX, S.A.P.I. de C.V.
4. EVM Energía del Valle de México, S.A.P.I. de C.V.
5. GPG Energía México, S.A. de C.V.
6. Iberdrola Generación, S.A. de C.V.
7. CFE Generación I, E.P.S.
8. CFE Generación II, E.P.S.
9. CFE Generación III, E.P.S.
10. CFE Generación IV, E.P.S.
11. CFE Generación V, E.P.S.
12. CFE Generación VI, E.P.S.
13. Electricidad Águila de Altamira, S. de R.L. de C.V.
14. Central Valle Hermoso, S.A. de C.V.
15. Central Saltillo, S.A. de C.V.
16. Central Lomas de Real, S.A. de C.V.
17. Central Anáhuac, S.A. de C.V.
18. Energía Azteca X, S.A. de C.V.
19. Grupo Energético Elan, S.A.P.I. de C.V.
20. Fortius Electromecánica, S.A. de C.V.
21. PIASA Cogeneración, S.A. de C.V.
22. Ammper Generación, S.A.P.I. de C.V.
23. Enel Generación, S.A. de C.V.
24. Compañía Cervecera de Coahuila, S. de R.L. de C.V.
25. Eosol Energy México, S.A.P.I. de C.V.
26. Operadora Tecnoambiental SEA, S.A. de C.V.
27. Tractebel Energía de Monterrey, S. de R.L. de C.V.
28. Energía Renovable del Istmo II, S.A. de C.V.
29. Fuerza y Energía Limpia de Tizimín, S.A. de C.V.
30. Parque Eólico Reynosa III, S.A.P.I. de C.V.
31. Central Generadora Eléctrica Huinalá, S. de R.L. de C.V.
32. Techgen, S.A. de C.V.
33. Cúbico Alten Aguascalientes Uno, S.A.P.I. de C.V.
34. Cúbico Alten Aguascalientes Dos, S.A.P.I. de C.V.
35. E2M Generador, S.A.P.I. de C.V.
36. Solar Park Viborillas, S. de R.L. de C.V.
37. FV Mexsolar I, S.A.P.I. de C.V.
38. FV Mexsolar II, S.A.P.I. de C.V.
39. Fisterra Energy Santa María 1, S.A.P.I. de C.V.
40. Parque Solar Don José, S.A. de C.V.
41. Parque Eólico El Mezquite, S.A.P.I. de C.V.
42. Emerging América Inmobiliaria, S.A. de C.V.
43. Villanueva Solar, S.A. de C.V.
44. Parque Solar Villanueva Tres, S.A. de C.V.

45. Recurrent Energy México Development, S. de R.L. de C.V.
46. Fisterra Energy Orejana, S. de R.L. de C.V.
47. ESJ Renovable II, S. de R.L. de C.V.
48. Engie Eólica Tres Mesas 3, S.A. de C.V.
49. Energía Sierra Juárez Holding, S. de R.L. de C.V.
50. Bluemex Power 1, S.A. de C.V.
51. AT Solar V, S. de R.L. de C.V.
52. Vega Solar 6, S.A. de C.V.
53. Energía Solar San Ignacio, S. de R.L. C.V.
54. Parque Salitrillos, S.A. de C.V.
55. Fisterra Generación, S. de R.L. de C.V.
56. FRV Potosí Solar, S. de R.L. de C.V.
57. Photoemeris Sustentable, S.A. de C.V.
58. Bravos Generación, S.A.P.I. de C.V.
59. 174 PG Torreón, S. de R.L. de C.V.
60. Ciclo Combinado Tierra Mojada, S. de R.L. de C.V.
61. ESJ Renovable I, S. de R.L. de C.V.
62. Tuli Energía, S. de R.L. de C.V.
63. Helios Generación, S. de R.L. de C.V.
64. Tuto Energy II, S.A.P.I. de C.V.
65. Recursos Solares PV de México IV, S.A. de C.V.
66. BNB Villa Ahumada Solar, S. de R.L. de C.V.

