Ministry of Foreign Affairs

Opportunities in the Mexican Renewable Energy Sector

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Opportunities in the Mexican Renewable Energy Sector

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Executive summary

The Energy Reform opened the production and distribution of oil, gas, petrochemicals and electricity to private investors, but also increased the share of renewables in the energy sector. The use of energy from renewable sources is promoted under Mexico's plan to increase the share of clean sources for the electricity generation. The Mexican government has the objective to generate at least 35% of the power from clean sources by 2024 and at least 50% by 2050. It also aims to reduce the greenhouse gasses and compounds (GHG) by 50% in 2050 in relation to those emitted in 2000.

These ambitions and the opening of the energy sector for private investors have brought opportunities for Dutch companies in the renewable energy sector. This report identifies the opportunities for Dutch small and medium-sized companies.

Currently, 20.8% of the electricity comes from clean energy, of which 15.5% comes from renewable energy. Mexico will need a fast transition to achieve its goal to generate 35% of the electricity from clean energy in 2024.

Hydropower has been for many years the biggest renewable energy source of electricity in Mexico, but due to arid conditions in big parts of Mexico, it's not expected to grow much further. The types of renewable energy with the best prospects in Mexico are photovoltaic, wind and geothermal energy and the area of application with the greatest opportunity for renewable energy is the transport sector. Remarkable is that the Mexican government hasn't set a goal yet for the share of renewable energy for the use in this sector.

The Netherlands has an international reputation in renewable energy research. It is a leader in solar power systems, wind turbines technology and green gas. Besides, it has great expertise in the use of geothermal energy for greenhouses and in small-scale hydroelectricity. It has also become a leader in technology for electric vehicles, especially in public charging infrastructure.

On the basis of a policy analysis, an analysis of the Mexican energy market and an inventory of the Dutch know-how and technology as regards to renewable energy, it appears that the biggest opportunities for Dutch SME's lie in:

- EV technology in the tourism sector
- EV technology for high use vehicles, like taxi's and public transport.
- Fast charging infrastructure with 100% renewable energy
- Renewable energy technology for greenhouses

Contents

1. Introduction

Mexico has risen from the 30th place to the 6th place on the Ernst & Young's Renewable Energy Country Attractiveness Index (RECAI) between 2013 and 2016 (EY, 2016; EY, 2013). In 2017 it was the country with the highest growth in the renewable energy sector. According to Rubin (2018), Mexico's renewable energy sector received 6 billion dollars on investments in 2017, which is nine times more than in 2016.

This increase in investments is largely due to the Energy Reform, in which the Mexican government implemented a series of institutional reforms to end the state-owned monopoly to enhance economic growth and competitiveness in the Mexican energy sector (Vietor, 2017). The energy monopoly in Mexico lasted over 70 years and was held by stated-owned *Petróleos Mexicanos* and the Federal Electricity Commission (CFE).

The Reform started in 2013, but it was in 2016 when everything changed in the energy sector. The first two power auctions were held that year and that led to record low electricity prices (Toguna, 2016) . The Energy Reform opened the production and distribution of oil, gas, petrochemicals and electricity to private investors, but also increased the share of renewables in the energy sector.

The upcoming president Andrés Manuel López Obrador, has indicated that he wants to continue stimulating the use of renewable energy to reduce the dependence on energy from abroad. The Mexican government needs to continue transforming the energy sector to a more sustainable one because it expects that the Mexican energy demand will increase significantly because of population and economic growth (IEA, 2017). The total energy demand has already grown by 25% since 2000, but it's still less than 40% of the average of OECD countries, so it's expected to rise (OECD/IEA, 2016).

The country has therefore already implemented the General Law for Climate Change in 2012 that has set the goal to generate 35% of the electricity from clean sources by 2024 (IEA, 2017a). It has also set the goal to reduce the greenhouse gasses and compounds (GHG) by 50% in 2050 in relation to those emitted in 2000 (IEA, 2017a). These ambitions and the opening of the energy sector for private investors have brought opportunities for Dutch companies in the renewable energy sector.

This report is prepared for the Embassy of the Kingdom of the Netherlands in Mexico with the objective to identify these business opportunities for small and medium -sized enterprises (SMEs). It aims to map the current situation and prospects of the Mexican renewable energy sector and the expertise of the Dutch as regards to renewable energy. The report also proposes a strategy for the embassy to strengthen the competitive position of Dutch companies in the Mexican renewable energy sector.

The report begins in chapter 2 with a policy analysis, which describes the legal and regulatory framework that promotes renewable energy in Mexico. In chapter 3 it discusses the stakeholders and in chapter 4 the current state of the Mexican energy market. Chapter 5 sets out the Dutch knowledge, services, products and players in the renewable energy sector. Chapter 6 describes the opportunities for Dutch companies.

2. Government policies

This chapter refers to the regulatory framework, the ambitions and subsidies in Mexico for renewable energy. Paragraph 2.1 gives the definition of renewable energy that is used in the Mexican legislation. Paragraph 2.2 describes the ambitions and paragraph 2.3 the actions and programmes as regards to renewable energy.

2.1. Definition of clean and renewable energy

The definition of renewable energy that is managed in the Mexican Law of the Energy Transition is the following (SENER, 2017a):

"Those whose source resides in phenomena of nature, processes or materials likely to be transformed into energy usable by the human being, which regenerates naturally, so is available on a continuous or periodic basis, and that doesn't release pollutants when generated"

Renewable energy includes bio-, wind-, geothermal-,hydroelectric-,solar energy. Clean energy includes besides the different types of renewable energy also the efficient cogeneration, nuclear energy, black liquor and energy from kinetic energy recovery systems (SENER, 2017a; SENER, 2017b). Natural gas is left out as clean energy in the Transition Law (Meana, 2015).

2.2. Regulatory framework of the energy transition

The use of energy from renewable sources is promoted under Mexico's plan to increase the share of clean sources for the electricity generation. The General Law of Climate Change (LGCC), that got published in 2012, has the objective to generate at least 35% of the power from clean sources by 2024 and at least 50% by 2050 (IEA, 2017a).

The LGCC also includes a set of goals in order to guide Mexico's performance towards a low carbon economy. It aims to reduce the greenhouse gasses and compounds (GHG) by 50% in 2050 in relation to those emitted in 2000 (IEA, 2017a).

Another important law that promotes the transformation towards sustainable energy in the long term, is the Mexican Law of the Energy Transition, which got published in 2015 (SENER, 2016a).

The Law of the Energy Transition defines four planning instruments for the energy transition:

- The Strategy of Transition to Promote the Use of Cleaner Technologies and Fuels (*Estrategia de transición para promover el uso de tecnologías y combustibles más limpios*)
- The Special Programme of the Energy Transition (PETE)
- The National Programme for the Sustainable Use of Energy (PRONASE)
- The Energy Efficiency Roadmap (*Hoja de Ruta de Eficiencia Energética*).

2.3. Actions and programmes

Around 56,5% of all public investments in Mexico is directed towards energy projects (Alemán-Nava, 2014). The biggest investments are the ones for hydrocarbons and amount 8.9 billion pesos. The Sectoral Fund Sustainability of SENER is the second biggest subsidy. It concerns clean and renewable energy and amounts 3.7 billion pesos (CONACYT, 2016). The subsidy is meant for educational institutions, centres of investigation, companies and individuals.

Direct funding for renewable energy programmes is provided by the Fund for the Energy Transition and Sustainable Energy Use (IRENA, 2015). The Fund for Sustainable Energy dedicates on renewable energy research and technology projects.

