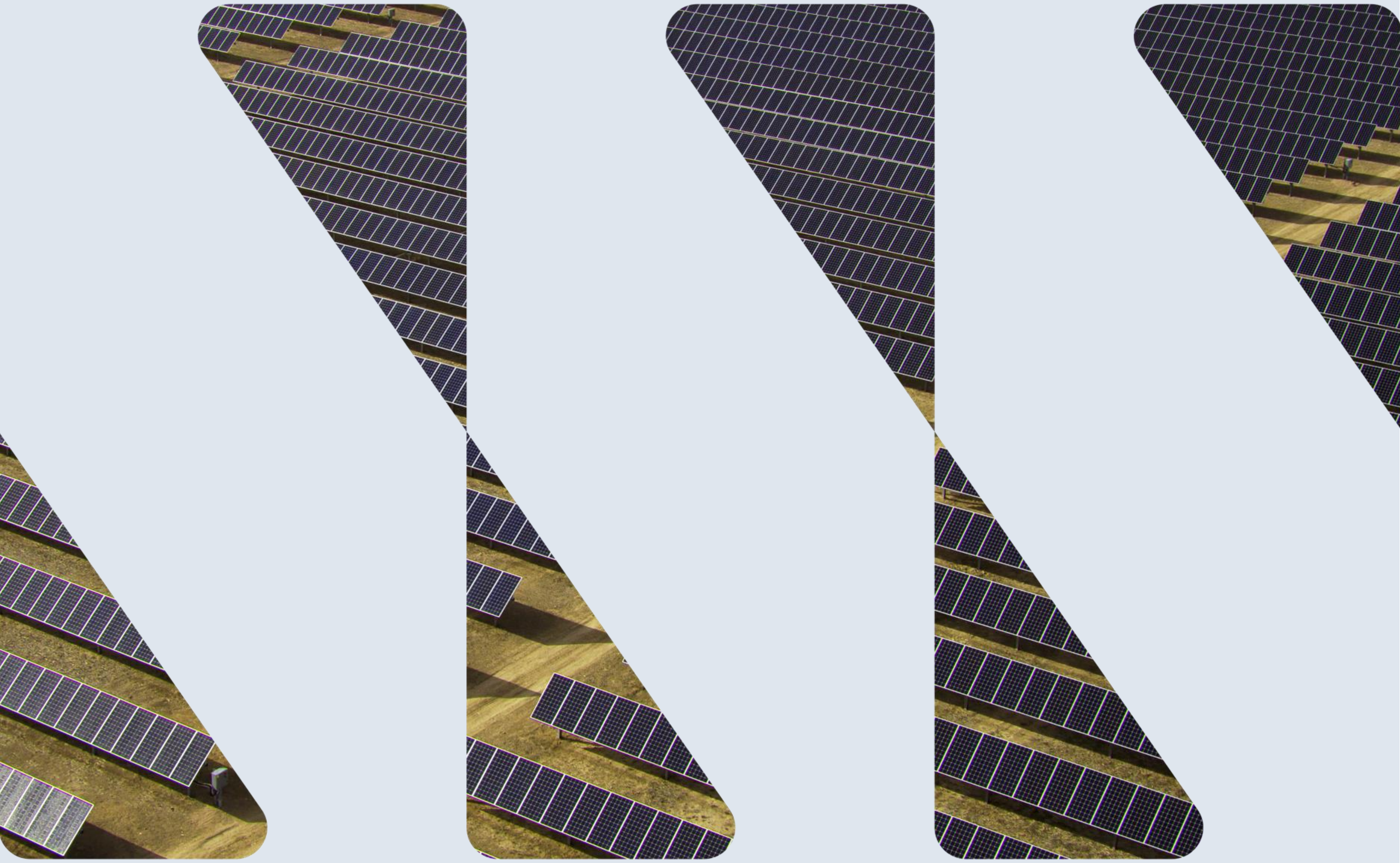


Distributed Energy Resources in Mexico

Market Study

Content

Executive summary

In Mexico, power generation remains one of the sectors with the highest GHG emissions. However, although efforts have been made to increase power generation from renewable energy sources, large-scale measures have not been sufficient for Mexico to reach the targets set in its NDCs. Therefore, the progressive adoption of clean technologies for small and medium-scale electricity generation is of utmost importance to reach these targets. In this sense, the use and integration of distributed energy resources (DER) technologies can contribute significantly to the decarbonisation of the country by allowing sectors such as power and transport to stop consuming fossil energy.

However, the benefit of distributed generation is not only environmental, but also economic. DERs allow consumers to reduce their overall energy costs by eliminating the need for costly infrastructure to transmit and distribute energy. This results in a direct decrease in the total cost of electricity supply, which means savings for the end consumer.

Currently, the national landscape for DER is composed of three technologies: solar PV, energy storage and electric vehicles. With an established market and significant growth estimates for the future. These technologies have a wide potential to establish different business models, which can be leveraged to generate benefits in the short term and develop a DER market in the medium term in Mexico.

In this sense, this document aims to improve the understanding of the national market focused on REDs through a market study developed by means of stakeholder mapping, direct interviews with relevant stakeholders and a cost-benefit analysis. This can be contextualised through the following key findings:

- The national DER landscape is predominantly composed of two mature technologies: solar PV and electric vehicles. PV technology is the dominant technology in the country, as it is used by 75% of project developers; 39% of distributors; and 50% of manufacturers. While the technologies with the lowest penetration are storage and EV infrastructure, as they are only used by 6% of manufacturers, 19% of distributors and 10% of project developers.
- Solar PV and electric vehicles have great potential to establish different business models, such as energy-as-a-service, fee-for-a-service, or the direct sale of electricity to third parties (in the case of electric vehicles). Since there are financing options and a sufficient regulatory framework, which makes it possible to exploit them and generate profits in the short term. It is identified that 84% of the companies base their operations on a traditional business model; 6% offer a leasing model in addition to the traditional one; 3% offer the PPA model in addition to the traditional one; and 7% offer both business models (leasing & PPA) in addition to the traditional model. 41% of the identified companies offer additional after-sales services, like O&M services.
- Energy storage in México is at an very early stage of penetration and therefore does not yet have an established market. As it does not have a specific regulatory framework to regulate its technical and market operation, its benefits cannot be fully exploited. As a result, it can only be used as an element

that provides the consumer with back-up energy (behind the meter), rather than turning it into a potential prosumer. However, this is expected to happen in the long term.

- The benefits of incorporating integrated DER technologies are directly dependent on the energy demand of the user, generating greater benefits to those who consume more energy. Depending on the type of tariff and type of technology integration, average payback periods range from 6.0 to 1.8 years. With average net benefits equivalent to USD 1.7 million.
- In general terms, the current context of the Mexican commercial sector and electricity market opens the door to the future development of a distributed energy resources market in the country. For this, it is of utmost importance that exist a binding collaboration between the different sub-national entities in the country to motivate and standardise proposals in terms of regulation, public policy or financing, in order to jointly find solutions that can motivate the development of a national DER market.

Introduction

For decades the world has relied on a centralised system of power generation in which energy utilities owned and operated huge power plants and grids, which are not only costly but also environmentally damaging. Much of the world's power plants tend to run on fossil energy sources, such as coal and natural gas, contributing to greenhouse gas (GHG) emissions. In fact, only 5% of the world's power plants are responsible for 73% of global electricity production emissions (Grant et al, 2021). According to the United Nations Environment Programme (UNEP), the concentration of greenhouse gases in the atmosphere directly affects the global average temperature, which has increased by 1.1°C; this has been linked to an increase in extreme weather events, such as heat waves, droughts, floods and forest fires. Experts consider a global average temperature increase of more than 1.5 degrees Celsius to be a major tipping point for climate disasters. To prevent warming from exceeding this threshold, emissions must fall by 7.6% each year between 2021 and 2030. However, our current energy systems are nowhere near meeting this target (UNEP, 2023).

In line with the above, during the G20 meeting in Naples, the importance of distributed energy resources (DER) for the decarbonisation of the electricity sector and climate change mitigation was emphasised (G20 Italy, 2021). Covering a wide range of technologies, such as energy efficiency and demand response solutions, photovoltaic systems and batteries. DERs can generate or store energy or manage their consumption depending on the type of consumer.

While energy efficiency and demand response solutions are not new, solar PV and electric vehicles (EVs) have driven recent DER growth in some countries. The IEA estimates that between 2017 and 2020, 179 GW of distributed solar was added globally, with China and the US contributing nearly half of the new installed capacity. Similarly, the EV fleet has tripled since 2017 and by 2020 exceeded 11 million. This means that 80% of vehicles on Chinese and European roads are electric, and these trends are expected to continue in more countries in the coming years (IEA, 2021a).

The use of DERs contributes to decarbonisation in different ways, notably through the substitution of energy sources, by enabling sectors such as electricity and transport to stop consuming fossil energy. As the scale of clean renewable electricity supply grows, EVs and other electrification solutions can extend their use to new sectors. In the IEA's Net Zero scenario, global EV sales increase 18-fold from 3 million to 56 million. In addition, some 600 million heat pumps will provide clean heating by 2030, while solar PV will more than quadruple to 633 GW by the end of this decade (IEA, 2021b).

However, the benefit of distributed generation is not only environmental, but also more cost-effective than the traditional centralised generation system, which, in addition to being costly, has become obsolete, inefficient and insufficient to meet the energy needs of the world's population. DERs allow consumers to reduce their overall energy costs because, as small energy generation and/or storage units close to the point of consumption, they eliminate the need for costly infrastructure to transmit and distribute energy. As a result, the total cost of energy supply decreases, resulting in savings for the end consumer. With a robust and effective implementation plan, the deployment of distributed energy resources could result in up to a 100% reduction in the localised cost of electricity.

In addition to generating savings, the use of DER can help consumers access new economic opportunities by enabling energy consumers to simultaneously become **prosumers**. This means that when energy transactions are placed in the hands of consumers (and not utilities) by owning and exploiting distributed energy resources, they can participate fully in the energy economy, generating energy locally and earning economic benefits. As a result, the consumer becomes a prosumer, meaning that he or she uses and produces energy at the same time. In this way, instead of relying on a large centralised grid system, communities can generate energy locally and earn additional income in the process. Facilitating energy affordability, reliability, viability, accessibility and sustainability.

Today, the transformation of energy consumers into prosumers is bringing about a major change in the energy landscape. Both residential and commercial consumers can choose to implement their own energy systems in their homes or workplaces, taking control of their energy consumption. Distributed energy generation has the power to revolutionise the energy landscape. Communities, governments and researchers around the world are working to transform our current energy systems and promote the adoption of distributed energy resources.

However, there are several challenges for DERs to overcome in order to reach their deployment targets, as there is still a lack of knowledge in some countries about the integration of their technologies and their benefits. There are also misconceptions about renewable energy sources, such as that they are expensive, inefficient and present more problems for the end consumer than a traditional centralised system. In reality, DERs help to alleviate the burden, inefficiency and instability of traditional electricity grids.

In this way, this document aims to improve the understanding of DER in Mexico through the development of seven sections. The first covers the national context of DER technologies, both the regulatory framework and their current status. This is followed by a market study based solely on documentary research and an analysis of sources of information and studies related to the aforementioned topics; the methodology, the mapping of actors and the analysis of results are developed here, focusing on solar photovoltaic distributed generation technologies, infrastructure for electromobility and electric vehicles[1] . Subsequently, the second part of the market study is presented, which is based on the information obtained from interviews with relevant market stakeholders. The fourth section externalises a cost-benefit analysis based in the information pointed out in the interviews, in order to establish the benefits of the implementation of DERs projects. Finally, recommendations and general conclusions are presented that can serve as a guide for the correct implementation of projects that involve the integration of DERs and promote the development of an internal market.

[1] The analysis of electric vehicles considers those commercial utility vehicles generally used for last mile delivery, including electric bicycles, electric motorbikes, non-commercial VAN-type delivery vehicles and some electric vehicles with specific characteristics for short-distance product delivery.

Current context of distributed energy resources in Mexico.

In Mexico, both the transport sector and electricity generation continue to be the sectors with the highest GHG emissions. Therefore, the use of large-scale renewable energy resources and support for the lithium and electric mobility industries (Ministry of Foreign Affairs, 2022) will be key for the country to meet its Nationally Determined Contributions (NDCs). However, large-scale measures are not sufficient for Mexico to meet its NDCs. Therefore, the progressive adoption of clean technologies and public policies focused on small and medium-scale electricity generation, which contribute to reducing the environmental impact of the energy sector, is indispensable (Sonar, Sony & Sharma, 2013). The integration of DERs is crucial, as it enables the rapid penetration and integration of this type of clean technologies at small and medium scale.

As mentioned above, the implementation of DER has been increasing globally, developing more widely in certain regions of the world. In the case of Mexico, solar PV technology is one of the best positioned DER technologies at the national level. The growth of distributed solar generation (DSG) in Mexico has been steady over the last decade, increasing from 14.9 MW installed in 2013 to more than 2,600 MW in 2022, which is largely due to the reduction in investment and installation costs (29% between 2020 and 2021) (GIZ, 2021) and the feed-in tariff schemes offered by the Mexican regulatory framework. Therefore, GSD is expected to continue to increase its share in the Mexican energy sector and is estimated to exceed 13 GW of installed capacity by 2035, remaining the main DER technology in the country.