SUMINISTRADOR DE SERVICIOS CALIFICADOS

1. Suministro Sustentable de Energía en México, S.A.P.I. de C.V.
2. CFE Calificados, S.A. de C.V.
3. Iberdrola Clientes, S.A. de C.V.
4. American Light and Power MX, S.A.P.I. de C.V.
5. Orden Cardinal, S.A.P.I. de C.V.
6. Ammper Energía, S.A.P.I. de C.V.
7. RC Energy, S. de R.L. de C.V.
8. Bid Energy, S.A. de C.V.
9. Energía Buenavista, S. de R.L. de C.V.
10. FSE Suministradora FENIX, S.A.P.I. de C.V.
11. Estrategia Energía Eléctrica Comercializadora, S.A.P.I. de C.V.
12. Blue Energy and Electricity, S.A.P.I. de C.V.
13. Servicios y Energía México SYEM, S.A.P.I. de C.V.
14. E2M Suministrador Calificado, S.A.P.I. de C.V.
15. Saavi Energía, S. de R.L. de C.V.
16. Suministradora Bennu, S.A.P.I. de C.V.
17. Ric Energy México, S.A.P.I. de C.V.
18. Enel Energía, S.A. de C.V.
19. Sujio, S.A.P.I. de C.V.
20. Ektria Suministro, S. de R.L. de C.V.
21. Panteón Energía, S.A.P.I. de C.V.
22. Tuto Power, S.A.P.I. de C.V.
23. Enicon Energy Suministro, S.A.P.I. de C.V.

COMERCIALIZADOR NO SUMINISTRADOR

1. Enicon Energy and Infrastructure Co., S.A.P.I. de C.V.
2. Vitol Electricidad de México, S. de R.L. de C.V.

3. Mexican Energy Trading Company, S.A. de C.V.
4. Tenaska Energía de México, S. de R.L. de C.V.
5. Energía EUM, S. de R.L. de C.V.
6. Edecsamex, S.A. de C.V.
7. Diversidad, S.A. de C.V.
8. MMA Energy México, S.A. de C.V.
9. Regulus 333, S.A.P.I. de C.V.

GENERADOR DE INTERMEDIACIÓN

1. CFE Intermediación de Contratos Legados, S. A. de C. V.

SUMINISTRADOR DE SERVICIOS BÁSICOS

1. Suministrador de Servicios Básicos, E. P. S. CFE

Appendix III: Electric nodes per area

Name	Company	Power MW	State
Aura Solar 3	Gauss	25	Baja California Sur
Santa Rosalia	CFE	1	Baja California Sur
Plantronics	3Tek Solar	1	Baja California Norte
Rumorosa Solar	Ienova	41	Baja California Norte
Cerro Prieto	CFE	3	Baja California Norte
Flextronics San Luis	Flextronics	2	Sonora
Oomaas Nogales	Oomapas/COCEF	1	Sonora
Pima Solar	Ienova	110	Sonora
Tuto II	Tuto Energy	137	Sonora
Orejana	Zuma	125	Sonora
Hermosillo	Iberdrola	100	Sonora
Bluemex Power 1	EDF	90	Sonora
Coppel Uno	Solarescape	1	Sonora
Yoreme	ERA Exacta	1	Sonora
Kaixo	BAS Corporation	64	Chihuahua
Flextronics 1	Flextronics	2	Chihuahua
Santa Maria	Zuma	148	Chihuahua
Ahumada Cinco	AMMPER	30	Chihuahua
Loa Santos Solar	Buenavista Renovables	20	Chihuahua
Ahumada Uno	AMMPER	30	Chihuahua
Ahumada Tres	AMMPER	30	Chihuahua
Ahumada Cuatro	AMMPER	30	Chihuahua
El trece Solar	Invex/Bester	30	Chihuahua
Camargo	Balam	30	Chihuahua
Torrencitos	Invex/Bester	30	Chihuahua
Villanueva Solar	ENEL	468	Coahuila
Villanueva Tres	ENEL	360	Coahuila
Parque Solar Coahuila	Macquarie	20	Coahuila
Laguna Solar	174 Global Power	101	Coahuila
La Laguna	Balam	30	Durango
TAI Dos	Eosol	6	Durango
TAI Tres	Eosol	4	Durango