Mexico has created with these funds some programmes that try to increase public and private investment in the clean and renewable energy sector like the following (IEA, 2017a):

- **The National Inventory of Clean Energies (INERE)**, a statistical and geo-referenced service that shows renewable energy potential and operational projects in Mexico.
- **The National Atlas of Potential Zones for Clean Energy Development (AZEL) ,** that provides information on potential zones for power generation by clean technologies. It is a geo-referenced tool that shows exclusion zones based on technical, environmental and social constraint.

To increase public and private investments the Mexican government has also reduced the number of days required from licensing, permitting and constructing a renewable energy project from 620 to 465 on average (IEA, 2017a). Furthermore it has created an Integrated Energy Services Program, that seeks to provide to the Federal Public Administration buildings self-supply capacity for electricity from renewable energy to reduce the costs for operation.

It has also created a programme of productive activities with renewable energy in rural areas and programmes to achieve market competitiveness in technologies such as geothermal, small and mini hydropower and bioenergy (KPMG, 2015; E. Villanueva Arcos, personal communication, June 19, 2018).

To provide more long-term certainty for foreign and private investors, the government has taken some measures like:

- The formation of a generation capacity market, designed to ensure capacity adequacy through remuneration of the fixed costs that are not covered by the energy market (OECD/IEA, 2016).
- The establishment of Clean Energy Certificates (CECs), that will be bought and sold at prices based on the supply and the demand. Firms that generate clean energy will earn CECs and the final-users will buy them from the producers. The CEC's get issued for each MWh of clean energy generated (Vietor, 2017). This increases the revenue for clean energy producers. The annual quota obligation for electricity consumption from clean sources for 2018 is 5% (IEA, 2017). In 2022 it will be 13.9% (SENER, 2018).
- Provision for long-term contracts and auctions, locking in prices for generators of clean energy (for a period of 15 year), capacity (15 years) and Clean Energy Certificates (20 years) (OECD/IEA, 2016).

3. Stakeholder analysis

In this chapter the Mexican players in the field of renewable energy will be appointed. Paragraph 3.1. sets out the most relevant government agencies involved in the renewable energy sector. Paragraph 3.2. explains who are the participants in the Mexican wholesale electricity market and paragraph 3.3. describes the most relevant Mexican renewable energy associations.

3.1. Government agencies involved in renewable energy

The most relevant institutions that are involved in the renewable and clean energy sector are the following:

The Ministry of Energy (SENER) is responsible for the design, leading and coordination of the national energy policy. SENER has established the requirements and criteria for the Clean Energy Certificates (CEC). So far, SENER has only set a goal for the share of renewable energy for electricity generation and not yet for the share of renewable energy for the use of transport and heat (IEA, 2017).

The Federal Commission for Electricity (CFE) transformed from monopoly into a state productive enterprise. Before the reform electricity in Mexico was mostly generated and controlled by CFE. Since the reform the CFE has been divided into subsidiaries for transmission, distribution and power generation (Yaneva, Tisheva & Tsanova, 2018).

The Energy Regulatory Commission (CRE) grants power generation permits. It issues standards, directive, methodologies and further administrative procedures for renewable and clean energy technologies and grants, regulates and monitors the fulfilment of the requirements of the CEC's (IEA, 2017).

The Nacional Centre for Energy Control (CENACE) is in charge of operating the wholesale electricity market to ensure least-cost dispatch of all power plants. It also plans the power system, defines capacity requirements, and runs long-term auctions (IEA, 2017).

The National Institute of Electricity and Clean Energy (INEEL) is a Mexican public research institute, which conducts innovation projects as regards to clean energy and energy saving (BNamericas, n.d.a).

The National Commission for the Efficient Use of Energy (CONUEE) is responsible for promoting the efficient use of energy. For instance, it sets goals for the energy efficiency in Mexico and promotes scientific research in this area (BNamericas, n.d.b).

3.2. Participants Mexico's wholesale electricity market

The energy reform made a wholesale electricity market in Mexico possible, which allows private companies to produce and sell electricity and to compete with CFE and each other (Mirec, 2018). Transmission and distribution of electricity is still the work of CFE, but the private sector is able to participate in these activities through agreements and joint ventures with state-owned agencies.

The participants in the Mexican electricity market, who are illustrated in figure 1, are the following (KPMG, 2015; Yaneva et al., 2018):

The Power Generators can be private generators or independent subsidiaries of the CFE. Generators are permitted to sell electricity directly in the market through the **CENACE** to a Qualified Services Supplier, to a Basic Services Supplier or to a Qualified User.

The Qualified Service Suppliers may purchase products in short-term and long-term markets, but may only supply to Qualified Users, users who consume 1MW or more (like Shopping Malls and amusement parks), for which the supply is non-regulated. Qualified suppliers must acquire at least 5 % of its energy from clean sources in 2018 and 13.9% in 2022.

Basic Services Suppliers purchase power from power generators and provide regulated supply to Basic users. Basic suppliers must also acquire at least 5% of its energy from clean sources in 2018 and 13.9% in 2022.

Qualified Users consume more than 1 MW. They can buy directly from Power Generators, through the CENACE or from Qualified Services Suppliers.

Basic Users are users that consume less than 1MW, like homes and small shops.

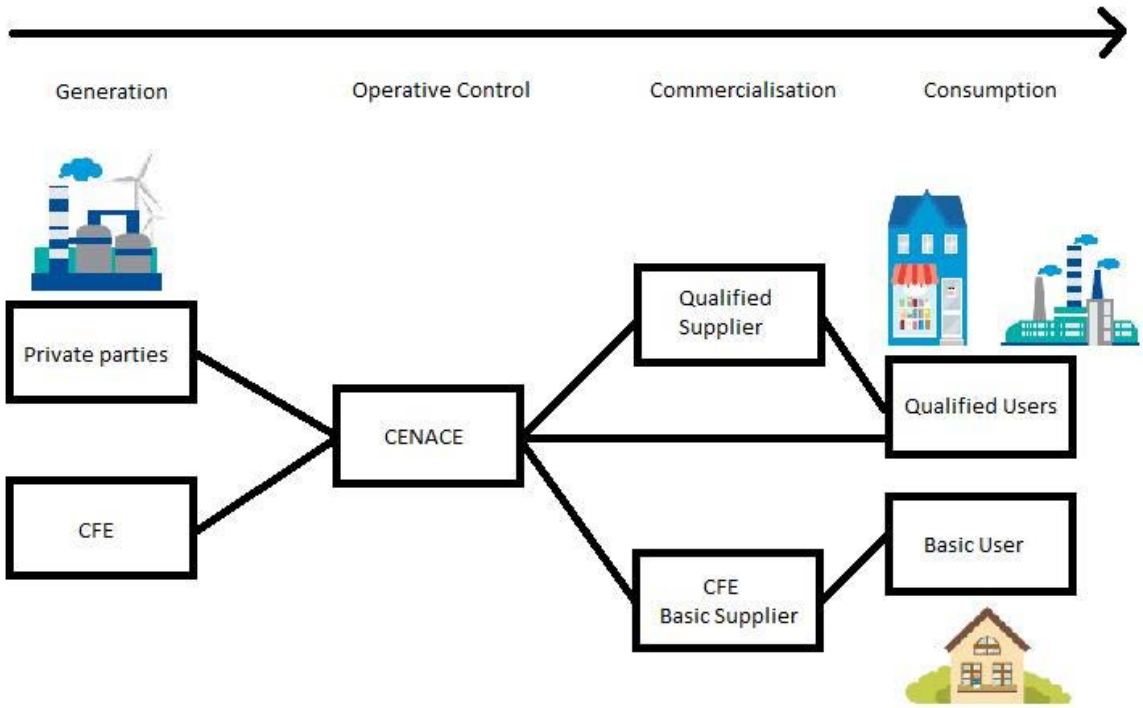

FIGURE 1. SIMPLIFIED IMAGE OF THE MEXICAN WHOLESALE ELECTRICITY MARKET. IMAGES RETRIEVED FROM: KPMG.