Another DER technology that has also shown significant growth in Mexico is electric vehicles. Between 2016 and 2023 (January), the number of this type of vehicle increased significantly, from 254 to 10,443 vehicles. As a result, the number of charging points for electric vehicles has increased at almost the same rate. By 2022, there were around 2,089 public access charging points distributed throughout the country. Although these charging points currently supply energy free of charge, given the increasing share of vehicles in the total national vehicle fleet, this could be a strategy that will no longer be profitable in the future.

Regarding energy storage, the implementation of this technology is in its initial stage and installations within the country are limited. However, many of the companies involved in the development of clean energy projects in the country are complementing their PV projects. As Mexico expands its PV market, companies are expected to increase storage operations to optimise solar power generated throughout the country.

As can be seen, the current national landscape for DER consists of three technologies, with an established market and significant growth estimates for the future. These technologies have a wide potential to establish different business models, which can be exploited to generate benefits in the short term and develop a market for DER in the medium term in Mexico.

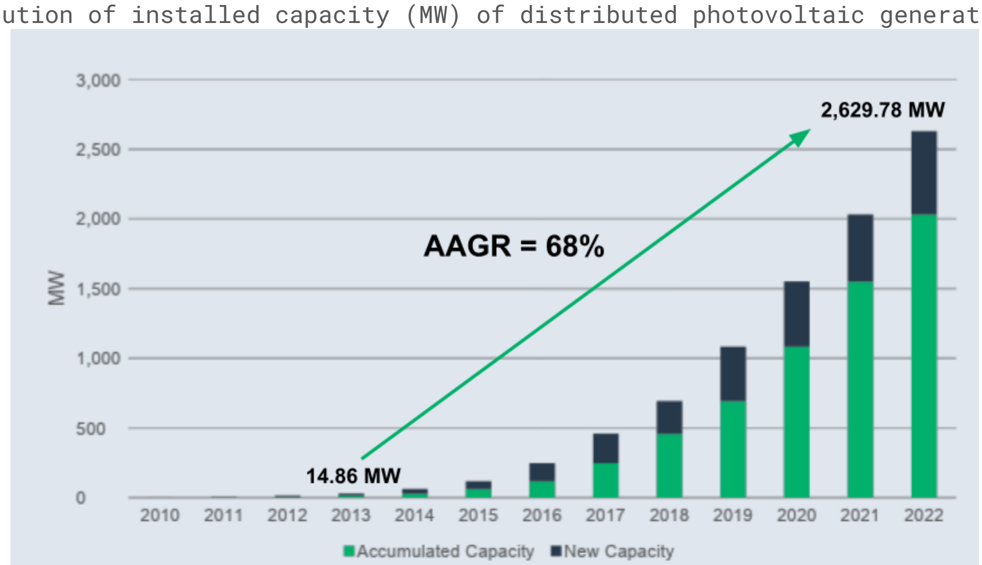
The following sections will deal more specifically with the current market and regulatory situation of the above-mentioned DER technologies.

Photovoltaic distributed generation

a. Market

In recent years, distributed photovoltaic generation (DGPV) has had a very dynamic growth in the country, increasing its installed capacity at an average rate of 68% annually. This means that the DGPV went from 14.9 MW in 2013 to 2,629.8 MW in 2022, through the issuance of 334,984 interconnection contracts (Figure 1).

Figure 1. Evolution of installed capacity (MW) of distributed photovoltaic generation 2010-2022.

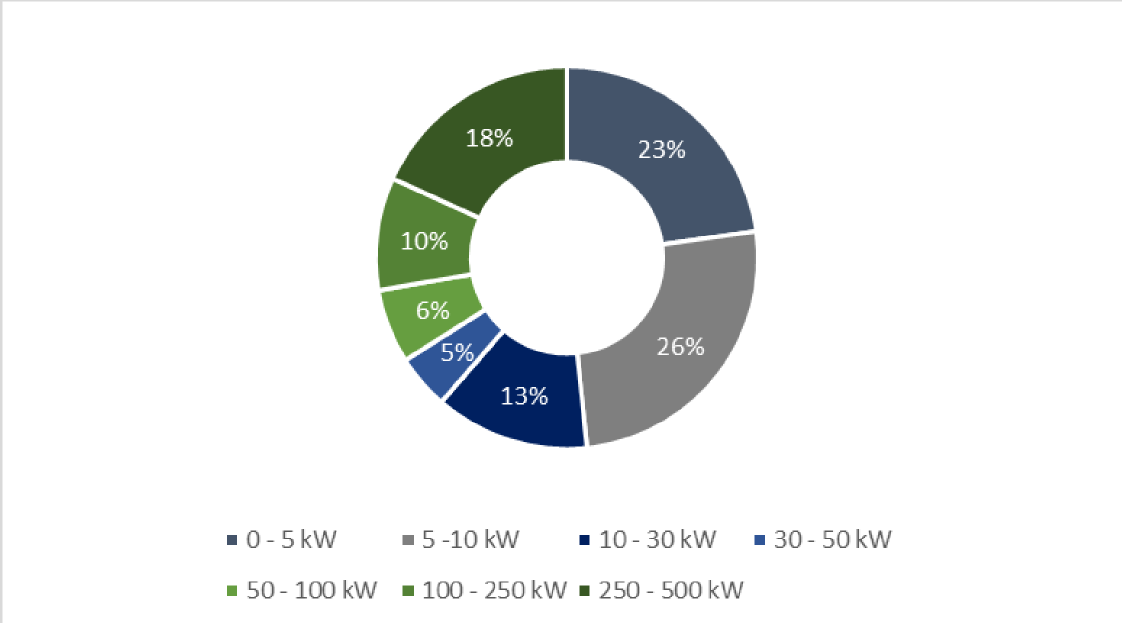


Source: (CRE, 2023)

As shown in Figure 2, of the total installed capacity, approximately 18% belongs to the small and medium-sized enterprises sector (with projects with capacities between 10 kW and 50 kW). This represents an investment of more than USD 383 million[2] (CRE, 2023).

[2] Assuming an average investment cost of 1.34 USD/Wp

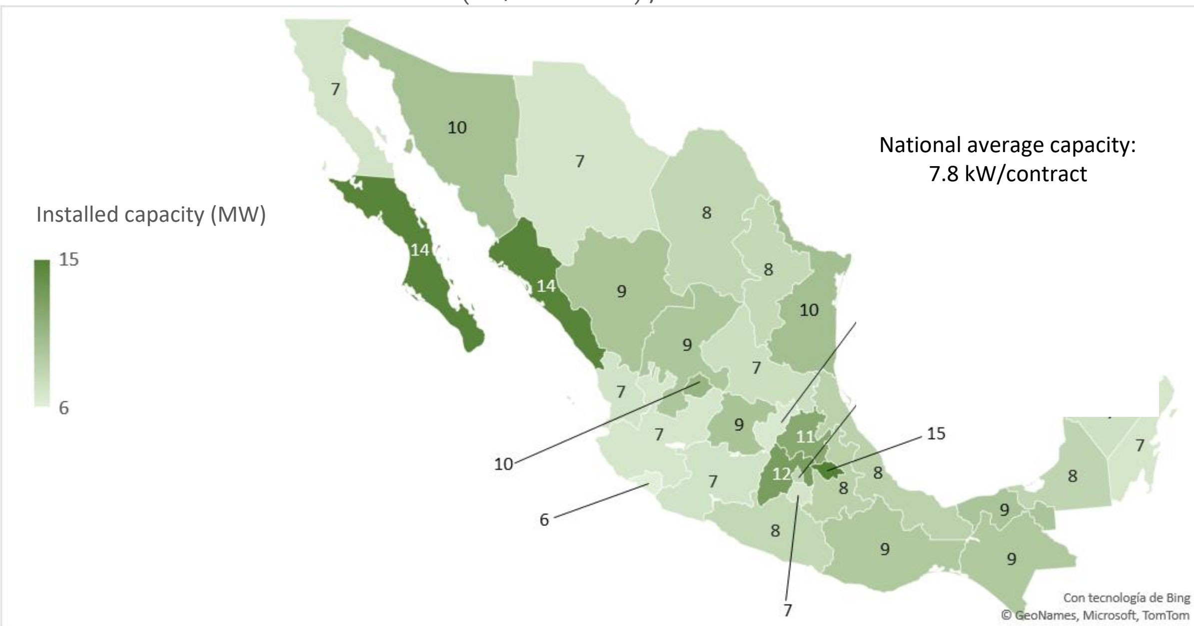
Figure 2. Installed capacity of distributed generation by capacity range, 2022.



Source: (CRE, 2023)

Regarding the distribution of installed capacity of distributed generation across the country, Jalisco is currently the state with the largest installed capacity in terms of distributed generation: 407.08 MW in 61,706 contracts (6.6 kW/contract). It is followed by the states of Nuevo León and Chihuahua with 282.18 MW (7.6 kW/contract) and 176.58 MW (6.7 kW/contract), respectively. Between these three states, they account for more than one third of the installed DGPV capacity in the country. On average, Mexico has an installed distributed generation capacity of 7.8 kW per contract (Figure 3) (CRE, 2022).

Figure 3. Distribution of installed distributed generation capacity across the country (kW/contract), 2022.



Source: (CRE, 2023)

Regarding investment costs, distributed PV generation in Mexico has reached competitive prices. On average, prices range from 0.85 USD/Wp for systems from 250 kW to 500 kW and 1.24 USD/Wp for smaller systems up to 5 kW, as can be seen in Table 1.

Table 1. Retail prices by range of installed power (USD/Wp)

Price dispersion (USD/Wp)	0 - 5 kW	5 - 15 kW	15 - 30 kW	30 - 50 kW	50 - 100 kW	100 - 250 kW	250 - 500 kW
Minimum	1.17	1.08	1.03	0.98	0.86	0.79	0.79
Q1	1.20	1.11	1.05	1.01	0.90	0.85	0.82
Medium	1.24	1.14	1.08	1.04	0.93	0.90	0.85
Q3	1.27	1.17	1.10	1.06	0.97	0.96	0.88
Maximum	1.31	1.20	1.13	1.09	1.00	1.01	0.91

Source: (GIZ, 2021)

Regarding the price per component, wholesale prices favour lower prices per component in distributed generation systems with higher installed capacity. This behaviour can be seen in Table 2 below:

Table 2: Retail prices per component (USD/Wp)

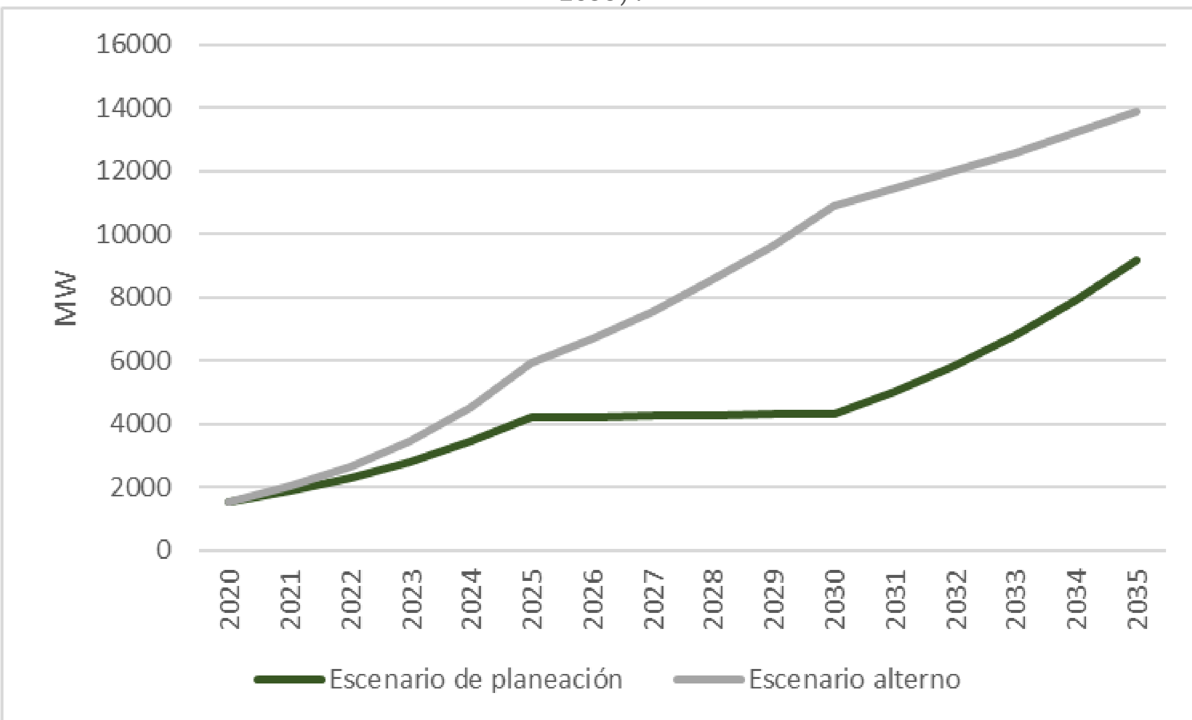
Price dispersion (USD/Wp)	0 - 5 kW	5 - 15 kW	15 - 30 kW	30 - 50 kW	50 - 100 kW	100 - 250 kW	250 - 500 kW
PV panel	0.50	0.50	0.47	0.44	0.47	0.37	0.40
Investor	0.25	0.22	0.19	0.22	0.15	0.15	0.17
Structure	0.22	0.21	0.13	0.12	0.12	0.14	0.14
Electrical equipment	0.10	0.09	0.09	0.09	0.16	0.09	0.08
Labour	0.11	0.11	0.10	0.10	0.10	0.10	0.07
Accessories	0.04	0.04	0.06	0.05	0.04	0.05	0.04
O&M	0.05	0.05	0.05	0.05	0.04	0.04	0.04
Additional (margin, indirect costs, contingency)	0.07	0.07	0.08	0.07	0.07	0.10	0.09
Electrical Installation Verification Unit (UVIE)	0.08	0.05	0.02	0.13	0.02	0.01	0.01
Electrical Inspection Unit (EIU)	0.11	0.25	0.04	0.13	0.02	0.01	0.01

Source: (GIZ, 2021)

Overall, distributed PV generation has the opportunity to continue to grow in the industrial and commercial sectors. Specifically for the agri-food sector, where there are significant savings opportunities given the current cost of tariffs for these sectors, which are between 0.13 and 0.17 USD/kWh (CFE, 2023).