TAI Uno	Eosol	16	Durango
TAI Cinco	Eosol	30	Durango
TAI Cuatro	Eosol	6	Durango
TAI Seis	Eosol	30	Durango
La Trinidad	Eosol	60	Durango
Alderaban	Reden Solar	15	Zacatecas
Potosi Solar	FRV	300	San Luis Potosi
Santiago	Iberdrola	170	San Luis Potosi
BMW SLP	BMW	5	San Luis Potosi
Tepezala	Ienova	100	Aguascalientes
Solem II	Alten/Cubico	140	Aguascalientes
Solem I	Alten/Cubico	150	Aguascalientes
Autren	IUSA	1	Aguascalientes
Aguascalienes Potencia I	Black Rock Infrastructure Fund II	63	Aguascalientes
Viborillas	Jinko Solar	100	Jalisco
HP	HP	1	Jalisco
Flextronics 2	Flextronics	1	Jalisco
Jalisco Uno	Fortius	8	Jalisco
Ecopur	Ecopur	3	Guanajuato
Don Jose	ENEL	225	Guanajuato
Guanajuato Solar	Xelio	60	Guanajuato
Solar Apaseo	Granite Chief	1	Guanajuato
El Tlacote	Prosolia	1	Queretaro
Plants Solar Guajiro	Atlas Renewable Energy	129	Hidalgo
IUSASOL Base	IUSA	1	Estado de Mexico
Iusasol 1	IUSA	18	Estado de Mexico
Magdalena II	ENEL	220	Tlaxcala
Lazaro Cardenas	Alter EnerSun	30	Yucatan
San Ignacio	Jinko/Aldesa	18	Yucatan

Appendix IV: Additional interview findings

Interview with Alberto de la Fuente, President and Director General of Shell Mexico

Q: In your opinion, what will the future of Shell look like in terms or renewable energy?

One of our key strategic ambitions is to thrive through the energy transition towards a low-carbon energy system. Even as Shell continues to provide the oil and gas the world needs, the company aims to reduce emissions of greenhouse gases per unit of energy our customers use. We will seek to do so by transforming our product mix over time. This is our industry leading net carbon footprint ambition.

Shell's ambition is to move with society towards achieving the goal of the Paris Agreement and decrease our net carbon footprint by around 20% by 2035, and by around 50% by 2050. Progress will be reviewed every five years to ensure Shell keeps pace with society: we cannot fall behind, and no business can survive if it moves ahead of what its customers want.

To achieve our ambition Shell must improve the efficiency of operations and adapt our product offering. It is likely to mean more natural gas in the company's energy mix because gas produces between 45% to 55% fewer greenhouse gas emissions than coal when used to generate power, according to data from the International Energy Agency.

Shell's New Energies business will have an important role. We plan to invest US$ 1-2 billion per year on average in New Energies until the end of the decade.

As the energy transition unfolds, we must continue to improve our fuels and lubricants to ensure maximum efficiency in traditional engines. And, over time, new fuels will become increasingly important for Shell, including low-carbon biofuels, hydrogen and battery power. We are already one of the world's largest suppliers of low-carbon biofuels through the Raízen joint venture. Raízen also produces some biofuel from the non-edible parts of plants and Shell is developing other advanced biofuel processes.

The company is also helping to build an infrastructure for hydrogen-powered vehicles. An example is the nationwide network of refueling points the H2 Mobility joint venture is developing in Germany. And we are involved in battery charging, with projects including the roll-out of Shell Recharge points on the company's forecourts. Another example is our acquisition of NewMotion, the owner of one of Europe's largest electric vehicle charging networks.

Producing, trading and supplying electricity, including from renewable sources, will also become a significant business for Shell. We are already making early progress. We are one of the top three power wholesalers in the USA. We are also the largest shareholder in Silicon Ranch, a leading US developer, owner and operator of solar energy plants. And Shell owns UK-based First Utility, allowing us to supply energy directly to hundreds of thousands of homes.

Taking greenhouse gas emissions out of some areas of the global economy will, nevertheless, present a very stubborn challenge for the world. For example, there are no easy, zero-carbon answers yet for steel and cement production or aviation.