3.3. Mexican Renewable energy associations

The most relevant Mexican renewable energy associations are shown in table 1.

TABLE 1. MEXICAN RENEWABLE ENERGY ASSOCIATIONS

Renewable energy associations		
Solar	Mexican Solar Photovoltaic Associations (ASOLMEX)	www.asolmex.org
	Mexican Association for Solar Energy (ANES)	www.anes.org
	Mexican Innovation Centre for Solar energy(CEMIE-Sol)	www.cemiesol.mx
Wind	The Mexican Wind Energy Association (AMDEE)	www.amdee.org
	Mexican Innovation Centre for Wind Energy (CEMIE-Eolico)	www.cemieeolico.mx
Geothermal	Mexican Geothermal Association (AGM)	www.geotermia.org.mx
	Mexican Innovation Centre for Geothermal Energy (CEMIE-Geo)	www.cemiegeo.mx
Biomass	Network of Bioenergy (REMBIO)	www.rembio.org.mx
	Mexican Innovation Centre for Bioenergy (CEMIE-Bio)	www.cemiebioalcoholes.org
Hydropower	Mexican Hydro Power Association (AMEXHIDRO)	www.amexhidro.org
	Mexican Innovation Centre for Oceanic energy (CEMIE-Oceano)	www.cemieoceano.mx

4. Market analysis of the Mexican energy sector

This chapter focuses on the current status and the developments of the Mexican energy sector. Paragraph 4.1. gives an image of the current status of the Mexican energy sector. Paragraph 4.2. describes the development of the different types of renewable energy. Paragraph 4.3. sets out the energy demand and CO2 emissions per sector and paragraph 4.4. concludes with the biggest findings of the analysis of the Mexican energy market.

4.1. Current Status of Mexico's energy sector

Mexico's energy mix is dominated by oil and gas , but partly due to the reduction of the costs of renewable energy, the share of renewable energy is increasing (OECD/IEA, 2016; SENER, 2016b). From June 2016 to June 2017, the capacity for the generation of electricity from renewable energy increased by 6.9% (SENER, 2017b).

The average share of renewable energy for the countries of the International Energy Agency was in 2015 10% of the total primary energy supply and 23.5% of the electricity generation. In Mexico, renewable energy accounted for 8.3% of its total primary energy supply and for 15.2% of its electricity generation in 2015 (IEA, 2017a).

As is shown in figure 2, 15.5% percent of the electricity came from renewable sources in the first six months of 2017; 5.3% came from other clean energy sources like nuclear power and efficient cogeneration and 79.2% came from fossil fuels (SENER, 2017b). Mexico will need a fast transition to achieve its goal to generate 35% of the electricity from clean energy in 2024.

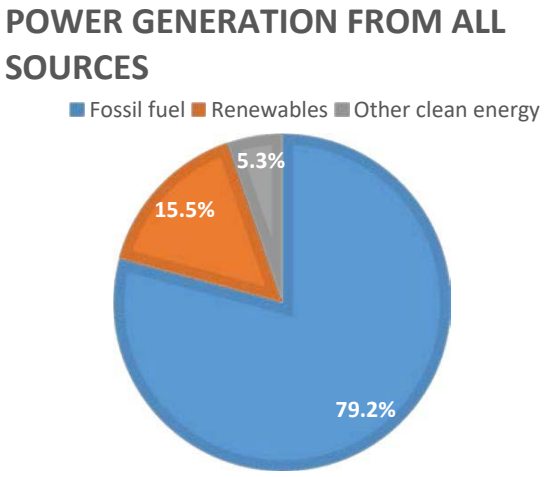

FIGURE 2. SOURCES OF POWER GENERATION IN MEXICO FROM THE 1TH OF JANUARY TO THE 30TH OF JUNE 2017

Figure 3 shows the distribution of the power generation of renewables over the different types of renewable energy; all the percentages together add up to 15.5%. As is displayed in figure 3, the biggest part of the electricity from renewables comes from hydropower (SENER, 2017b). Hydropower has been for years the biggest renewable source of electricity in Mexico, but due to arid conditions in big parts of Mexico, energy from hydropower will not grow further (IEA, 2017a) . However, wind and solar power production have increased tremendously and they still have a lot of potential.

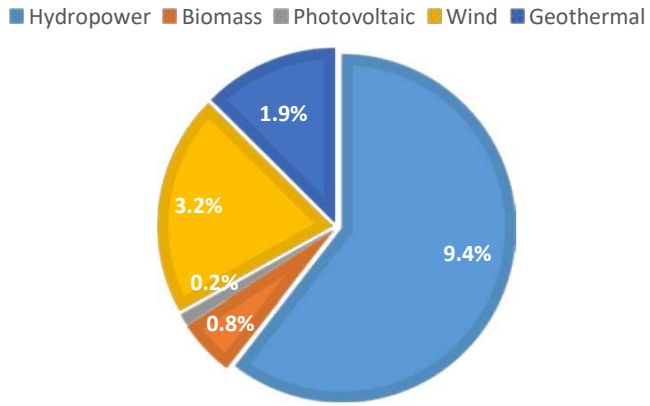

FIGURE 3. DISTRIBUTION OF THE POWER GENERATION OF RENEWABLES OVER THE DIFFERENT TYPES OF RENEWABLE ENERGY FROM JANUARY 1ST TO JUNE 30TH 2017.

4.2. The development of renewable energy in Mexico

Mexico is highly rich in renewable energy sources, but the potential of this type of energy has not fully been exploited. This paragraph discusses the potential and prospects of the renewable energy sources in Mexico.

4.2.1. Solar

According to Víctor Ramírez, the executive director of the National Solar Energy Association (ANES), 60 percent of the new energy that will be injected into the grid from 2018 will be from solar power (Mexico Energy Review, 2017).

Energy from the sun can be used to generate electricity or to heat water or the inside of buildings, for example. There are three different types of solar energy technology (EIA, n.d.a.):

- Photovoltaic cells: convert sunlight directly into electricity.
- Solar thermal power plants: generate high temperature with concentrated sunlight and convert it to electricity.
- Solar heating systems: collect the heat from solar radiation with heat-absorbing liquids and transfer it to a heat storage system.

Mexico is the third most attractive country in the world to invest in photovoltaic solar projects (ProMexico, 2016). The potential of solar energy in Mexico is so high because the country is located in the so called “solar belt” which has a radiation exceeding 5kWh per square meter per day (Alemán-Nava, 2014). The complete country is located between 15 ° N and 35 ° N, the most favourable latitudes for solar radiation(Pérez-Denicia et al., 2017).

Photovoltaic solar energy only represented 0.2% of the power generation and 0.6% of the total capacity in Mexico in June 2017, but it has a big potential, as is shown in figure 4 (SENER, 2017b). There have been more photovoltaic systems installed in Mexico in the last two years than in the last three decades (Promexico, 2017).