Going forward, it is expected that DGPV will continue to increase its share in the country. As shown in Figure 4, two growth scenarios for distributed PV generation are estimated for the next 15 years, a baseline scenario (planning scenario) and a scenario of increased penetration of distributed generation (alternative scenario). As shown in Figure 4, in a planning scenario, the installed capacity will be 9,179 MW by 2035, while, for an alternative scenario, distributed generation will reach an installed capacity of 13,869 MW. In other words, by 2035, about 50% of the current capacity allowed by the National Electricity System (SEN) for distributed generation of 28 GW would be covered (SENER, 2021). In terms of the real increases in installed capacity presented by distributed generation in the country, it can be concluded that the growth of GDFV in Mexico is in line with the alternative scenario.

Figure 4. Estimated evolution of installed capacity (MW) of distributed PV generation (2020-2035).



Source: (SENER, 2021)

b. Regulatory Framework

As part of the regulatory context, DGPV is regulated in technical, market and administrative aspects. In this sense, the Electricity Industry Law (LIE) defines DG as the generation of electricity by the owner of one or several power plants with a capacity of less than 0.5 MW (exempt generator), which must be carried out in a power plant that is interconnected to a distribution circuit containing a high concentration of load centres. No studies are required to determine the specific characteristics of the infrastructure necessary for the installation of the power plant; only for those cases in which the electrical energy generated by the DGPV power plant is used for high voltage services and/or for services in places of public concentration, for which a verification unit[3] must certify that the installation of the power plant complies with the applicable official

[3] An Electrical Installation Verification Unit (UVIE) is an entity accredited by the Mexican Accreditation Entity (EMA) and approved by the Ministry of Energy (SENER) to verify and certify whether PV systems (and other electrical installations) comply with applicable national (especially NOM-001-SEDE-2012 for electrical installations) and international standards.

Mexican standards. In any case, it is necessary to make the interconnection request to the CRE and the CFE through an interconnection contract (DOF, 2014a; 2014b; 2016).

In market and administrative terms, the CRE published the General Administrative Provisions on distributed generation. This document aims to establish the general guidelines on distributed generation; define the model Interconnection Contract; establish the general technical specifications related to distributed generation; authorise the model Compensation Contract and develop the methodology of Counter-remuneration. These provisions include new obligations and considerations, such as the right to access markets for the sale of energy, payment of overdue credits, among others. These provisions establish three main compensation mechanisms with their respective payments for surpluses or injections to the General Distribution Network, which are listed below:

- **Net Metering:** considers only the energy exchange in a billing period, calculated as the difference between the total energy delivered by the Basic Services Supplier (BSS) and the total energy generated by the Distributed Generation (DG) system delivered to the General Distribution Network (GDN). When this difference is negative, it is considered as a credit in favour of the generator, which will be paid in the next billing period for a maximum of 12 months. At the end of this period, the generator is paid the overdue credit at the average value of the Locational Marginal Price (LMP) during the time interval in which the credit was generated, calculated at the node corresponding to the interconnection point.
- **Net billing:** the energy consumed is settled at the value of the final contracted tariff and the energy fed into the grid is paid to the generator at the hourly LMP calculated at the node corresponding to the interconnection point.
- **Total energy sale:** occurs in the case where there is no electricity supply contract. The total generation is injected into the grid and paid at the hourly LMP calculated at the node corresponding to the interconnection point.

Likewise, the LIE establishes that, if a third party wishes to sell electricity to an end user, this exchange will not be considered as commercialisation, as long as it is generated through distributed generation and within the end user's facilities. This opened up the possibility of a leasing market for photovoltaic systems and new financing schemes in the national DGPV market.

c. Barriers and opportunities

Despite the considerable growth of the national DGPV, there is currently a moment of uncertainty as a consequence of the current energy policy, which has put at risk the continuity of several projects focused on the generation of electricity through the use of solar energy.

The above arises mainly as a result of the project presented by the CRE on 28 October 2022, which aims to modify various aspects of the General Administrative Provisions on distributed generation, the main regulation that applies to DGPV. If this draft amendment is accepted, it would affect DGPV mainly in two aspects:

- The Project aims to modify the compensation schemes that DG can access in order to generate economic benefits. This would mainly affect Net Metering, as instead of considering the current value of the electricity tariff for the energy delivered to the grid. A single value of consideration estimated annually (not yet established) is considered, which would apply equally to all tariffs (regardless of whether they are residential or commercial); directly impacting all consideration contracts. In this sense, if the consideration value is lower than the current one, this may affect the investment returns of the projects.

- The Project contemplates carrying out the same interconnection studies that currently only apply to generation plants with a capacity of more than 0.5 MW. The cost of these studies exceeds 40,000 USD in some cases, which would make any DGPV project unfeasible.

This has led to an atmosphere of misinformation and lack of clarity in the processes that regulate the distributed generation sector, which means that the quality of photovoltaic installations is not optimal, from the equipment and components to the completion of procedures with the corresponding authorities. This unfortunately generates mistrust in the end user and can become an obstacle that prevents the development of a DER market in Mexico.

However, there are several incentives for DGPV projects in the country, which still motivate consumers to implement distributed generation projects. The main incentives are listed below:

- **Income tax.** According to the Income Tax Law, article 34, section XII, establishes that the total cost of the installation of a photovoltaic system is 100% tax deductible in the first year, i.e. in an accelerated manner, without having to wait for depreciation. This tax incentive has the condition that the solar panel system is in operation 5 years after the deduction was made. This means that each year it is necessary to report by means of a supplementary declaration that the solar panels are operating on the company's property. It is worth mentioning that this tax benefit allows to reduce the return on investment for more than one year and thus anyone can be eligible regardless of the state of the Republic in which the company is located.

- **Payroll and Wage Tax.** This benefit reduces by a certain percentage the tax applicable to payroll and salaries; it applies to companies that have environmental improvement programmes and works as follows:
  - 20% reduction when their normal operating conditions decrease from 30% to 44%.
  - 30% reduction when their normal operating conditions decrease from 45% to 59%.
  - 40% reduction when their normal operating conditions decrease from 60% to 100%.

  In order to benefit from this reduction, it is essential to specify the benefits of your photovoltaic system for the environment.

- **Property tax.** This benefit involves a reduction in property tax for companies that install systems that help reduce pollutant emissions and works as follows:
  - 10% reduction when they install systems that reduce their pollutant emissions by 30% to 39%.
  - 15% reduction when they install systems that reduce their pollutant emissions from 40% to 49%.
  - 20% reduction when they install systems that reduce their pollutant emissions by 50% to 100%.

  To qualify for this reduction, it is necessary to present a certificate issued by the Ministry of the Environment, which specifies the benefits that the solar panel system represents for the improvement of the environment, among other aspects.

In addition, it is important that Mexico continues to work on new public policies that promote mechanisms that encourage investment to fairly distribute the benefits of distributed generation between the State and users. Examples of these policies include the following:

- Increasing the capacity limit for distributed generation from 0.5 MW to 1 MW. This would expand the possibility of generation for medium-sized companies in the commercial and industrial sector, with considerable energy consumption, but which cannot access the electricity market to improve energy costs. In addition, this could double the installed capacity, with larger projects, increasing the demand of the domestic PV market and reducing investment costs.
- At the end of 2019, the CRE approved a regulation agreement for collective distributed generation (CDG) which, although its publication is still pending, identifies an important potential to promote the advancement of CDG as a mechanism to increase social participation in the energy transition by providing new alternatives to supply their electricity consumption needs to users who do not have the physical space or economic capacity to acquire their own system. The CDG model has many advantages in addition to the benefits of individual distributed generation:

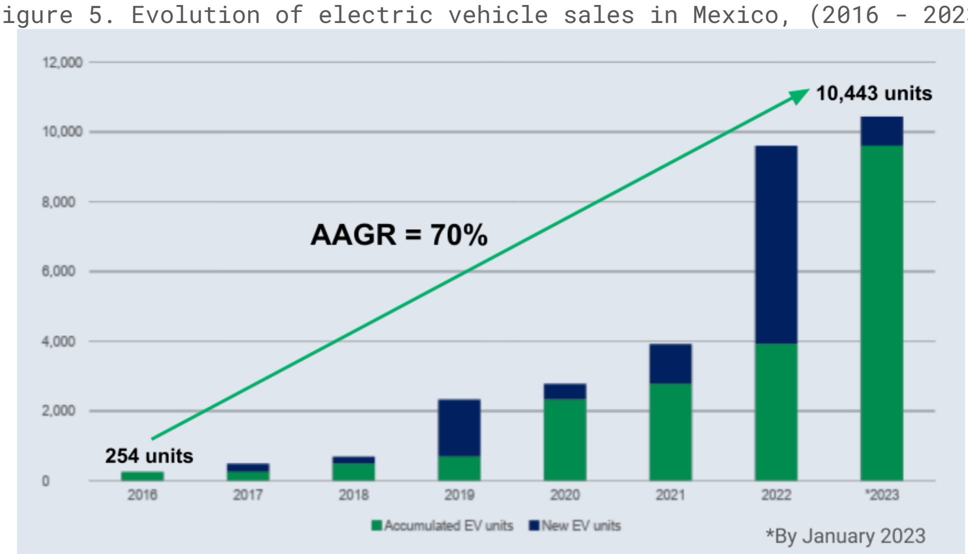
- Increased energy independence.
- Reduced installation costs due to economies of scale.
- Generation of local jobs.
- Diversification of the energy matrix at local level.
- Reduction of energy losses in the transmission and distribution system.

Electromobility

a. Market

According to the National Institute of Statistics and Geography (INEGI, 2023), as of January 2023, there are 10,443 electric vehicles (EVs) in the country, representing an average annual increase of 70% compared to 2016, where a total of 254 EVs were sold, as shown in Figure 5. Of the EVs marketed until 2023, it is estimated that around 15% are vehicles for commercial purposes.

Figure 5. Evolution of electric vehicle sales in Mexico, (2016 - 2023)



Source: (INEGI, 2023)

As is well known, electric vehicles require battery charging to operate. This charging can be done from charging points installed at residential level or in infrastructure prepared to handle appropriate voltage and current magnitudes to reduce recharging times, which are commonly referred to as electro-power stations. These charging stations are divided into three different levels, according to the manageable power supply capacities for different types of charging, as shown in Table 3 below.

Table 3. Characterisation of charging centres for electric vehicles.