Projects that capture carbon dioxide and store it away will be an important part of the global solution. Shell's Quest carbon capture and storage (CCS) facility in Canada already prevents over a million tons of CO2 from reaching the atmosphere each year.

As we seek to meet our net carbon footprint ambition, Shell is likely to be involved in more CCS projects, and in other projects that create new forests and wetlands that can remove CO2 from the atmosphere.

Interview with Tjerk Suurenbroek, Business Development Manager at The Association of Dutch Suppliers in the Offshore Energy Industry (IRO) and Daniëlle Veldman, CRM Manager at Netherlands Wind Energy Association (NWEA), both representing the Dutch wind energy sector.

Q: How would you describe the current status of the wind energy market in the Netherlands?
The Netherlands has made large steps in the years following the Paris Climate Accord in 2013 and created a new market for offshore wind energy driven by the targets set in this agreement. Offshore wind is one of the main elements in energy mix of the Netherlands. The country created a public-private partnership where the Dutch government plays a vital role in licensing, marine spatial planning and tenders, greatly contributing to reducing the risks for contractors. Improvements in the supply chain have led to a cost reduction of 60% compared to 7 years ago. This means the The Netherlands have a solid basis to start exporting know-how of about how to set up an offshore wind energy policy in a country.

The Netherlands currently sources 8% of its energy from renewables, resulting in the lowest score in Europe in terms of percentage renewable energies of the total energy consumption. In the coming 20 to 30 years the Netherlands is focusing on offshore wind in its energy mix. Government and private sector have set ambitious targets to reach 11.5GW from offshore wind projects by 2030.

In terms of onshore wind community participation and social acceptance are key. As onshore wind in the Netherlands has a decentralized approach and each region is responsible for its own renewable energy planning, it is important that communities participate and get a financial gain to have greater ownership over projects. In term of acceptance social stakeholders are reluctant to accept onshore wind in their close vicinity due to noise and visibility issues. Because of this, there has been a shift from onshore to offshore wind energy in the Netherlands.

Q: Despite efforts, The Netherlands is still one of the lowest ranking countries in the EU in terms of renewable energy use. Why do you think this is so, and how can it be changed?
One of the main factors is that the Netherlands started far too late with its renewable energy policy and investment. It was only in 2013-2014 that the government agreed its first energy accord. Due to its large gas reserves; the Netherlands have always leaned heavily on fossil fuels for its energy supply. This deterred the sense of urgency needed to start making the shift.

In terms of implementation a clear direction for energy transition is missing. There is no holy grail in one particular type of renewable energy. Wind, solar, geothermal and nuclear will all need to be part of the mix. Although the sense of urgency is understood by most people, clear ownership and leadership is missing.

Q: There are those who doubt the ability of wind energy to be an effective source of renewable energy. Some have also raised concern about the ability to recycle wind turbines. What is your opinion of on this?

Wind has a yield that is high enough. There is indeed a lot of discussion on the performance of offshore wind in terms of providing consistent electricity. There is a loss when wind levels are down, which makes it less reliable. Yet, it is an effective source when there is wind. The same can be said for solar power. What is needed is other sources of energy which that can compensate when the supply is down.

Wind energy is not a mature sector yet, unlike oil and gas. There is still a lot of ongoing innovation and development, which means that very few wind parks face decommission. One of the NWEA members recycles blades by using them as material to reinforce bridges and coastlines. There is also a technique called pyrolysis, which heats the material and returns it back into its original composites. These composites can then be reused for new turbines. This is still an expensive process, but it is undergoing further development. There are also many countries at an early phase of wind energy, which can receive still functionable wind turbines from countries where they have been decommissioned. This is an effective way to extend their life cycle.

Appendix V: General laws and NOMS waste sector

These are the main norms and laws that currently apply in Mexico regarding waste management:

- LGPGIR, General Law for the Prevention and Integral Management of Residues.
- General Law for the Balance and Protection of the Environment.

- Manual for the Municipalities that guide the integral management of municipal waste.

- NOM-083-SEMARNAT-2003: Norm that specifies site selection, construction, management, surveillance, and complementary infrastructure for a landfill of Urban Waste and Special Management Waste.