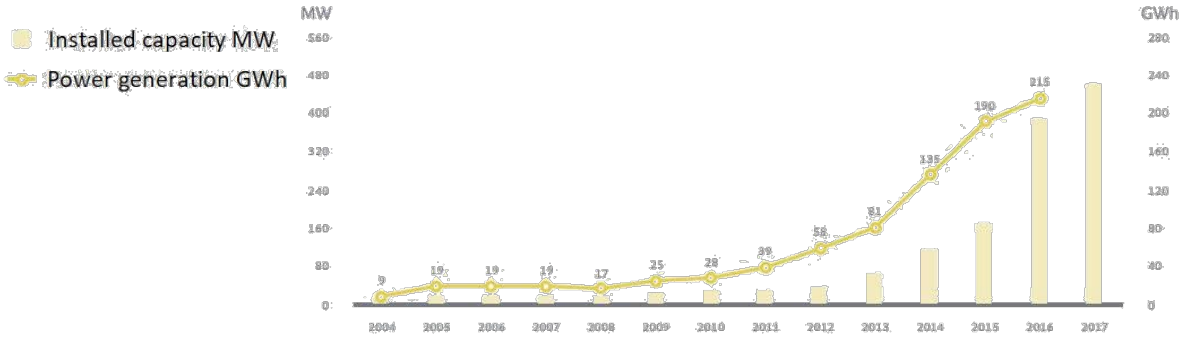

FIGURE 4. DEVELOPMENT OF SOLAR ENERGY PRODUCTION AND CAPACITY THROUGH THE YEARS. SOURCE: SENER (2017B)

According to Antonio Echeverria, president of Eosol Energy Mexico (personal communication, July 10, 2018), and Jonathan Ramirez, Co-Founder of Green ID (personal communication, June 10, 2018) almost all solar energy technology used in Mexico comes from China.

4.2.2. Wind

There are five regions with high wind source potential in Mexico: the Isthmus of Tehuantepec (Oaxaca), the State of Baja California, the coast of the Gulf of Mexico, the Northern and Central Region and the coast of the Yucatan Peninsula (Alemán-Nava, 2014).

As is shown in figure 5, the power generation from wind has increased extremely in the last few years. Due to its high competitiveness, the reduction of its costs and the high potential for wind energy in the country, the Ministry of Energy expects that the generation of electricity from wind will increase by 388% from 2017 to 2031 (2017a).

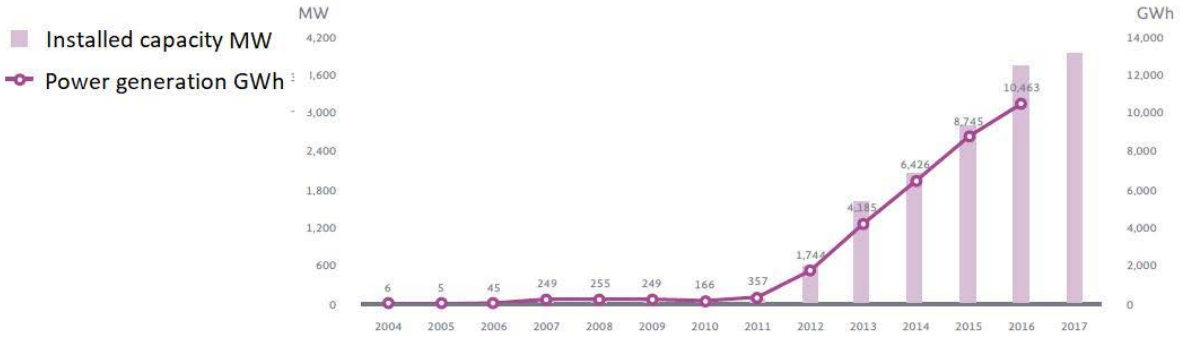

FIGURE 5. DEVELOPMENT OF WIND ENERGY PRODUCTION AND CAPACITY THROUGH THE YEARS. SOURCE: SENER (2017B)

4.2.3. Geothermal

Geothermal energy is local sustainable heat from the subsurface for the heating of houses, greenhouses and industry or for power generation. The temperature rises with the depth: the deeper the warmer. The naturally present hot water is pumped out of the underground. The heat is removed and a pump

ensures that the cooled water flows back into the same earth layer after which it heats up again (Platform Geothermie, n.d.).

Mexico is the 6 th country in terms of the production of geothermal energy (Promexico, 2016). However the generation of energy from geothermal sources has maintained constant over the last few years (see figure 6), SENER expects that the electricity from geothermal energy will increase by 365% from 2017 to 2031, seeing that a lot of projects are still in the exploration phase (SENER, 2017a; SENER, 2017b).

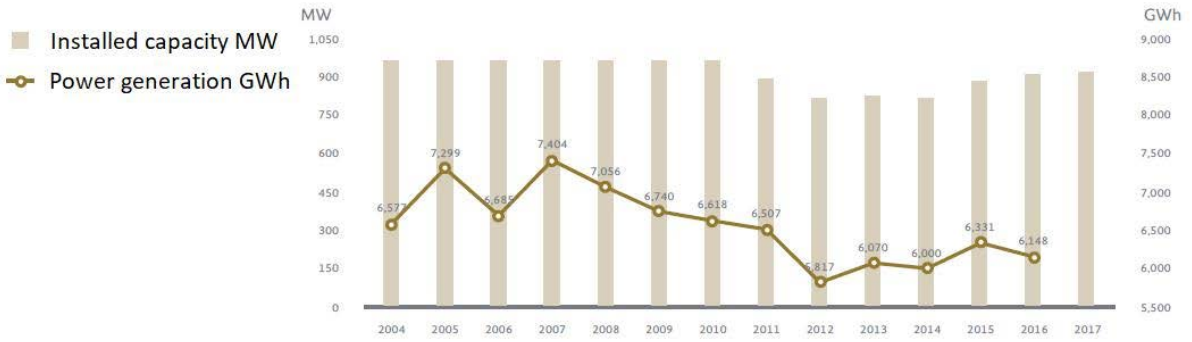

FIGURE 6. DEVELOPMENT OF GEOTHERMAL ENERGY PRODUCTION AND CAPACITY THROUGH THE YEARS. SOURCE: SENER (2017B).

4.2.4. Biomass

Bio-energy is renewable energy from biomass, organic material that comes from plants and animals. When biomass gets burned, energy gets released as heat. There are two options to gain bio-energy: the biomass can be burned directly or it can be converted to liquid or gas biofuels, that can be burned. Biomass has a high potential for the production of electricity and for the use in the transport sector.

One special type of bio-energy is energy from waste. At special waste-to-energy plants the biomass part of the municipal solid waste gets burned and used to generate electricity or to heat buildings (EIA, n.d. b.).

In 2016, the installed capacity for biofuels was 1.2% of the total capacity, of which 1.1% corresponded to bagasse of cane and 0.1% to biogas. Figure 7 and figure 8 show the development of the power generation from biogas and bagasse of cane. From 2017 to 2031, it is expected that the capacity of electricity production from bio-energy will increase 6.3% annually (SENER, 2017a).

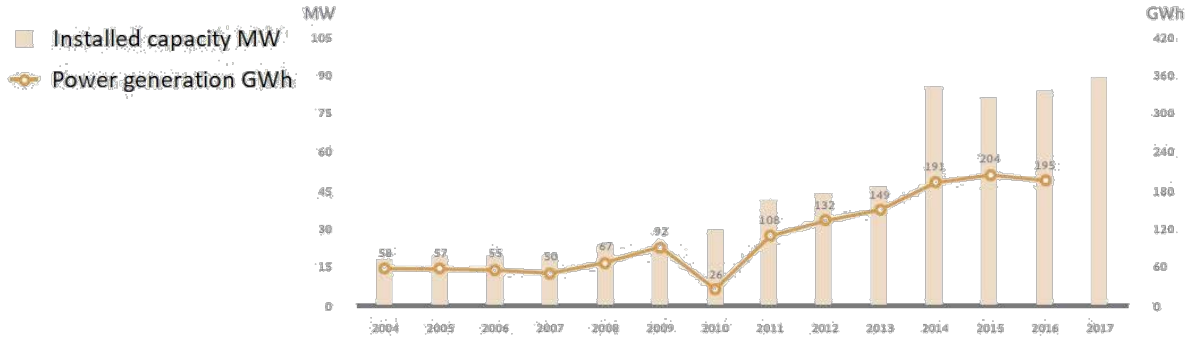

FIGURE 7. DEVELOPMENT OF THE CAPACITY AND POWER GENERATION FROM BIOGAS THROUGH THE YEARS. SOURCE: SENER (2017B).