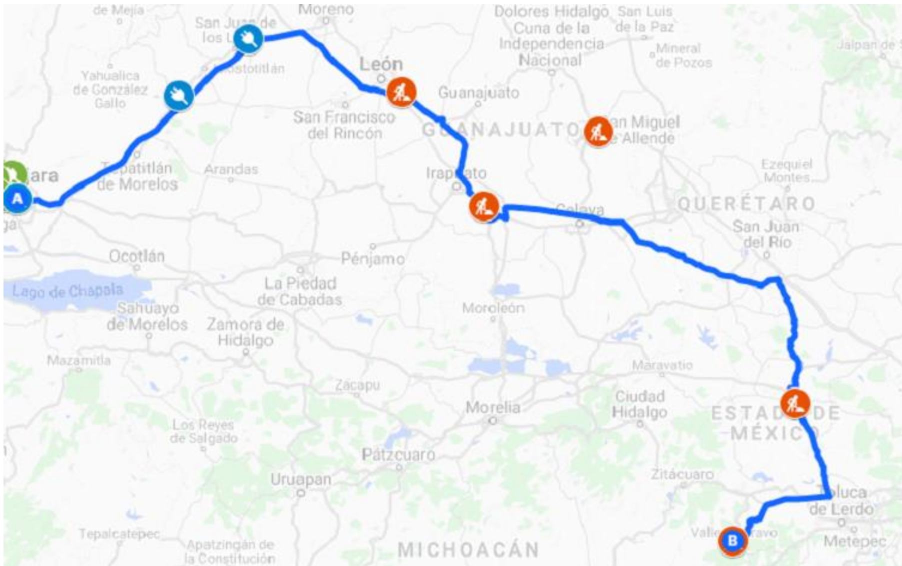
	Amperage (A)	Voltage (V)	Kilowatts (kW)	Autonomy (km travelled/charging time)	Location of load centres
Level 1	12 a 16	120	1.3 - 1.9	3 - 8 km / 1 hour charge	Charging in residential areas and workplaces
Level 2	Up to 80	208 - 240	Up to 19.2	16 - 32 km / 1 hour charge	Charging in residential areas, workplaces and public spaces
Fast charging	Up to 200	208 - 600	50 a 150	96 - 128 km / 20 min charge	Public spaces
Ultra fast charging	400	1000	350	200 km / 7 min charge	Public spaces

Source: (SCT, 2020)

The automotive industry in Mexico has seen the potential and advantages of electric mobility and has played an active role in infrastructure investment, concentrating most of the country's public access charging centres. In turn, the CFE has promoted the deployment of infrastructure for electric cars and plug-in hybrids. In coordination with SENER and the Technical Committee of the Fund for Energy Transition and Sustainable Energy Use (FOTEASE), they developed the Programme for the Promotion of Electromobility through Investment in Charging Infrastructure (PEII). The Programme envisages the installation of 100 electric charging stations in public access sites in the metropolitan areas of Mexico City, Monterrey and Guadalajara, of which 74 are completed (71 Level 2, and 3 Level 3) and 13 are under construction. Likewise, the CFE plans to deploy 9 electricity corridors distributed in 10 states of the republic that will cover the state of Morelos, Mexico City, the State of Mexico, Queretaro, Guanajuato, Jalisco and Aguascalientes. While a northern corridor will cover from the North American city of Mc Allen to Reynosa, Tamaulipas, followed by Monterrey, Nuevo Leon and Saltillo, Coahuila.

Figure 6 shows the first of these corridors already in operation. It has 2 operating electro-lift stations and 4 more under construction. This corridor covers a 632 km stretch from the city of Guadalajara to the magical town of Valle de Bravo. The blue circles indicate the operating electric stations, while the orange circles indicate the electric stations under construction:

Figure 6. First electric corridor enabled by CFE for charging electric vehicles on road sections.



Source: (CFE, 2021)

In addition to the above, there are around 2,089 public access charging centres in the country, distributed throughout the national territory and located mainly in shopping centres and concessionaires (RENAEL, 2022). Fifty-four percent are located in Baja California, Mexico City, Jalisco, State of Mexico and Nuevo Leon. In contrast, the states where fewer chargers have been installed are Campeche, Tabasco and Tlaxcala.

Figure 7. Distribution of electric vehicle chargers nationwide.

Source: (RENAEL, 2022)

Finally, according to information from INEGI, it is estimated that EV commercialisation in Mexico will increase at an average annual rate of 20.1%, reaching a total of 24,621 new EVs commercialised by 2030; this trend is expected to be reflected in the implementation of EV charging infrastructure.

b. Regulatory framework

The transition to electrified transport systems in Mexico has accelerated over the last decade as a result of efforts to combat climate change, improve air quality and people's mobility. In general terms, electric vehicles are those that use electricity as a source of energy, either partially or totally. For the purposes of this document, electric vehicles (EVs) are considered to be those vehicles that are powered solely by an electric motor, i.e. they do not have hybrid systems (IMT, 2020).

The progress of electromobility in Mexico has focused on the electrification of integrated and mass transport systems. However, the development of infrastructure for public charging of EVs, as well as the incorporation of new electromobility technologies for private passenger and freight transport, have seen significant growth and increased participation in their respective sectors. However, electromobility in the country still has a great area of opportunity in other fundamental aspects such as: regulatory framework, business models and greater penetration and use of these technologies.

Recently, the Ministry of Foreign Affairs and the MX Alliance[4] published a document entitled *Grupo de Trabajo para la Electrificación del Transporte: Diagnóstico y recomendaciones para la transición de la Industria Automotriz en México (Working Group for the Electrification of Transport: Diagnosis and recommendations for the transition of the automotive industry in Mexico)*, which proposes a transition to electromobility from various perspectives, including regional industrial integration, transformations within the different actors in the value chain, as well as long-term planning focused on electromobility for passengers, freight and public transport. Likewise, taking as a transversal approach the improvement and acceleration of women's participation in the different activities of the value chain that integrates the sector. The document also sets out the intention of generating a roadmap for the integration of electromobility at the binational level between Mexico and the United States (SRE & Alianza MX, 2023).

In terms of regulation, the Energy Regulatory Commission published in 2018 the agreement issuing the interpretation criteria on the way in which the sale of energy between individuals (end users and third parties) can be carried out, including electric vehicle charging stations (DOF, 2018). However, the regulatory framework in Mexico regarding technical aspects of electromobility infrastructure and batteries, as well as that linked to automobiles (electric and hybrid) and their different components, has not been extensively developed.

In this sense, there are some projects to modify the Mexican Official Standards (NOM)[5] , with the aim of including some characteristics that allow the concept of electromobility, its components and systems to be put on the map, such as:

- **NOM-194-SE-2021[6]** , Essential safety devices in new vehicles-Safety specifications (Safety devices and their specifications in special vehicles. This adds the term essential safety devices for electric vehicles (DOF, 2022).
- **NOM-163-SEMARNAT-ENER-SCFI-2013**, Carbon dioxide emissions (CO_2) from exhaust and their equivalence in terms of fuel efficiency (modification to the incentive for highly efficient technologies - electric vehicles - hybrids) (INECC, 2020).

In turn, at the end of 2022, it was announced that the Mexican Ministry of Economy is currently collaborating to develop an Official Mexican Standard related to electric vehicle batteries. This information was shared through the director of Process Improvement and Promotion of the Ministry of Economy, Juan Carlos Rivera Guerra (Energía a debate, 2022 & Portal Movilidad, 2022).

On the other hand, the Association for Standardisation (ANCE) has developed Mexican Standards (NMX) which, unlike NOMs, are not officially enforceable and therefore do not establish mandatory technical regulation. In this respect, the following NMX can be mentioned, included in the four corresponding

[4] University of California MX Alliance

[5] The Official Mexican Standards, called NOMs by their initials, are mandatory.

[6] NOM-194-SE-2021, Safety devices for new light vehicles-Requirements and specifications. It cancels NOM-194-SCFI-2015 published on 9 May 2016.

categories (personal protection systems, power supply equipment, and plugs, receptacles, connectors, couplers and flanged plugs, as well as inductive and non-inductive charging systems) according to the systems they regulate (ANCE, n.d.):

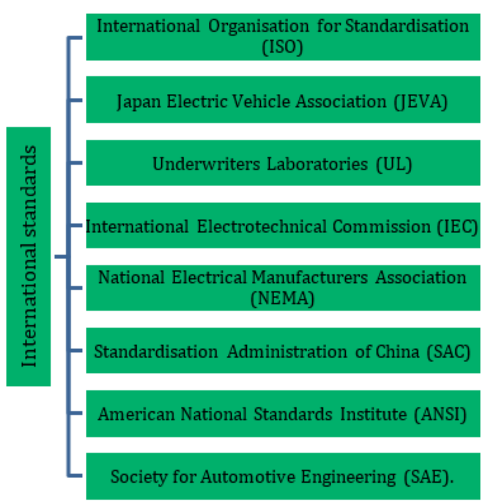
Although the regulatory framework in Mexico has many areas of opportunity, the inclusion of and compliance with international standards plays a fundamental role in supporting the characterisation and specification of materials, technologies, vehicles, batteries and electromobility infrastructure.

In this regard, through the consensus and knowledge of various international experts, guidelines are developed that shape the compliance of various manufacturers, project and infrastructure developers, as well as product distributors. In general, international standards take the following as their main focus:

- Manufacture of vehicles, vehicle components and batteries
- Utility companies
- EV charging infrastructure project developers
- Other services such as:
    - Operation of battery switching stations
    - Service and technical-electrical inspection
    - First aid
    - Insurance companies

The main international standardisation organisations are shown in Figure 8 below:

Figure 8. International standardisation organisations linked to EVs and their infrastructure.



Source: Own elaboration

These associations have a large number of standards that identify key features and specifications for compliance across multiple dimensions such as: safety of electric and hybrid vehicles, charging infrastructure, EV communication interface to the grid, power testing, labelling, performance, as well as best practices for installation and verification of components.

In terms of energy storage, the 2022 National Electricity System Development Programme mentions it as one of the pillars for achieving the country's energy transition. However, there is no standard or regulation that determines technical characteristics or validation tests in terms of energy efficiency in this area (SENER, 2022).

c. Barriers and opportunities

The generation of a solid and precise regulatory framework is essential for the correct application of strategies that facilitate the implementation of electromobility projects, electric charging infrastructure for cars, as well as the development of energy storage projects. In terms of charging infrastructure and electromobility, despite the existence of an agreement for the sale and purchase of electricity between individuals, no specific tariff has been defined for the use of electric charging stations (DOF, 2018). And in turn, the regulation is not clear regarding the existence of differentiated or transfer tariffs between the owners of the electric charging stations and the end user (EV owner).

On the technical side, there are no mandatory national standards on the characteristics of electrical energy charging installations, their components and compliance with the specifications of the connectors used.

The growth of the electric vehicle market in Mexico has been fostered in large part through government schemes that promote incentives to purchase an electric vehicle. The Mexican government published a decree that presents the benefits of using an electric vehicle, such as Income Tax, Value Added Tax Law, the Fiscal Code of the Federation and the New Car Tax Law, being this the main incentive. The following table presents the main incentives for owners of this type of vehicle

On the other hand, the growth of the electric vehicle market in Mexico has been fostered in large part by tax benefits and incentives for the adoption of this type of technology at the individual level, such as: exemption from payment of vehicle registration fees[7] , exemption from annual verification[8] , as well as better interest

[7] The payment of tenure is a tax derived from the acquisition of a vehicle, thus being one of the obligations when owning a car. This tax is heterogeneous throughout the country and is calculated according to certain characteristics of the vehicle such as: make, model, year and series of the vehicle. In some cases, such as in Mexico City, the tenure payment depends on the invoice value of the car.
[8] Vehicle verification is a programme that is compulsory in some states of the Republic, with the particular objective of recognising that the vehicle complies with technical and emission limitation standards. It is worth mentioning that not all states have this type of programme.

rates for the acquisition of this type of vehicle. On the other hand, these vehicles do not stop circulating in case of an environmental contingency. Table 4 below presents the main incentives for owners of this type of vehicles:

Table 4. Main incentives applicable to electric vehicles.

Incentive	Description
New Automobile Tax Exemption (ISAN)	Electric vehicles do not pay New Car Tax.
Tenure exemption	Tenure exemption in most states. In the State of Mexico, the tenure is not paid for the first five years, after which it is paid with a 50% discount.
Gummed E	In Mexico City and the State of Mexico, a special sticker is assigned to identify electric vehicles.
Environmental Verification Exemption	Electric vehicles, given the technologies used for their propulsion and the fact that they do not produce polluting emissions, are exempt from the vehicle verification programme, which involves a biannual emissions check and the restriction of the "no driving today" programme.
Income tax deductibility for the acquisition of petrol stations	In the General Economic Policy Criteria for the Revenue Law Initiative and the Draft Federal Expenditure Budget for Fiscal Year 2017, a tax credit is established to deduct 30% of the ISR of infrastructure for charging electric vehicles with public access.
Tariff elimination	Elimination of tariffs for the import of vehicles that use electric motors, including cars, vans and cargo trucks. This applies to companies that subscribe to the decree for the support of competitiveness, as proposed by the Ministry of Economy.
Green car number plates	Identify vehicles with hybrid or electric technology.
ECOTAG	Special 20% discount for electric and hybrid cars on TeleVía roads in Mexico City (Autopista Urbana Norte, Autopista Urbana Poniente and Autopista Urbana Sur).

Additional meter	To promote the adoption of electric vehicles, the CFE installs a separate meter in the owner's home to bill exclusively for the consumption of the vehicle and maintain the household tariff level.
Preferential parking	Many establishments offer their visitors using hybrid and electric vehicles preferential parking spaces and/or charging stations.

Source: Own elaboration with information from (SCT, 2020).

Energy storage

a. Market

In Mexico, energy storage, used as a complement to increase the benefits provided by renewable energy technologies, is in an initial stage of market penetration. Especially in the distributed generation market; therefore, there is currently insufficient information to allow us to assess the current situation of this DER technology in the country. However, there are currently several companies developing projects that already include this technology as part of their energy solutions. It is therefore expected that in the medium term, this technology will increase its share of the DER technology market.

b. Regulatory framework

Currently, there is no specific regulatory framework in Mexico for energy storage systems to regulate their operation both technically and in the energy market, as there is for other DER technologies available in Mexico, so the storage systems identified in the country, in addition to being outside the permitted limit of installed capacity for DG (less than 500 kW), are not interconnected to the national energy grid (Table 5).