- NMX-AA-020-SCFI-2008: Determines the semi-volatile organic compounds in products PECT

- NMX-AA-001-SCFI-2008: Liquids and solutions that causes steel and carbon corrosion.

- NOM.040-SEMARNAT-2002: Regulates the ovens that produce hydraulic concrete.

- NOM-052-SEMARNAT-2005: Depicts the criteria and process for the selection of hazardous residues.

- NOM-053-SEMARNAT-1993: Indicates the process for the extraction test that identifies the hazardous compounds.

- NOM-054-SEMARNAT-1993: Indicates the process to determine the incompatibility between one or more residues consider as hazardous on the norm NOM-052-ECOL-1993

- NOM-055-SEMARNAT-2003: Establishes the requirements that a site needs to comply with to storage hazardous residues.

- NOM-056-SEMARNAT-1993: Establishes the requirements for the design and construction of a site to storage hazardous residues.

- NOM-057-SEMARNAT-1993: Establishes the requirements for the design and construction for cells to storage hazardous residues.

- NOM-058-SEMARNAT-1993: Establishes the requirements for the operations for a storage of hazardous residues.

- NOM-087-SEMARNAT-SSA1-2001: Indicates the classification and operation of biological infectious residues.

- NOM-098-SEMARNAT-2002: Limits the emissions from the burning of waste.

- NOM-133-SEMARNAT-2015: Stipulates environmental protections against BCPs

- NOM-138-SEMARNAT/SSA-2012: Stipulates a maximum threshold of hydrocarbon in soils, and the actions to compensate.

- NOM-145-SEMARNAT-2003: Indicates standards with respect to storage of residues in saline caves.
- NOM-147-SEMARNAT/SSA1-2004: Provides criteria to determine the pollution in soils of different elements.
- NOM- 157- SEMARNAT-2009: Provides criteria and guidance for treatment and selection of mining residues.
- NOM-161-SEMARNAT-2011: Provides guidance, criteria, and requirements for municipalities to design and execute their municipal waste management plan, including urban and special management waste.

Appendix VI: Mexican Companies Active In The Biogas Industry

1) The Bordo Poniente, is a landfill in Mexico City which will soon count one of the biggest waste treatment plants with the ability to generate electricity from biogas. This will used to (partly) supply the energy consumed by public lighting, public buildings and transportation services as metro.

2) SIMIPRODE, is the first landfill that produces electricity by using biogas in Monterrey, one of the biggest cities of Mexico located in the north of the country. The plant produces 7MW. This is enough to light half of the local public lighting, the subway and public offices. They collect 4.5 tons of waste daily.

3) Bio Bolsa, is one of the oldest companies in Mexico that produces bio-digestors, in the form of a bag system. They help to install the bag and if needed the engine to produce electricity and the system to collect heat for heating purposes. They started with small scale production; the first product with a capacity of 4m3. Nowadays the have the possibility to create bags and systems from the 4m3 to 400m3, costing 700 Euro to 6,000 Euro. They are already available internationally with export to South America and planned expansion to Europe. They claim that a BioBolsa will allow a farmer to generate electricity, heat and fertilizer, by using the manure of two cows. Two hundred cows would provide sufficient manure to generate electricity for grid supply.

4) Red Mexicana de BioEnergia, is a network that focuses on the diffusion of knowledge about bio energy through spreading information, supporting research and conducting workshops. The aim is to increase the participation in biogas production efforts. They also create books that help to understand the different technologies.

5) Nopalimex, from Jalisco, conducted research of biogas production using the “nopal”, a cactus that is widely used in Mexico. This started as a project to provide gas for the mill and furnaces of a company that produces tortilla chips and nachos in huge number for the region. After this, they patented the technology and started the second phase in which they upgrade de biogas into biofuel for cars. Currently they have a contract with the municipality to run cars on this fuel. The price is 12 Mexican pesos/m3 (0.5 Euro/m3)

6) Generators in Milpa Alta; In the Southern part of Mexico City there is an area called Milpa Alta. Ay bio-waste treatment plant was built here which can convert 170m3 of biogas into 175kW/h. The investment was about US$750 thousand dollars. Currently, it generates electricity for this part of the city.