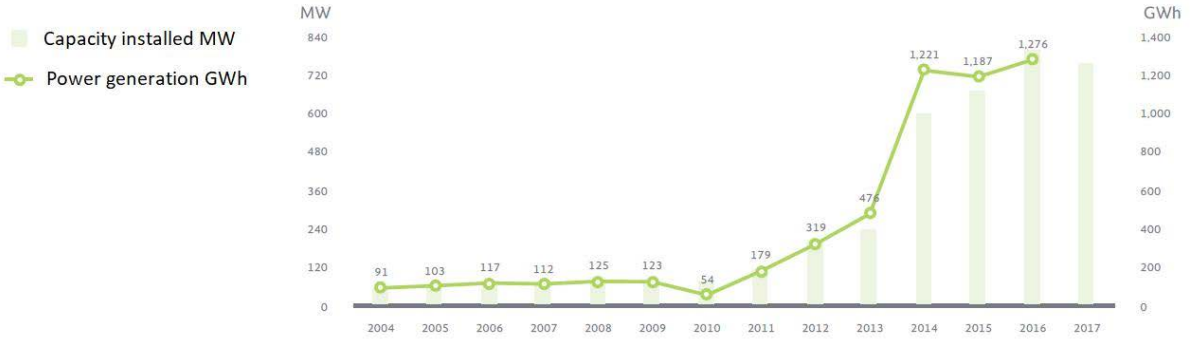

FIGURE 8. DEVELOPMENT OF CAPACITY AND POWER GENERATION FROM BAGASSE OF CANE THROUGH THE YEARS. SOURCE: SENER (2017B).

4.2.5. Hydropower

Hydropower is the energy produced from the force of flowing water. The volume of the water flow and the change in elevation from one point to another determine the amount of available energy in moving water (EIA, n.d. c.).

At the end of 2016, 85 hydroelectric plants with a total installed generation capacity were registered of 12,589 MW and an energy generation of 30,909 GWh (SENER, 2017a). According to SENER, power generation from hydropower only increased by 1.8% from 2006 till 2016 (figure 9). SENER expects that the capacity for the hydroelectric generation will increase by 13% from 2017 to 2031.

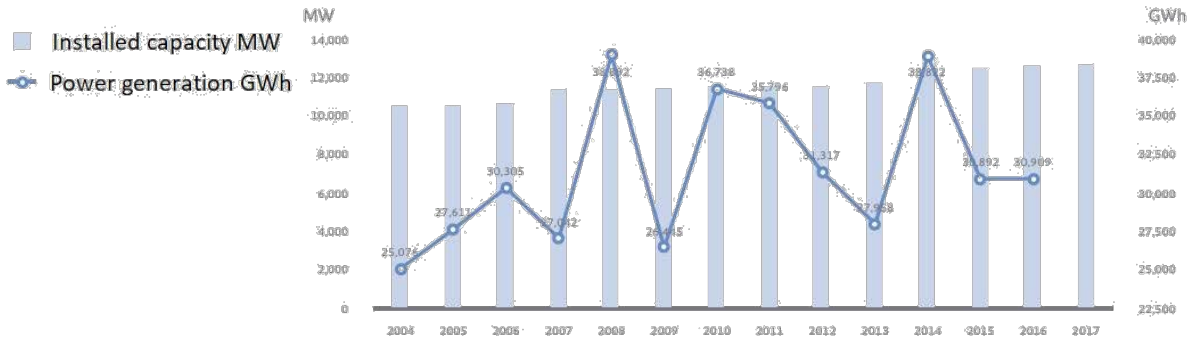

FIGURE 9. DEVELOPMENT OF HYDROPOWER PRODUCTION AND CAPACITY THROUGH THE YEARS. SOURCE: SENER (2017B).

4.3. Sectors with opportunities for renewable energy

To know which sectors have the biggest opportunities for renewable energy, there is also research done about the energy demand and the energy related CO_2 emissions per sector. This paragraph discusses these topics.

4.3.1. Energy demand per sector

The energy demand of the transport sector accounted in 2014 for 40% of the total final consumption. The energy demand for industry and buildings represented 28% respectively 20% (see figure 10)(OECD/IEA, 2016). As is illustrated in figure 11, the demand of the transport sector is for a big part petroleum based, which has led to serious air pollution problems.

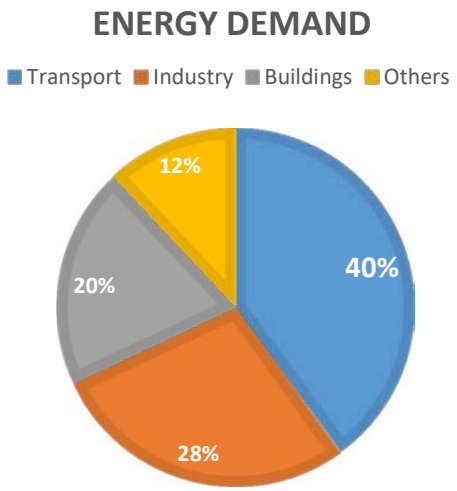

FIGURE 10. PERCENTAGE OF THE TOTAL FINAL ENERGY CONSUMPTION PER SECTOR IN 2014

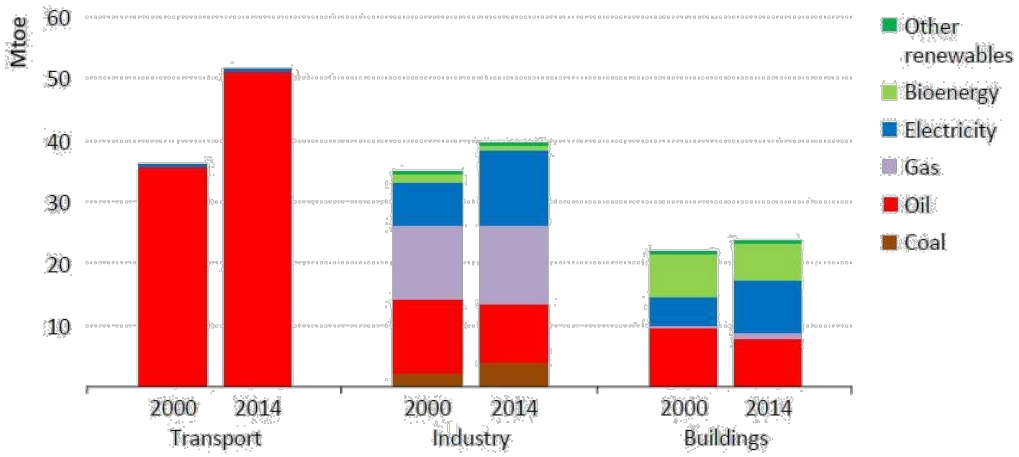

FIGURE 11. THE SHARE OF DIFFERENT ENERGY SOURCES IN THE ENERGY DEMAND PER SECTOR. SOURCE: OECD/IEA (2016).

4.3.2. Energy related CO_2 emissions

As shown in figure 12, the largest CO_2 emitting sector in Mexico is the transport sector, representing 35.1% of the total in 2014. Power generation accounts for 32.0% and industry (manufacturing and construction) for 13.4%. Other energy industries, including refining, emit 12.1% of the total. The least emitting sectors in Mexico are households (4.2% of the total) and commercial services and agriculture (3.2%) (IEA, 2017a).