Table 5. Energy storage projects identified in Mexico.

Name	Technology	Capacity	Purpose
Solar Aura III	Solar PV + Lithium-ion batteries	10.5 MW/7.0 MWh	Network stabilisation
Arroyo Power Energy	Chemical batteries	12 MW/12 MWh	Back-up power

Source: Own elaboration with information from (INECC, 2020).

However, the National Institute of Ecology and Climate Change (INECC) prepared a report on the results of a national workshop held to review and evaluate experiences and trends in electricity storage technologies in Mexico (INECCb, 2020). The report considers including energy storage systems in the Electricity Market Rules, as well as in the planning of the National Transmission Grid and General Distribution Networks; it also includes establishing regulations for the testing, certification and interconnection of storage systems, promoting research and technological development of devices and storage (metal-ion batteries, chemical and supercapacitors with a focus on renewable energies) and disseminating the technical and economic viability of energy storage systems in Mexico to facilitate their acceptance.

In line with the objectives of the aforementioned workshop, an agreement updating the *Estrategia de Transición para Promover el Uso de Tecnologías y Combustibles más Limpios* (*Transition Strategy to Promote the Use of Cleaner Technologies and Fuels) was* published in the Official Journal of the Federation. This publication contains lines of action in line with the workshop held by the INECC, in addition to the objectives of promoting business models that facilitate the integration of storage systems in the value chain and publishing information from the Electricity Market that facilitates the modelling of energy storage in the SEN (DOF, 2020).

Market study on distributed energy resources in Mexico.

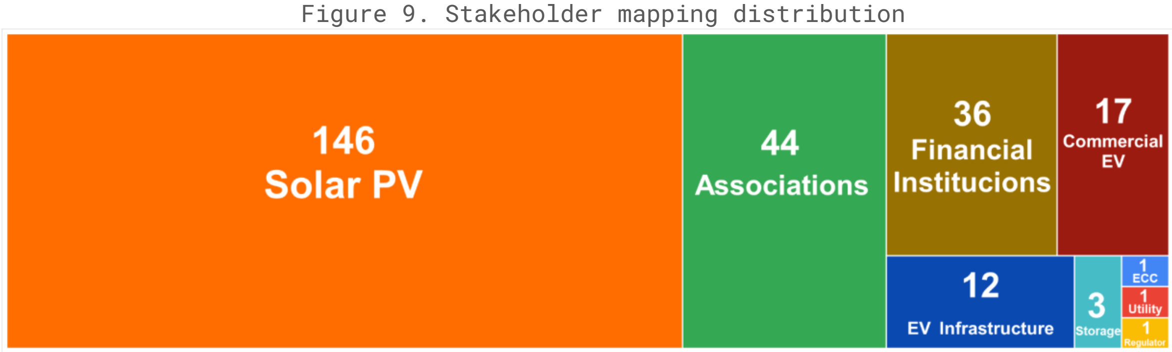
Part 1: Market mapping

As mentioned at the beginning of the document, this section presents a market study, which is developed in two parts: the first part presents the results of a market mapping conducted by the ICM team, including the mapping of stakeholders, technologies, and business models. This is based on desk research and an analysis of information sources, studies and documents related to the topics of interest. This market mapping will provide an in-depth understanding of the current market conditions, as well as the needs and areas of opportunity for growth. The second part presents the results obtained from interviews with relevant stakeholders in the sector, such as developers, technology providers, associations from the PV, EV and related sectors, as well as governmental/regulatory institutions. The methodology applied for the development of the market study can be seen in the Annex section.

Stakeholder mapping

As a result of the stakeholder mapping, it was detected that there are at least 256 stakeholders related to the distributed generation and electromobility sectors in Mexico. Of the total number of identified actors, 16% are associations belonging to different sectors of the food, PV, electromobility, commercial, restaurant and hotel industries; 56% are companies directly related to the development of PV projects; 1% are companies dedicated solely to energy storage; 5% are companies focused on EV infrastructure; and 7% are companies that distribute EVs for commercial purposes. In addition to the above, 12% were identified as financial institutions offering exclusive products for clean energy; and the remaining 1% corresponds to a Regulator; an Energy Controlling Centre; and 1 Energy Utility provider (Figure 9).

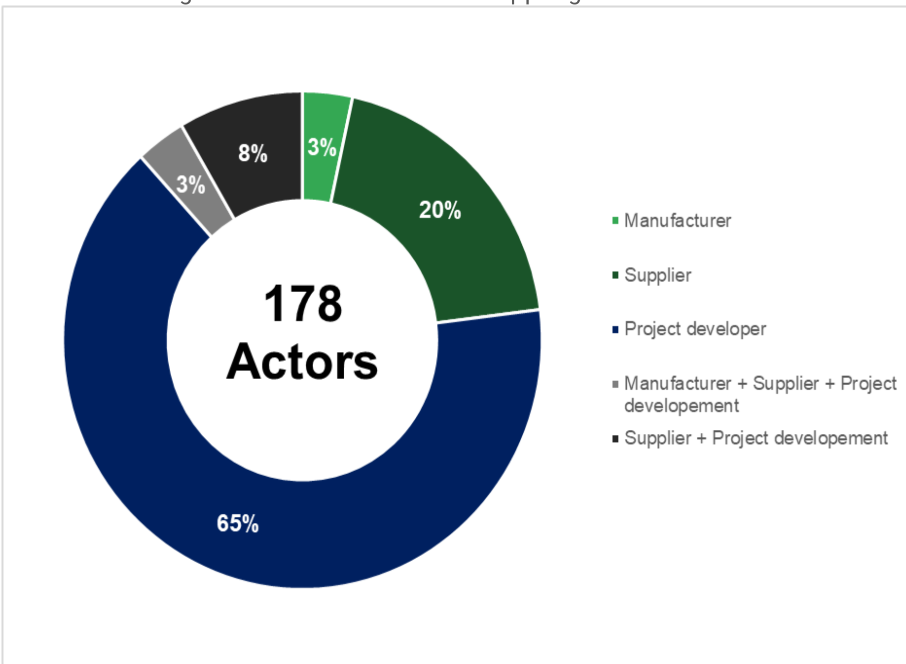
Figure 9. Stakeholder mapping distribution



Own elaboration

In line with the above, 178 actors were identified as manufacturing, distributing and/or developing projects related to the DER technologies available in the country. Of these, 6 are companies that only manufacture DER technologies and/or some of their main components in the country (e.g. inverters for PV systems); 35 are only suppliers and 116 are only project developers. There are also companies that combine these services, so that in Mexico there are 6 manufacturers that are also technology distributors and project developers; and 15 companies that are distributors and project developers. The participation of each of these actors is shown in Figure 10.

Figure 10. Stakeholder mapping distribution

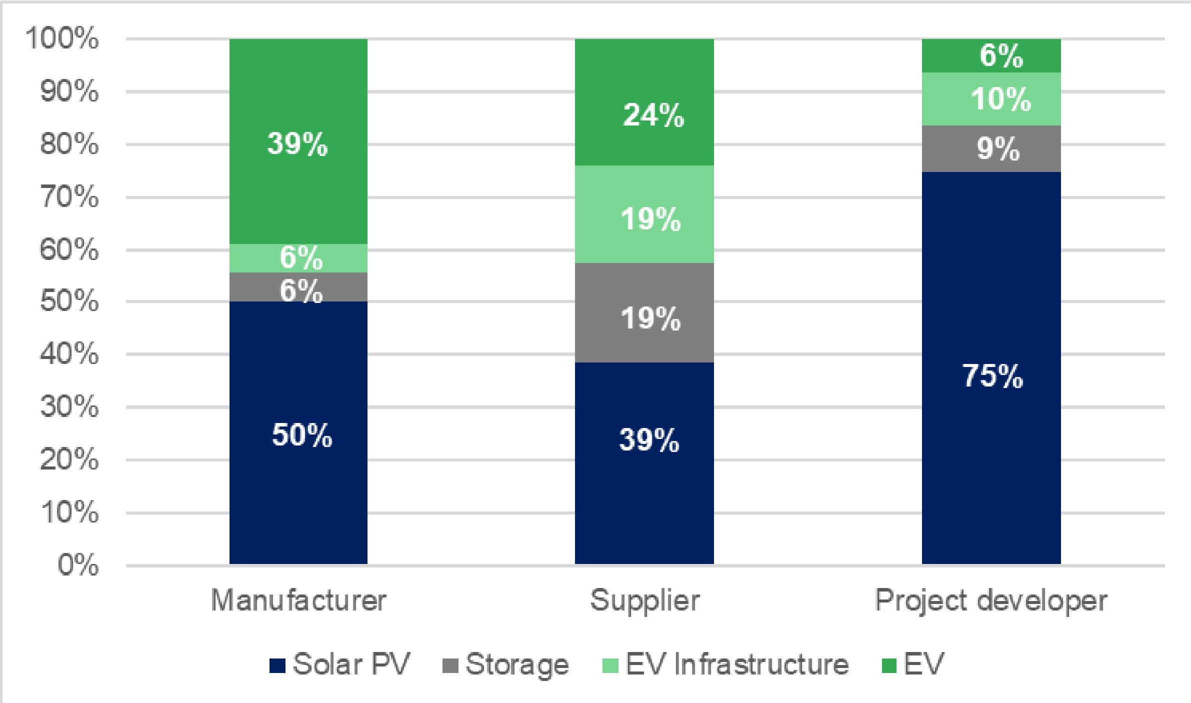


Own elaboration

Mapping of DER technologies

Regarding the type of DER technology, Figure 11 shows that PV technology is the dominant technology in the country, as it is used by 75% of project developers; 39% of distributors; and 50% of manufacturers. While the technologies with the lowest penetration are storage and EV infrastructure, as they are only used by 6% of manufacturers, 19% of distributors and 10% of project developers.

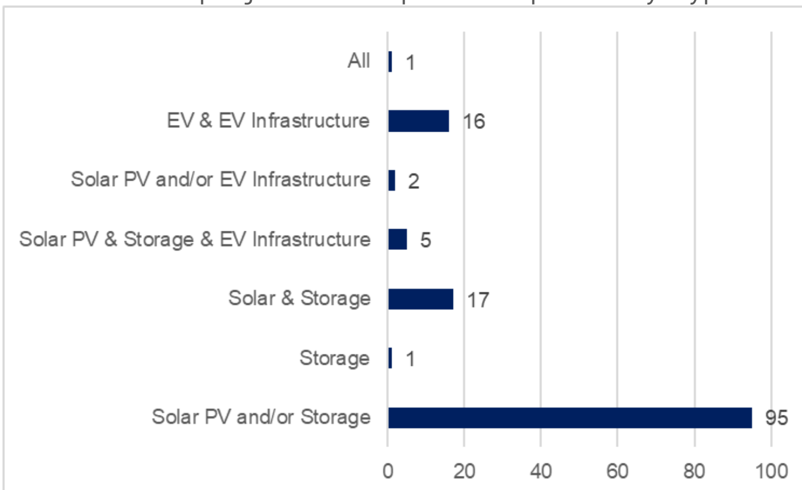
Figure 11. Distribution of DER technologies by type of actor



Own elaboration

With regard to project development, the dominance of PV technology in the country is emphasised, with 69% of the companies developing projects with PV and/or storage technologies only, followed by a group of companies developing PV technology projects with storage and another group developing EV projects that include infrastructure, both of which together account for 12%. Meanwhile, 4% of the companies of this type develop projects that include PV technology, storage and EV infrastructure. Finally, with the lowest share, there are three sets of companies, those that develop projects only for storage, PV technology and/or EV infrastructure, and a single company that includes all the technologies considered, all three with a share of 1%. Figure 12 shows more clearly the number of companies involved in the development of projects with the different DER technologies considered.

Figure 12. Distribution of project development companies by type of RED technology.



Own elaboration

In addition to the above, it is important to clarify that the companies considered as part of the EV sector were those that manufacture, distribute or develop projects with light and last mile EVs. Of these companies, 65% have focused on minivans or light-weight vehicles and 35% on motorbikes. On the other hand, 25% have focused on electric bicycles, which is a means of transport that has increased its use in cities due to its environmental benefits. An electric bicycle consumes 1 kWh/hour for every 100 kilometres travelled and emits between 9.65 and 13.65 grams of CO_2 /km, compared to a conventional car which consumes 40 kWh/100 km and produces 170 to 250 g CO2/km (CONUEE, 2017).