7) CEMEX ENERGIA, is a division of the international cement company CEMEX. They have a Pilot Project of 70 ha to plant nopal and to produce biogas for their ovens. They say they have 680 million dollars to invest. They need help with the proper technology.

8) Fenosa, is one of the biggest natural gas companies that already has 16,000km of their own pipelines. They are interested in producing biogas and cleaning in order to reach greater volume and cheaper gas to sell to their customers.

9) Enestas, a company that also offers natural gas, providing services tailored to their customers with respect to the customer’s demand. They also offer infrastructure for storage of gas. They do not have pipelines; however, they have their own fleet to transport gas.

Appendix VII: Electric Vehicle production per state

EV per state/per year	2016	2017	2018	2019	total
Aguascalientes	1	0	2	0	3
Baja California	3	5	3	1	12
Baja California Sur	0	0	0	0	0
Campeche	0	0	0	0	0
Coahuila de Zaragoza	2	1	1	0	4
Colima	2	0	0	0	2
Chiapas	0	0	0	54	54
Chihuahua	32	0	2	0	34
Ciudad de México	95	140	66	56	357
Durango	2	0	2	0	4
Guanajuato	2	7	4	14	27
Guerrero	1	0	0	0	1
Hidalgo	29	1	0	2	32
Jalisco	31	30	19	38	118
México	7	12	4	18	41
Michoacán de Ocampo	2	1	2	4	9
Morelos	9	2	1	5	17
Nayarit	1	0	1	0	2
Nuevo León	11	16	13	9	49
Oaxaca	3	0	0	5	8
Puebla	3	5	6	6	20
Querétaro de Árteaga	2	6	4	10	22
Quintana Roo	1	0	1	2	4
San Luis Potosí	1	3	0	0	4
Sinaloa	2	5	0	2	9
Sonora	3	0	2	2	7
Tabasco	0	0	0	0	0
Tamaulipas	3	2	0	0	5
Tlaxcala	1	0	0	1	2
Veracruz de Ignacio de la Llave	3	0	0	0	3
Yucatán	2	0	1	1	4
Zacatecas	0	1	1	1	3
Not specified	0	0	66	0	

Appendix VIII: General laws and NOMS Green Buildings

The National Housing Commission (CONAVI) promotes energy efficient solutions in residential buildings. In collaboration with the German PassivHaus institute special software has been applied to build 230,000 houses in Mexico. (GlobalABC, 2018)

The Sustainable Building Certification Program (Programa de Certificación de Edificios Sustentables, PCES) promotes energy efficiency systems in new and existing buildings. (SEDEMA, 2006)
In the year 2013 the norm NMX-AA-164-SCFI-2013, "Sustainable building; criteria and minimum environmental requirements" ("Edificación sustentable, criterios y requerimientos ambientales mínimos") was published . (Mexico, 2018)

Other norms that apply for the energy efficiency are (CONUEE, 2013):

- NOM-003-ENER-2011: Thermal efficiency for water heaters for commercial and residential use.
- NOM-004-ENER-2014: Energy efficiency for water pumps for residential use.
- NOM-007-ENER-2014: Energy efficiency for lighting systems for non-residential buildings.
- NOM-008-ENER-2001: Energy efficiency for buildings facades for non-residential buildings.
- NOM-009-ENER-2014: Energy efficiency for industrial thermal insulation.
- NOM-011-ENER-2006: Energy efficiency for AC
- NOM-018-ENER-2011: Thermal insulation for buildings
- NOM-020-ENER-2011: Energy efficiency for residential buildings facades.
- NOM-024-ENER-2012: Thermal and optic glass requirements for buildings.
- NOM-030-ENER-2016: Energy efficiency for LED lights

There are 422 Mexican norms related with the construction that apply to all new buildings in Mexico. (ONNCCE, s.f.)

Mexico was the first country to develop a NAMA (Appropriate National Mitigation Actions) in 2018. These are voluntary activities aimed at reducing greenhouse gas (GHG) emissions in developing countries. In Mexico these are oriented to energy efficiency of social housing. (GlobalABC, 2018)

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