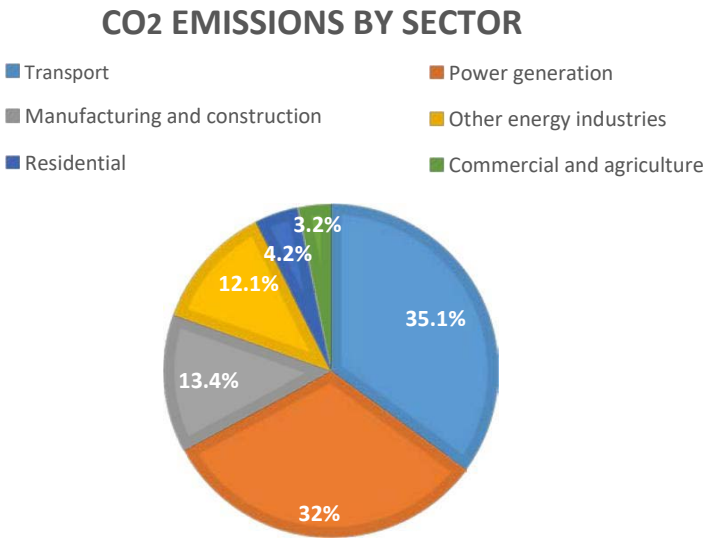

FIGURE 12. CO_2 EMISSION BY SECTOR IN 2014.

4.4. Conclusions

Currently, 20.8% of the electricity comes from clean energy, of which 15.5% comes from renewable energy. Mexico will need a fast transition to achieve its goal to generate 35% of the electricity from clean energy in 2024.

Hydropower has been for many years the biggest renewable energy source of electricity in Mexico, but due to arid conditions in big parts of Mexico, it's not expected to grow much further. The types of renewable energy with the best prospects in Mexico are photovoltaic, wind and geothermal energy.

The transport sector is the most energy demanding and polluting end-use sector. Remarkable is that the Mexican government hasn't set a goal yet for the share of renewable energy for the use in this sector (IEA, 2017). Another end-use sector that is very energy demanding and polluting is the industry sector. Since the General Law for Climate Change has also set the goal to reduce greenhouse gasses and compounds by 50% in 2050 in relation to those emitted in 2000, it's interesting to examine these sectors in more detail for opportunities for renewable energy.

5. Dutch renewable energy: organizations and best practices

This chapter will examine the Dutch offer of knowledge and technology in the field of renewable energy.

5.1. Renewable energy

The Netherlands has an international reputation for research in renewable energy, partly due to the work of the consortium for Knowledge and Innovation Offshore Wind (TKI Wind op Zee), the consortium for Urban Energy (TKI Urban Energy), the Energy Research Centre of the Netherlands (ECN), the Netherlands Organisation for applied scientific research (TNO) and Delft University of Technology—one of the world's leading institutes in sustainable energy (RVO, 2017a).

The Netherlands is experimenting with energy from waves, algae and biomass and the Dutch have developed innovative solutions in decentralised energy production in greenhouses, CO_2 'recycling' and waste heat utilisation for the energy intensive horticulture industry (RVO, 2017a).

The Netherlands also has leading expertise in offshore wind energy, co-combustion of biomass in coal-fired power plants, pre-treatment methods of biomass and the use of heat pumps combined with heat- and cold-storage (RVO, 2017a).

5.1.1 Solar

The Netherlands is an international leader in the manufacturing industry for solar power systems and components, especially for advanced PV cells and panels, production processes and equipment, materials, PV semi-finished products and end products (Topsector Energie, 2017).

The Netherlands has an international reputation for research in renewable energy in the field of solar energy, with institutes such as DIFFER, ECN and The Delft University of Technology. The TU Delft has won 7 times the World Solar Challenge, a competition for solar cars, most recently in 2017 (NOS, 2017).

5.1.2. Wind

The Netherlands provides over 60% of the wind energy turbine technology in the world. Wind energy – particularly offshore wind farms – is fast gaining ground in the Netherlands and worldwide. Dutch experts are eager to share their expertise about domains for building offshore wind farms (RVO, 2017a).

There is currently no serial manufacture of wind turbine components in the Netherlands. However there is ample knowledge and experience available concerning component and integral design, system optimization and testing of wind turbine systems.

5.1.3. Geothermal

Geothermal energy use has increased tremendously in the Netherlands over the last years (Richter, 2016). Currently, geothermal energy is mainly used in the Netherlands for heating of greenhouses and homes. The Netherlands has today the best expertise as regards to the design of greenhouses which has allowed the Netherlands to become a leader in, among other things, geothermal heating of greenhouses (Madoyan, 2014).

5.1.4. Biomass

The Netherlands is establishing itself as leader in 'Green gas' technology. Green gas is mostly generated from the anaerobic digestion of organic biomass and residues produced in agriculture, food production

and waste processing (IEA Bionergy, 2018) . Studies indicate that this renewable gas, that has been patented by ECN, can replace around 10% of Dutch-consumed natural gas by 2020 (RVO, 2017a).

Besides, in the Netherlands 7.5 million tons of municipal waste is converted in 13 efficient and clean waste incinerators to power, heat and reusable resources from the ashes (RVO, 2017a). Amsterdam's City Hall, trams, underground trains and street lights use green electricity of Waste disposal firm AEB. Its plant can supply 75% of all households in Amsterdam (RVO, 2017b).

5.1.5. Hydropower

Although the Netherlands is a waterland, the energy production by hydropower currently doesn't play a major role. Hydropower is usually generated by using the flow rate of the water and the differences in water levels and because the Netherlands does not have any significant differences in water levels, this form is not used there. However, the Netherlands uses hydroelectric power plants, in which large quantities of water pass in a short time (Milieucentraal, n.d.) . There are four medium-sized hydropower plants in the Netherlands and a number of small water mills.

Nonetheless, something that the Netherlands has a lot of knowledge about is tidal power. Tocardo, a Dutch company, has installed "underwater turbines" at the Oosterschelde flood barrier, which can be optimized for both ebb and flood currents and generate enough electricity to power 1000 homes (RVO, 2017b).

5.2. Sustainable mobility

An area in which the Netherlands is a leader is the adoption of electric vehicles; it has the second largest fleet of plug-in electric vehicles in the world (NFIA, n.d.). It has been decided to include this technology in the report because electric vehicles are able to run on renewable energy electricity with zero emissions.

The Netherlands is rolling out infrastructure such as charge stations to enable electric driving. 10% of the global public charging infrastructure is located in the Netherlands (RVO, 2018). One example of an innovative charging station is the 'Power by the Sun' station along highway A2 where sunlight is transformed into energy. What's not used for charging electric cars is stored for later use (RVO, 2017a).

The Netherlands is the only country in the world with a mature market model for charging infrastructure with vested players and millions of transactions. Examples of companies are New Motion, EVBox, Greenflux and Allego, all of which are also internationally active (RVO, 2018).

Besides charging infrastructure, the Netherlands has great expertise in (RVO, 2018):

- The manufacturing of electric buses in relation to zero emission public transport. Examples are: VDL and Ebusco.
- Manufacturing of new and converted electric trucks in relation to zero emission city distribution. Examples are: Ginaf, Terberg, Benschop, E-Trucks, Emoss and DAF.
- Manufacturing of Light Electric Vehicles in relation to zero emission city distribution and passenger transport such as a.o. Stint, 2Getthere and Qwic.
- Manufacturing of solar car roofs such as Holst Centre/Solliance Solar Research and applications on buses, cowls (Inalfa Room Systems), etc.
- New solar electric car concepts such as Lightyear and Amber Mobility.