Business Models

As part of this study, it was identified that the companies analysed base their operations on three different business models:

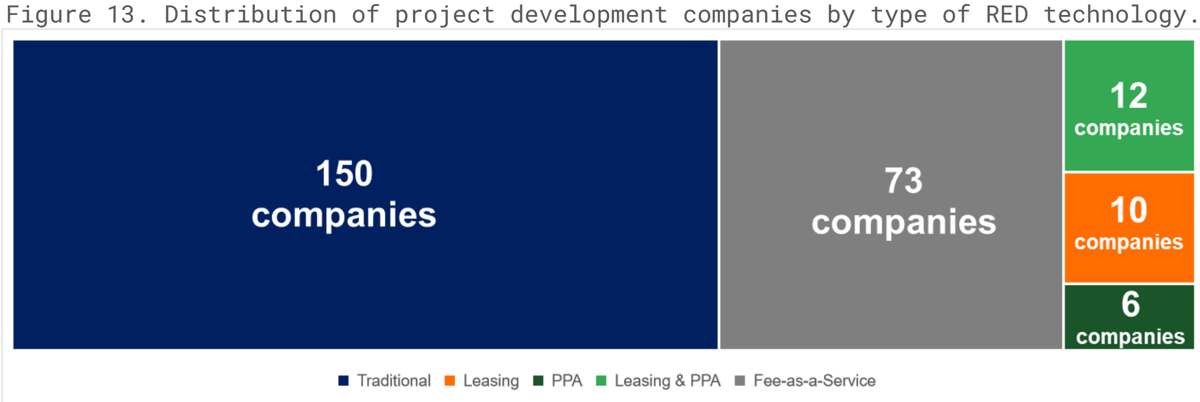
- **Traditional model:** Companies buy technologies from manufacturers or distributors and then sell them to customers at a price that allows them to cover costs and make a profit. This is the most common and most widely used business model in the country.
- **Energy as a service:** In general, this business model considers the delivery of energy from a supplier to the consumer in exchange for a monthly payment. The supplier bears the costs of acquiring the technology, its installation and other elements. In this sense, the leasing model and the power purchase agreement (PPA) are specifically applied in Mexico. In the former, consumers agree to pay a fixed fee for the use of technology, thus avoiding the need for a large upfront capital

investment. In the second, they are an alternative to leasing and the consumer agrees to purchase a certain number of kWh of energy from a supplier. The supplier can either generate the energy on the consumer's premises or transmit it from another location, and is responsible for the procurement of the technology, its installation, maintenance, repairs and recovery of the generating equipment. PPAs typically require a long-term commitment, typically ten or more years, to be profitable. Although these business models currently have low penetration, more and more companies are beginning to adopt them.

- **Fee-for-service:** In this business model, companies charge a fixed fee for a specific after-sales service. In this case, companies apply it when offering operation and maintenance (O&M) services and monitoring the performance of technologies.

In line with the above, it is identified that 84% of the companies base their operations on a traditional business model; 6% offer the leasing model in addition to the traditional one; 3% offer the PPA model in addition to the traditional one; and 7% offer both business models (leasing & PPA) in addition to the traditional model. Finally, 41% of the identified companies offer additional after-sales services as mentioned above (Figure 13).

Figure 13. Distribution of project development companies by type of RED technology.

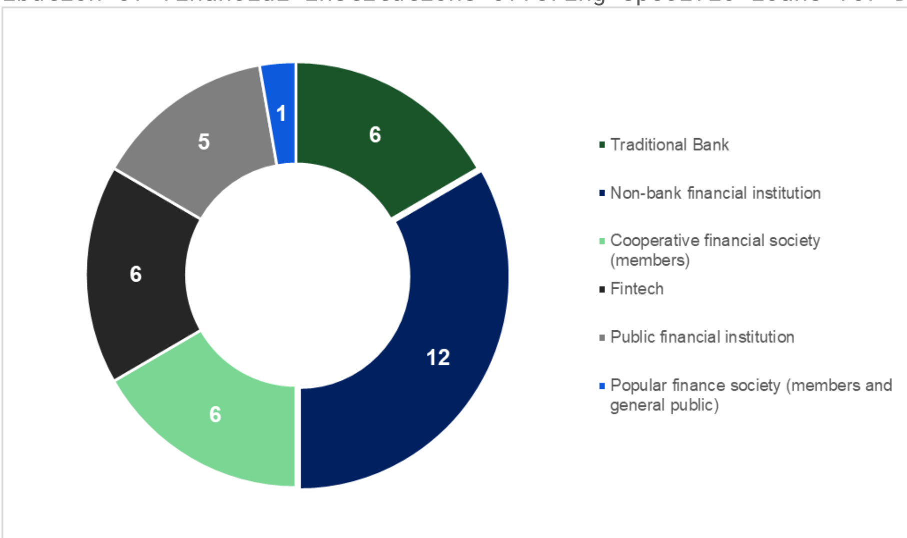


Own elaboration

Funding

Respect to financing, 36 financial institutions were identified that offer specific credits for the acquisition of clean energy technologies, among which are the DER technologies that are part of this study. Of these institutions, 17% are banking institutions (traditional banks); 33% correspond to non-bank financial institutions, i.e. they operate with private funds but do not have the infrastructure of a traditional bank; 17% operate under the cooperative financial society scheme and only members can access credit; 17% are Fintech; 14% are public financing institutions; and 3% correspond to popular finance societies (members and the general public).

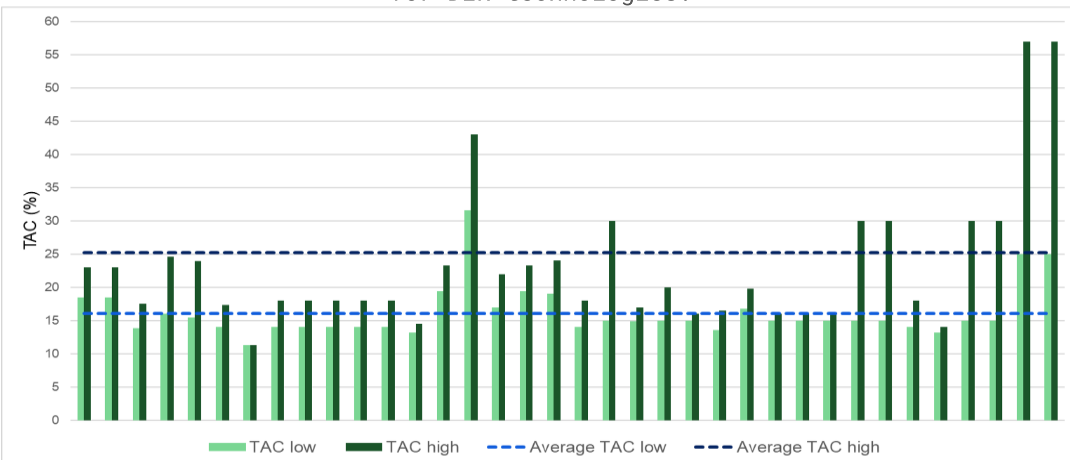
Figure 14. Distribution of financial institutions offering specific loans for DER technologies.



Own elaboration

In relation to interest rates, the average total annual cost (TAC), at the low end, is 16.1%. While the average TAC at the high end is 25.2%. Regarding the low TAC, a quarter of the financial institutions offer loans below the low average. While with regard to high TAC, only 19% offer loans above the high average. This can be seen in Figure 15 below.

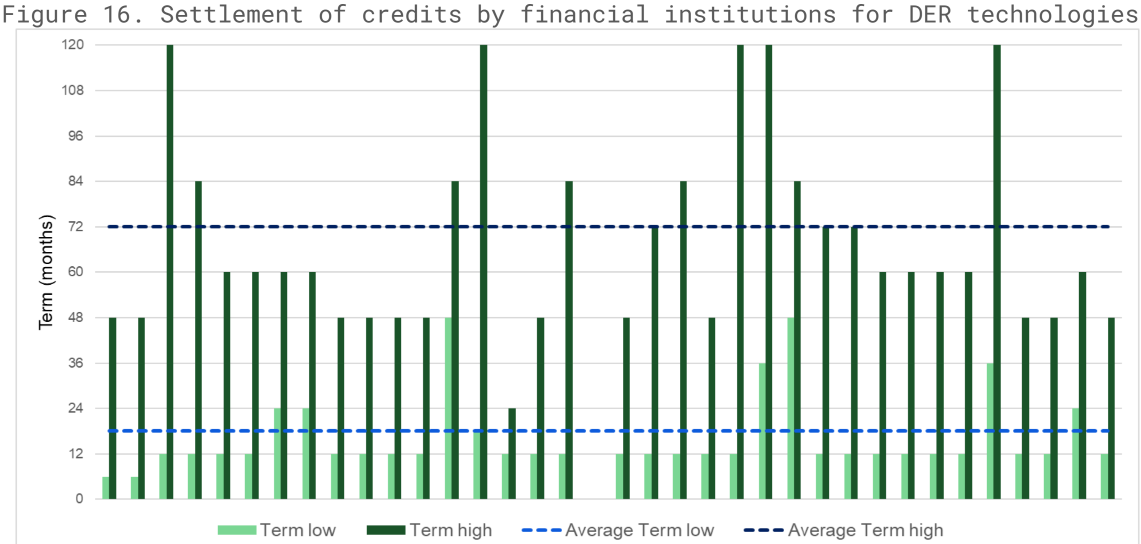
Figure 15. Distribution of the TAC offered by financial institutions providing specific loans for DER technologies.



Own elaboration

Finally, the terms for loan repayment are between 12 and 120 months. Nineteen percent of the institutions offer terms below the low average limit (18 months). While 28% offer terms above the high average limit (72 months), as shown in Figure 16 below.

Figure 16. Settlement of credits by financial institutions for DER technologies.



Own elaboration

Conclusions

As can be seen, the national landscape in relation to DERs is predominantly composed of two technologies, solar photovoltaic and electric vehicles, both of which have an established market with significant growth estimates for the future. Therefore, both technologies have a large potential to establish different business models, as they have financing options and a sufficient regulatory framework, which allows them to be exploited and generate benefits in the short term. Unlike energy storage, which is at an early stage of penetration and therefore does not yet have an established market. In addition, its benefits cannot be fully exploited, as it does not have a specific regulatory framework to regulate its technical and market operation. As a result, it can only be used as an element that provides the end user with back-up energy (behind the meter), rather than turning it into a potential prosumer. This is expected to happen in the long term.

Part 2: Interviews

Supply side

In order to complement the mapping of actors that was done previously, a market study was carried out based on interviews with developers of DER technologies, State Energy Agencies, as well as sector associations.

Sixteen interviews were conducted with the aim of gaining a more in-depth understanding, from the point of view of the participating actors, of the conditions of the RED technologies market and its integration in Mexico. The questions asked were specific to each type of stakeholder and focused on the following topics: economic and technical viability; training; regulation; financing; public policy; challenges; costs; technological availability; and prospects.

The overall results of this study conclude that the growth of this market in the country is promising, due to economic and trade conditions. With the benefits of the free trade agreement with the United States and Canada, there has been a growth in the import of affordable technologies. Similarly, the *Nearshoring* phenomenon is an opportunity that the participants considered for the future economic growth of the country and the market for DER technologies. Furthermore, in Mexico there is sufficient technical feasibility and training for these technologies to be installed, although there is still not much knowledge about the integrated installation of these technologies.

Specifically, all interviewees, both developers and associations and agencies, consider that in the short term future DER technologies will impact the Mexican market, which means that there will be a growth in the installation of solar panels, batteries for storage and electric vehicle chargers in the coming years. However, although the DER technology market has grown in Mexico, the study showed that it has not had sufficient penetration in the food or agri-food sector.

Participants claim that solar photovoltaic technology is currently the most widely used technology in the country. However, this will change in the coming years, due to the increasing use of batteries for energy storage. Similarly, the use of batteries has increased; however, their price is not yet affordable for large-scale growth. According to the results of the interviews, the costs of DER technologies in Mexico are high; solar PV is between USD 0.75 and 1.3 per kWh, while with integrated storage the prices double.

The demand for DER technology, according to the interviewees, has grown, but electric vehicle chargers are the technology that has attracted the least interest. This is also due to the lack of information about its benefits and its integration with other technologies, so one of the most important challenges for the market in Mexico is socialisation.

Likewise, the interviewees agree that the regulation of DER technologies is one of the greatest challenges facing the country for their installation and growth. The current regulation is old and does not include new technologies such as batteries, so legal loopholes are an impediment to their integration with PV technology. However, interviewees believe that this will change in the future, due to the momentum that is being given internationally.

With regard to financing, the respondents stated that there are financial mechanisms in Mexico for RED technologies. However, these are unknown and still have high interest rates, so people do not consider them as a viable option. In addition, the Energy Agencies agree that small and medium-sized enterprises should receive additional support for the installation of DER technologies in an integrated manner; this support can also be considered within a financial plan with the collaboration of international development banks.

The specific results of the market research are presented below by topic covered in the interviews.

Suppliers

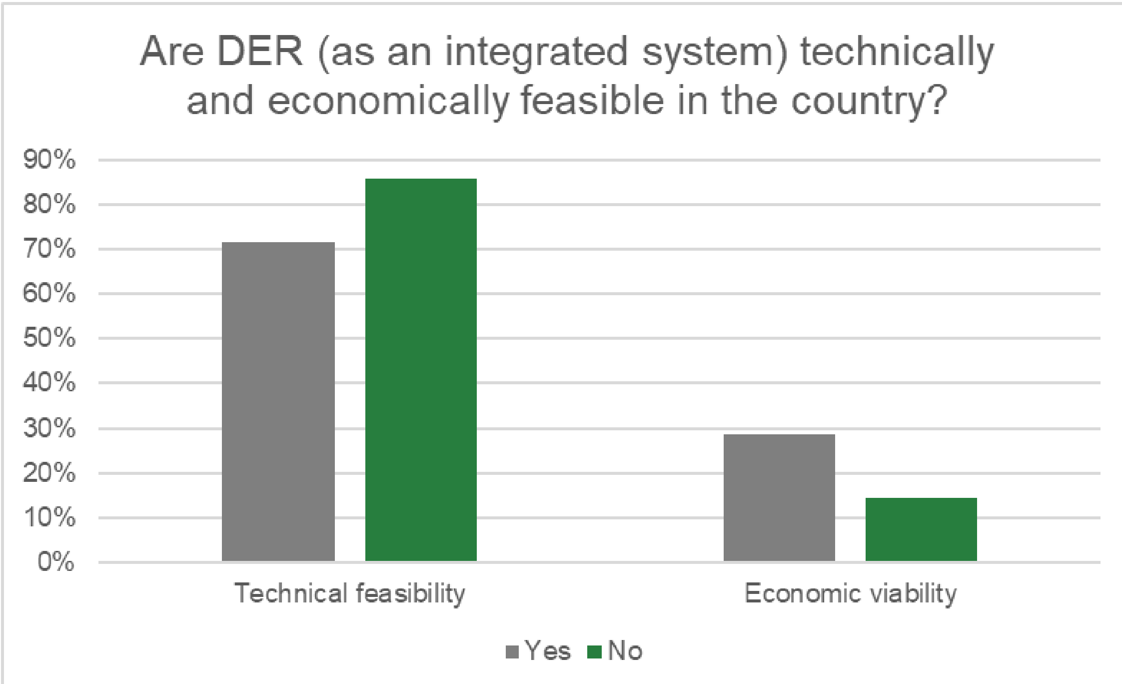
Of the 16 interviews conducted, 7 were with suppliers and developers of DER technology, who consider that the country has good conditions for market growth. The technical and economic feasibilities make this possible, although there are certain barriers that still need to be addressed.

One of them, according to the developers, is that engineers need to complement their specialisations to learn more about new technologies and their integration. Therefore, there is an opportunity in terms of education and specialisation that would make the reliable installation of DER technologies possible.

This relates to training, which is a key element for technical viability in the country. Developers are concerned about the training of installers and recommend that investment should be made in improving the technical skills of those involved in the market. In fact, 71.4% of the suppliers interviewed are of the opinion that more training is needed, while 14.3% mention that the existing technical training is sufficient; 14.3% did not give a concrete answer to this issue.

Developers also comment that the standards of competition in the market should be reviewed and analysed. In this way, investment in training and specialised education in certain technologies is feasible. For example, it was suggested that there should be diploma courses in storage, which would help to cover this need in the market. It is also proposed that there should be training for end-users, specifically in electric vehicle technology, as this is the most unknown among users as part of DER technologies.

In addition, there are other challenges in terms of space, the capacity of the lines, the conditions of the site where the technologies are to be installed, among others, that hinder technical feasibility. However, 71.5% of the developers have a positive outlook and consider that Mexico has sufficient technical feasibility for the development of these technologies.



On the other hand, 85.7% of the suppliers mention that in Mexico there is economic viability for the development of DER technology integration, mainly because there is good supply and demand; although the current demand does not yet require an interconnected system. Also, the high electricity tariffs of the CFE make this market economically viable.

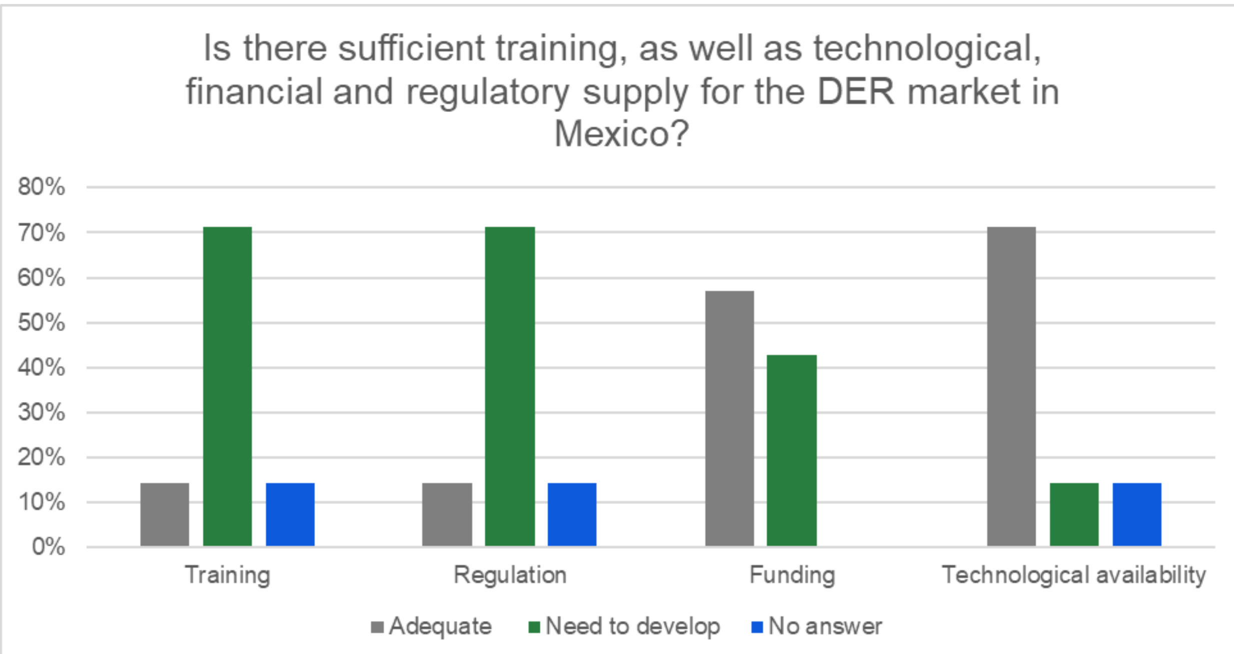
Regarding costs, suppliers replied that, on average, solar PV technology is between USD 0.75 and 1.30 per kWh, while PV technology integrated with storage doubles in price; it can reach up to USD 2 per kWh. Solar PV technology has decreased in price over time due to increased demand; it is an affordable technology for Mexicans. However, the price varies between companies, so there is a price war between developers.

71.4% of the respondents consider that the costs for DER technologies are still very high, while 14.3% assess that, as costs fluctuate, they depend on the situation and the company providing the services, so it is not safe to give an exact figure of how much the installation will cost; the last 14.3% did not give a concrete answer to this issue.

Since the prices of these technologies are still considered high for end users, financial instruments are crucial for their scaling up in the future. According to 42.9% of the suppliers, financial instruments in Mexico for DER projects are not sufficient or not adequately developed. Developers believe that financing is the main barrier in this market, as credits are handled with very high interest rates that are not attractive. Although it is easier to obtain financing nowadays than before, the programmes that finance private sector RED projects are not sufficient or are difficult to obtain. In contrast, government programmes for installing

RED have more opportunities to obtain financing. Also, financial institutions not only provide loans, but also have other financing schemes such as PPAs and leasing.

On the other hand, 57.1% of the developers think that existing financing is sufficient and consider that small projects do not need plans to finance technology because the prices are affordable. The financial institutions for RED technologies most mentioned during the study were: *FIDE, Red Girasol, CIBanco, Banverde*.



On the other hand, suppliers state that the regulation of DER technology is a major challenge for Mexico. 71.4% of respondents believe that this is an area that needs to be developed in order to define the role of the technologies and the use that can be made of them in an integrated system. Regulation in Mexico for DER technologies dates back to 2012, so the respondents consider that there are gaps and grey areas in storage issues and in practices such as *peak shaving*.

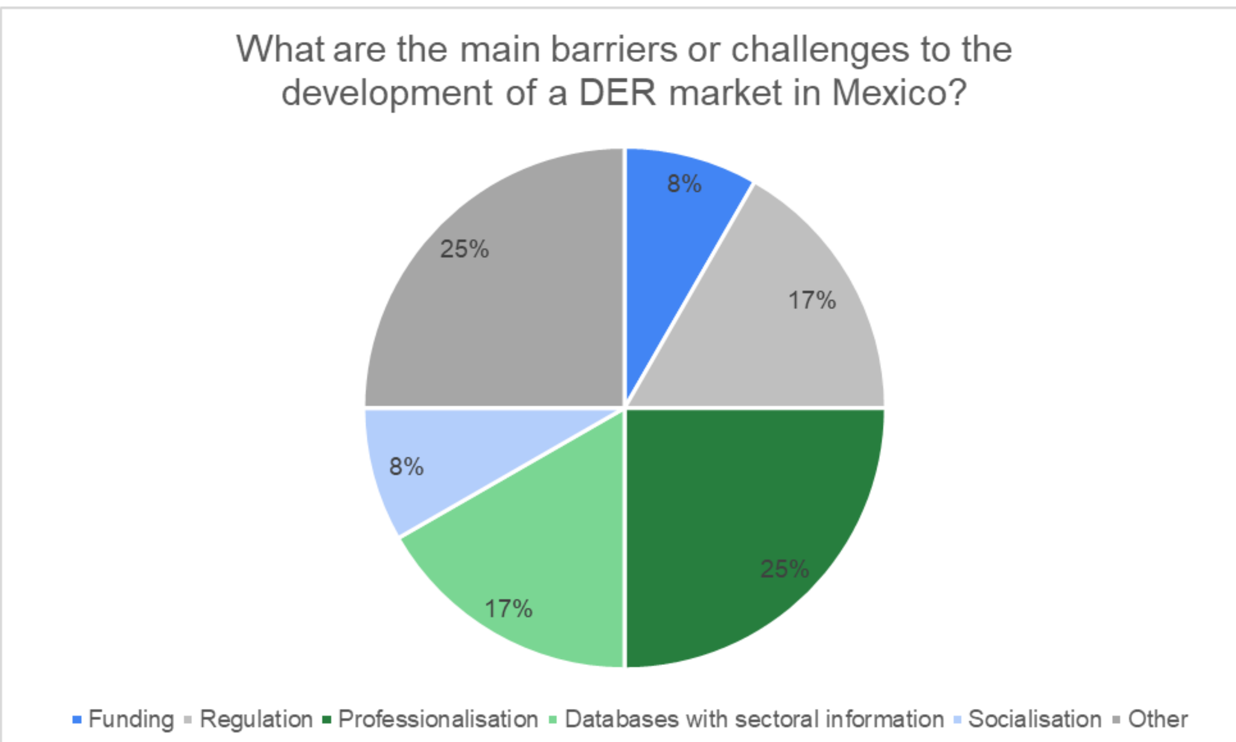
However, 14.3% of the respondents consider that the current regulation needs to be modified but are concerned that updating it could stop projects or make the market too complex as a result of over-regulation. The remaining 14.3% did not give a concrete answer to this issue.

Providers consider that not only the updating of regulation is important for the market, but also the creation of public policies to complement the regulatory framework. Although the majority did not give a specific answer on public policies (71.4%), in general they consider that they can be both financial and non-financial. However, public policies should consider climate change mitigation at their core and not only the economic viability of projects.

This is one of the challenges facing the market for DER technologies, because public policies and regulation depend on the political will of public officials. Although 14.3% consider regulation to be one of the biggest obstacles in the market, another 14.3% believe that the costs of technology are difficult to bear in the country. This is because prices are high and financial instruments are scarce for demand.

However, 42.9% consider professionalisation to be the biggest barrier to the market for DER technologies. Technical knowledge and training are key elements for the market to grow in the country and currently there is specialisation in solar PV, but not in storage and electric vehicle chargers. The lack of adequate professionalisation for these technologies could lead to supply not being able to meet demand in the future, which puts the growth of the market and the interest of end-users at risk.

The remaining 28.5% believe that there are other important challenges, such as: the socialisation of technologies for both developers and end users; the lack of supply of electric vehicles; the conditions of transmission and distribution networks; financing; and the lack of a CFE database and costs within the market.



Even with these obstacles, 85.7% of the developers have a positive outlook, while 14.3% did not give a concrete answer on this issue. 85.7% think that the DER market will grow in the future in different sectors: industrial, vehicles, parcel delivery, supermarkets, delivery companies, among others, because people will no longer be prejudiced about the technologies. Moreover, if we take into account that the demand for electricity will continue to increase, then all Mexicans are potential customers of this technology. According to the interviewees, *peak shaving* and electromobility will continue to grow in Mexico, especially due to *Nearshoring* because it will provide opportunities to relocate certain industries.

Finally, respondents consider it important to segment the PV market from other DER technologies, as it has different characteristics from other technologies due to its growth over the last decade.