- Smart grids (there are more than 10 projects with experiments in this innovative technology). Examples are Lomboxnet, Smart Grid in Balance and Invade.
- Charging services, smart charging and roaming. Multiple innovative players test propositions, such as ELaad, Living Lab Smart Charging, Jedlix and Greenflux.
- The assisting and advising of municipalities on the roll-out of charging infrastructure. Examples of EV consulting organizations are APPM, EV Consult, Overmorgen and FIER.
- Electric car leasing (such as Mister Green, Athlon, Alphabet and Leaseplan) and Mobility as a Service and electric taxis.
- The monitoring of electric transport operations, such as Viricity.

5.3. Branch organizations

All the relevant branch organizations in the Netherlands related to renewable energy are shown in table 2. Appendix 1 contains a brief explanation per association.

TABLE 2. DUTCH BRANCH ORGANIZATIONS AND NGO'S RELATED TO RENEWABLE ENERGY

Branch organizations / NGO's	
Renewable energy in general	Cleantechholland
	Dutch Sustainable Energy Association (NVDE)
Solar	HollandSolar
Wind	The Dutch Wind Energy Association (NWEA)
	Holland Home of Wind Energy (HHWE)
Geothermal	BodemEnergieNL
	Stichting Platform Geothermie
	Dutch Association of Geothermal Operators
Biomass	Groengas Nederland
	BioBased Economy
	Platform Bioenergie
Hydropower	ENVAQUA
Electric vehicles	DOET
	Elaad
	AutomotiveNL
	eViolin
	Dutch-Incert

5.4. Conclusions

The Netherlands has an international reputation in renewable energy research. It is a leader in solar power systems, wind turbines technology and green gas. Besides, it has great expertise in the use of geothermal energy for greenhouses and in small-scale hydroelectricity. It has also become a leader in technology for electric vehicles, especially in public charging infrastructure.

6. Promising fields of application for Dutch knowledge and technology

Based on these previous analyses there is made a selection of two sectors for further investigation on opportunities for Dutch companies (see appendix 2). These two sectors are: the transport sector and the greenhouse horticulture sector.

6.1. Transport

Renewable energy has opportunities in all end-use sectors, but mainly in the transport sector (IRENA, 2015). Energy demand for transport in Mexico accounted in 2014 for over 40% of the final consumption; which is higher than the average of 33% of the OECD countries. It has been rising with 2.6% annually since 2000 and it has led to serious air pollution in the big cities.

6.1.1. Electric vehicles

A solution for the air pollution and the reduction of energy demand in the transport sector is the use of electric vehicles. Electric vehicles have a higher efficiency than conventional cars, produce less noise and emit less emissions. With the use of renewable energy, the net emissions can be nearly zero. Currently, the electric cars also recover around 35% of the energy that comes from braking and slowing down. Another advantage of the EV's, is that they can play a role in the energy storage of renewable energy, when they are connected to the grid (Bauer, Rieck & Weijnen, 2018a).

Mexico is set to see an increase in production investments for gasoline and diesel vehicles, but also for electric vehicles (EVs) (BMI Research, 2018). The Association for the Mexican Auto Industry (AMIA, 2018) reports that during January 2018, the sale of hybrid and electric vehicles was 973 units, of which only 11 were electric and 962 hybrid. Although that is 64.1% more than the sale that was registered in the first month of 2017, the EVs market is still in its infancy. A massive adoption for EV's isn't expected soon.

6.1.2. Incentives to increase the production and adoption of EVs

The Mexican government has made some efforts to increase the production and adoption of EVs. In February 2017, the government announced it had scrapped tariffs on electric vehicle components of EVs including chassis, bodywork and electric motor components. Previously the tariffs were 15% on finished electric vehicles and 5-20% on their major components. The scrapping of these tariffs should help the development of EV assembly operations in the country by making it easier to import key components (BMI Research, 2018).

The Federal Commission for Electricity has also made some efforts for the adoption of EVs. Because there are different household electricity tariffs for different levels of electricity consumption (see table 3), the CFE has introduced a scheme to install separate residential electric meters for EV's, so that consumers won't be penalized with higher tariffs for greater electricity consumption.

TABLE 3. ELECTRICITY PRICES OF JULY 2018. SOURCE: CFE (2018)

Tariffs for energy consumed		
Basic consumption	$ 0.793	For each of the first 75 kilowatt-hours
Intermediate consumption	$ 0.956	For each of the following 65 kilowatt-hours

Excess consumption	$ 2.802	For each additional kilowatt-hour to the previous ones

6.1.3. Developments in the electric vehicle market

Currently, no EVs are massively assembled in Mexico; only the Mexican company Zacua assembles EVs in a tempo of one unit per day (BMI Research, 2018; Rodríguez, 2018). However, automakers have begun to show an interest in building EV technology in Mexico and the tariff reduction will only serve to intensify that interest. An example that highlights the potential in the electric vehicles production is the partnership of Giant Motors, manufacturing firm Moldex and the world's largest bakery, Bimbo. The partners announced in February 2017 that they will design and build their own electric truck for commercial release in 2018 (BMI Research, 2018).

Also upward of 2020, Ford will begin to assemble electric cars in Mexico, to take advantage of Mexico's lower labor costs and its extensive network of trade agreements (Boudette, 2017).

6.1.4. Obstacles: Costs and infrastructure

Low EV adoption is partly due to the higher purchase price of EVs. Currently, EVs compete in the Mexican luxury car segment, which only a small part of the population can afford (Marchan & Viscidi, 2015).

According to Bauer, Rieck and Weijnen, three professors of the TU Delft specialized in EVs, EVs will have in 2022 the same showroom price as the conventional cars because of economies of scale in the battery production and the supply chain for the EV's parts (2018b).

Another obstacle for the adoption of electric vehicles is the scarce public charging infrastructure. Currently the charging stations offer services for free, provided by automakers and other business related to EVs to encourage the use of EVs until charging services can be commercialized (Marchan & Viscidi, 2015).

BMWi and Nissan Leaf have also cooperated to make a map that indicates the location of the charging points in Mexico (Chargenow, n.d.)

6.1.5. Opportunities for EV technology

There are opportunities for electric transport and EV charging stations in the tourism sector. The tourism sector is very important for Mexico (7.4% of the GDP in 2016) and is expected to rise (World Travel and Tourism council, 2017). Besides, there is an increase in eco-tourism, that goes together with the increase in the environmental awareness; hotels in Mexico are starting to provide clean taxi services or charging points to their customers (Hardasmalani, 2016; Harrop, 2016).

There are also opportunities for Dutch SME's in the high use vehicles like busses for public transport, taxi's and trucks for city logistics. Focusing on high use vehicles is very effective, because they operate more frequently than private cars and they demonstrate the effectiveness of EV technology to a large scale of people (Marchan & Viscidi, 2015).

Finally, there are opportunities in fast charging infrastructure with 100% renewable energy. The Netherlands is a leader in normal and fast charging of electric cars and implementing this technology with a 100% renewable energy supply could significantly help reduce the serious air pollution problems in Mexico's big cities.

6.2. Greenhouse horticulture sector

Other opportunities for Dutch SME's lie in renewable energy technology for the horticulture sector, since the Netherlands already has a great image worldwide in the field of horticulture and the Mexican horticulture sector is increasing fast. Besides, Mexico and the Netherlands already have a strong horticulture connection because Mexico is a very important export market for Dutch equipment for greenhouses and middle-tech and low-tech greenhouses.

6.2.1. Renewable energy systems in greenhouses

There are many ways to make greenhouses more sustainable. This paragraph will give an overview of the possibilities for renewable energy in greenhouses.

6.2.1.1.Geothermal energy

An important alternative for the use of natural gas in the greenhouse horticulture is geothermal energy. In the Netherlands geothermal energy is still at the start of the development with 15 realized projects, but 14 of them are in the greenhouse horticulture (Kas als energiebron, n.d.b). The current working geothermal heat sources and projects under development can be found on the websites of DAGO and Platform Geothermie (Appendix 1).

6.2.1.2. Bioenergy

Another alternative for the use of natural gas in greenhouses is bioenergy. The CO_2 that comes from the conversion of biomass can also be recycled (Kas als energiebron, n.d.c.). Currently, over twenty greenhouse horticulture companies in the Netherlands are using a form of bio-energy as energy supply for their greenhouses (Bouwmeester, 2018).

6.2.1.3. Solar energy

Solar energy can also be used in greenhouses. In 2014 already 64 horticulture companies in the Netherlands applied the harvesting and reuse of solar heat. Greenhouses are, so to speak, large solar collectors. There is sufficient solar energy in the greenhouse to heat it all year round and to even supply heat or electricity to third parties. However, the availability of this energy at the right time and in the right form (heat, electricity or hot water) is costly (Kas als energiebron, n.d.d.).

6.2.1.4. CO_2 recycling

Because plants need CO_2 for their optimal growth, CO_2 is dosed in most of the greenhouses. Usually gases which are released during the combustion of natural gas are used for this. Due to energy saving, the application of geothermal and residual heat, the use of natural gas reduces and because of that the availability of CO_2 for dosing reduces too. To solve this problem, CO_2 can be recycled (Kas als energiebron, n.d.a.). AVR, a Dutch company will start in 2019 with the capture and recycling of CO2 for greenhouses. (Messenger, 2018).

6.2.2. Horticulture in the Netherlands

The Netherlands is worldwide known for its greenhouse design and has become a leader in (Madoyan, 2014):

- Saving energy in greenhouses
- Decreasing the CO_2 emissions and generating energy in greenhouses for the local community
- The use of geothermal energy in greenhouses

- Consulting in design, construction, education and crop management

Horticulture is very important for the prosperity in the Netherlands, through the considerable volumes, the good quality and the technological innovations in this field. Covering nearly 2500 hectares, the Westland is the largest unbroken horticulture area in the world (RVO, 2017c).

To stimulate energy saving and renewable energy in the horticulture, the Dutch ministry of Agriculture, Nature and Quality has created the innovation programme *Greenhouse as Energy Source* (in Dutch: Kas als Energiebron).

6.2.3. Developments in the horticulture in Mexico

The protected horticulture in Mexico has an average annual growth of 12% and has an installed infrastructure whose value is more than 3,500 million dollars (AMHPAC, n.d.). Today greenhouses have become one of the most powerful economies of the primary sector.

The excellent geographical position towards the market of the United States and the growing domestic market make that Mexico has a fast increasing horticulture (Kipp, 2010). The young horticulture market has had a constant increase in the recent years and the ambition of Mexico to be the central protagonist of the region as a producer of fresh foods, has created opportunities for Dutch greenhouse technology (Horticultivos, 2016).

6.2.4. Incentives to increase renewable energy use in the horticulture

There is no incentives policy of the Mexican government for the reduction of CO_2 emissions or for the increase of renewable energy use in the greenhouse horticulture sector. However, energy costs account for 20 to 30% of the production costs, and companies could reduce these costs by supplying their greenhouses with renewable energy (Hemming, 2010). The disadvantage of the renewable energy systems, is that it has high fixed costs. Horticulture companies in Mexico will need to be convinced by the lower variable costs to switch to renewable energy.

6.2.5. The opportunities for renewable energy in greenhouses

There lie opportunities in all the applications for renewable energy in the greenhouse horticulture sector. However, because the Mexican government wants to stimulate market competitiveness in the geothermal energy and the Netherlands has great know-how in the application of geothermal energy in the greenhouse horticulture, the opportunities for Dutch SME's seem to be greatest in this area.

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Appendix 1: Dutch branch organizations related to renewable energy

Branch organizations / NGO's	
Renewable energy in general	Cleantechholland
	Dutch Sustainable Energy Association (NVDE)
Solar	HollandSolar
Wind	The Dutch Wind Energy Association (NWEA)
	Holland Home of Wind Energy (HHWE)
Geothermal	BodemEnergieNL
	Stichting Platform Geothermie
	Dutch Association for Geothermal Operators (DAGO)
Biomass	Groengas Nederland
	BioBased Economy
	Platform Bioenergie
Hydropower	ENVAQUA
Electric vehicles	DOET
	Elaad
	AutomotiveNL
	EViolin
	Dutch-Incert

Cleantechholland is the export association for Dutch clean energy businesses, universities, R&D establishments, governments and nonprofit organizations. It organizes several trade- and innovation missions to help promote Dutch products, services, innovations and solutions worldwide in the cleantech sector.

The Dutch Sustainable Energy Association (Nederlandse Vereniging Duurzame Energie, NVDE) is the organization of entrepreneurs in sustainable energy in the Netherlands.

Holland Solar is the branch organization of Dutch experts in solar energy with approximately 130 members, including suppliers, manufacturers, installers, consultants and architects (Holland Solar, n.d.).

The Dutch Wind Energy Association (NWEA) is the branch organization of the entire wind sector: from developers of wind farms, energy companies and energy cooperatives to manufacturers of wind turbines, consultancy firms, educational institutions, financial or legal service providers, suppliers and maintenance companies (NWEA, n.d.).

Holland Home of Wind Energy (HHWE) is the independent industry association for promoting export and enhancing international cooperation. It represents, facilitates and promotes their members and the Dutch wind industry as a whole (HHWE, n.d.).

BodemEnergieNL is the sector organization for all companies and organizations that are in a way involved in geothermal energy (BodemEnergie, n.d.).

Stichting Platform Geothermie is a non-profit organization (NGO) aimed at promoting the responsible use of geothermal energy in the Netherlands (Platform Geothermie, n.d.).

Dutch Association for Geothermal Operators stimulates knowledge-sharing between the member of DAGO. On its website you can find all the associated companies (Dago, n.d.).

Groengas Nederland: represents more than 125 companies and organizations in the biogas industry (Groengas Nederland, n.d.).

BioBased Economy: is a platform for the government, research institutes, companies and NGO's that are involved in energy for biomass (BioBased Economy, n.d.).

Platform Bioenergie's goal to promote responsible production of sustainable energy from biomass. The foundation represents the entire bio-energy business (Platform Bionenergie, n.d.).

ENVAQUA connects and represents 125 Dutch enterprises occupied in the water- and environment industry.

DOET is the association for electric transport in the Netherlands. DOET is committed to creating international (cooperation) opportunities for members. Active collaborations have already been set up with Germany, the US, Turkey, Canada, France, Sweden and the Association Kingdom (DOET, n.d.)

ElaadNL is the knowledge and innovation center in the field of smart charging infrastructure in the Netherlands.

AutomotiveNL is the cluster organization of the Dutch automotive and mobility industry. It aims to strengthen the international position of its members and provides effective support to the member companies that are active internationally or want to become active. AutomotiveNL also ensures promotion and utilization of economic opportunities by organizing trade promotion activities, such as trade missions, participation in trade fair and network meetings (AutomotiveNL, n.d.).

EViolin is an association of charging station operators and service providers (eViolin, n.d.).

Dutch-INCERT (Dutch Innovation Center for Electric Road Transport) has been established as a platform for closely linking scientific or practical research, technological innovation and educational innovation as regards to electric transportation (Dutch-INCERT, n.d.).

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