State Energy Agencies and Associations

The Council of Photovoltaic Energy Professionals (CPEF), the Mexican Photovoltaic Industry Association (AMIF) and the National Solar Energy Association (ANES), as well as the State Energy Agencies of Baja California, Jalisco, Nuevo León, Tamaulipas and Veracruz were interviewed for this market study.

The associations and the Agencies consider that the RED market has good technical and economic viability in the country. Before the pandemic, the economic viability was not as good as it is now, so it is expected that the conditions for the growth of this market will continue to improve. Although there are still no concrete projects for the integration of technologies, the technical feasibility is undisputed.

In addition, with the appreciation of the Mexican peso in the last months of 2023, DER technology has become cheaper, which encourages the domestic market. If the necessary economic viability did not exist, Mexicans would not be interested in integrating the technologies; 62.5% of those interviewed stated that the economic viability exists in Mexico. On the other hand, 25% believe that it depends on where in the country DER technology is to be installed, as not all areas in Mexico have the same technical and economic characteristics. It also depends on the type of electricity tariffs that the population has, since this economic factor makes the use of DER technology viable or not. The remaining 12.5 did not give a concrete answer in this respect.

With regard to training, 50% of the associations and agencies interviewed believe that there is a need to develop technical skills, as well as to increase financial education due to the lack of professionalisation. One of the proposals made was that trained developers should be awarded badges or recognition to encourage them to provide quality services. Likewise, they commented that educational institutions do not have integrated DER technology curricula. However, 12.5% consider that there is good training in universities where specialised courses are given, although they accept that new technologies need to be integrated into the curricula; 37.5% did not give a specific response to this issue.

Regulation also plays a fundamental role for this market in Mexico, as new technologies are not encouraged due to the lack of clarity in the regulatory framework. Like developers, 37.5% of associations and agencies believe that the most essential thing is to regulate storage, as there are no regulations for new technologies. Meanwhile, 25% consider that a tariff model should be established that is clear and gives incentives for

Distributed Generation (DG). The remaining 25% say that DG capacity should be increased, but with data that substantiates the need for it in the country. In this way, officials are prevented from regulating the market by demands, but make the best decisions based on the precise needs of developers, associations, agencies and end-users.

As a consequence of regulatory gaps, interviewees comment that Nuevo León, Jalisco and Yucatán have been complementing regulation with state regulations that include storage and electromobility. This reflects the need for state and local governments to have a clear regulatory framework with respect to these technologies.

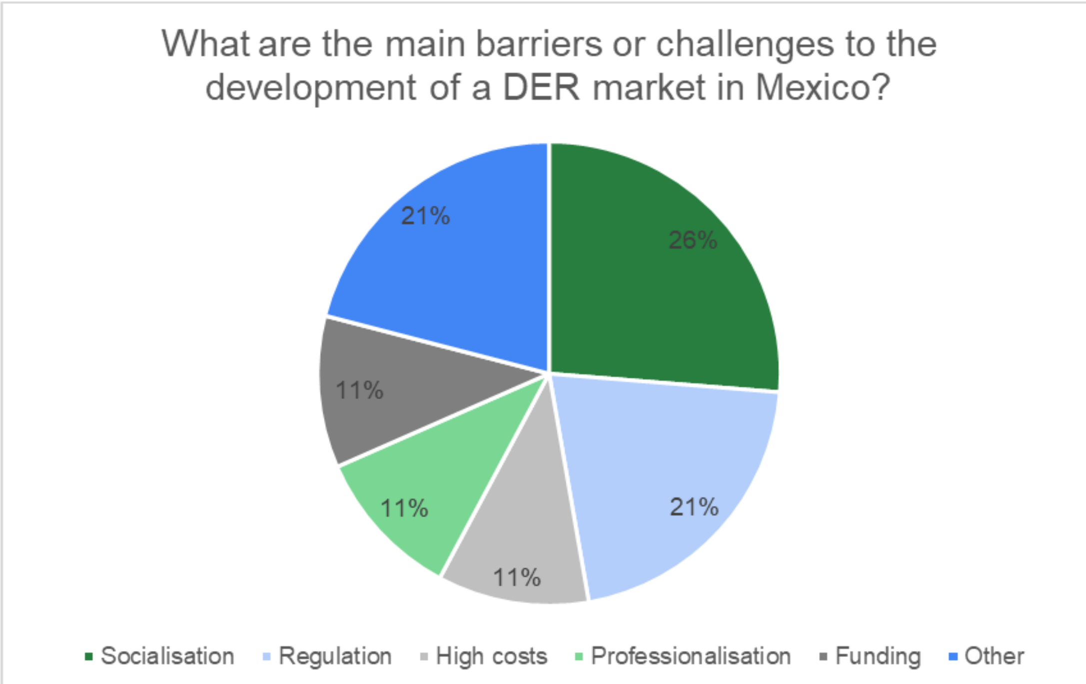
Furthermore, public policies are necessary for the development of the DER market. 62.5% of the interviewees agree that public policies should not focus on financial measures, but should invest in infrastructure for transmission and distribution networks; in streamlining permitting processes; in an effective communication plan to disseminate the benefits of these technologies for businesses and residences with success stories; and in optimising demand.

For their part, 37.5% consider that financial measures and economic incentives are vital public policy instruments to get end users interested in installing DER technology. The interviewees state that incentives through public policies are more attractive to users than financial institutions because of the distrust towards these institutions. Economic incentives should be targeted especially at small and medium-sized enterprises. However, associations and agencies comment that incentives have to come from state and local governments. They also warn that incentives should not be uncontrolled and unsustainable, but should be well structured to provide a real return on investment.

Financial instruments are fundamental, because the prices of RED technologies are not yet accessible to all end users. 37.5% of the associations and agencies see DER technologies as having high costs, which is an obstacle to their widespread use in the country. However, 25% think that the costs are not high, but that there are technologies such as solar photovoltaic that are accessible and that do give a real return on investment. They also recognise that storage prices will fall in the coming years in response to increased demand and technology transfer from countries such as the United States.

Therefore, for 50% of the total respondents, i.e. State Energy Agencies, they consider that the best form of financing is through traditional banks or other types of investment funds, e.g. associations that fund these projects with non-repayable resources or preferential rates that are below market financing rates. In contrast, the other 50% of respondents representing developers and end-users prefer financing through the new "leasing" modalities, because it provides an economic benefit to both. This is because the end-user does not invest the full amount in the system, but pays a fixed fee. In this way, the developer makes a difference, which is his profit.

Furthermore, the Associations and Agencies identified barriers that limit the massification of the RED market in Mexico:



26.3% of respondents mentioned that socialisation is the main barrier to the RED market in the country, because Mexicans do not yet have the knowledge and awareness that these technologies exist and that they have benefits for them and for the environment. In contrast, 21% consider that regulation is what limits this market the most, while 10.6% are more inclined towards high costs. Another 10.6% argue that professionalisation is one of the most important obstacles, as well as financing, while the remaining 21% consider that there are other limitations to the market.

One of these other limitations is that the states have worked unilaterally with regard to DER technologies and for this reason, a community among the Agencies has not been built. This weakens proposals for regulation, public policy or funding, so solutions that can be presented to the market and the federal government must be worked out together.

Demand Side

This section presents the demand-side responses, in which representatives of Grupo Posadas[9] (Posadas Group); El Poder del Consumidor[10] (Consumer Power); and the Asociación Nacional de Tiendas de Autoservicio y Departamentales[11] (ANTAD, National Association of Self-Service and Department Stores) participated.

The interviews conducted with these relevant actors are of utmost importance as they reflect what the end consumers of the commercial sector consider of DER technologies in Mexico. They focused on the following topics: technical and economic viability of DER technologies as part of the commercial sector; perception of the development of a national DER market; perception of the development of technical capacities and socialisation focused on DER technologies; and financing and incentives.

Broadly speaking, these actors consider that consumers reflect that these technologies will increasingly be in demand in the country, but for economic rather than environmental reasons. In other words, end-users are looking to switch to DER technologies because of their economic performance (cost-benefit), so environmental issues take a back seat. Despite this, they are convinced that demand will increase in the short term, although they recognise that photovoltaic systems are in the lead, so in sectors such as hotels they will continue to grow.

With respect to economic and technical feasibility, interviewees consider that there is feasibility in both aspects, but recognise that Mexico has different conditions than other countries, where these technologies are developing faster. The economic and social conditions in Mexico are important factors for consumers, as this defines whether they are interested in new technologies or not. The interviewees think that multinational companies and governments in other countries have forced the entry of this technology as they do in their own countries, when in Mexico, conditions are different. Therefore, the penetration of DER technologies should consider social, cultural and economic factors, so that Mexican consumers socialise the importance of the energy transition and therefore decide to invest in new technologies.

The interviewees also explain that in the hotel, commercial and service sector, energy is mainly used in refrigeration, air conditioning, lighting and heat pumps. In the hotel sector, heat pumps and air conditioning are the most energy-intensive technologies. Therefore, DER technologies are attractive to supply this demand, especially because costs are decreasing and because of the good image that emission mitigation

[9] Grupo Posadas is a Mexican hotel company founded in 1967. It currently owns, leases, operates and manages more than 120 hotels and resorts, with more than 20,000 rooms in Mexico.
[10] El Poder del Consumidor is a non-profit civil association that works to defend consumer rights. Its activities include the study of products, services and public policies, monitoring the performance of companies, identifying favourable options for consumers and denouncing practices that affect their rights.
[11] ANTAD is an organisation that focuses on the retail trade and its suppliers. It currently represents more than 3,200 self-service shops, more than 2,500 department stores and more than 41,000 specialised shops. In total, it represents 47,358 businesses in Mexico.

generates in their corporations. However, not all shops and hotels have the characteristics or meet the conditions for integrated technologies to be installed. According to the interviewees, the costs of photovoltaic systems have been decreasing over the years, making them increasingly affordable. For example, a medium-capacity hotel must invest approximately 170,000 USD in a PV system, which is recovered in 1.3 to 1.4 years. However, newer technologies, such as energy storage, still involve high investment costs.

Regarding the relationship between the public and private sector, interviewees consider this relationship to be very important, as it opens up opportunities and diversifies the market. This could help to further lower the prices of technologies. However, interviewees do not have a good outlook on the willingness of the next federal administration to work with the private sector on energy issues. Despite this, they claim that the private sector can achieve a broad development of projects focused on DER technologies.

With regard to the development of technical capacities, they distinguish that there is indeed a need to develop them so that the integration of RED technologies increases and becomes more attractive to consumers. They also consider that education and a change of perspective from a cultural approach is extremely important for new technologies to penetrate the market, without being seen as competition for the country's parastatal companies and the sectors that depend on fossil fuels. Although there is some awareness, end-users feel that there is a lot of political uncertainty that discourages consumers from installing this technology. Therefore, the development of new regulation and public policies is important to reduce uncertainty and benefit a higher penetration of DER projects in Mexico.

In terms of financial models, they consider that the two most widely used in Mexico are leasing and PPA. Leasing is mainly used by small companies, as they have less capital to make the initial investment, so they prefer to pay a monthly rent for the use of the asset, even if they do not own it. On the other hand, larger companies, with higher cash flows, tend to absorb the full cost of the investment from the outset and take ownership of the technology.

They also believe that as an incentive for the development of DER projects, a special regulated tariff is the most attractive for consumers, because it is necessary to segment the markets, especially the commercial market, as there are small and large businesses with the same electricity tariffs, which does not really reflect what is happening within the sector. On the other hand, if there were a special tariff, electricity tariffs could be segmented, which would support the owners of many businesses. On the other hand, they also consider that high electricity costs are in themselves an incentive for end-users to invest in new technologies to reduce their energy consumption.

Finally, interviewees warn that the Mexican government must solve the structural problems that prevent the upgrading of transmission and distribution grids, which will allow the growth of distributed generation. A strategic actor for the modernisation of the infrastructure is the Federal Electricity Commission; however, they mention that the parastatal company does not have the will to invest in this modernisation. This discourages consumers from switching to DER technologies.

Conclusions

In conclusion, all interviewees agree that a DER market will develop in Mexico and DG will continue to grow, at least in the next five years. For this, it is important to encourage storage and to change the regulation in this respect. Therefore, it is of utmost importance that there is a binding collaboration between the different sub-national entities in the country to motivate and standardise proposals in terms of regulation, public policy or financing, in order to jointly find solutions that can motivate the development of a national DER market. This market will be driven by the global and regional development of these technologies, which will allow the electricity system to be less centralised and supply for all.

In terms of financing models, interviewees consider leasing to be the best model, as it allows Mexicans not to absorb the investment in new technologies all at once. It is also one of the best known financing models. The PPA model is also one of the most popular in the country.

Finally, the main obstacles that prevent end users from investing in DER technology are: regulation, the long times associated with procedures and permits, training, technology transfer, and the outdatedness of the transmission and distribution grids. In addition, the interviewees mentioned the lack of political will on the part of the government and the negative prospects for the next six years, as well as the lack of socialisation of the technologies.

Economic benefits of the use of Distributed Energy Resources in the commercial sector in Mexico.

This chapter focuses on demonstrating the potential economic and environmental benefits of using distributed energy resources (DER) technologies for the commercial sector in Mexico.

In Mexico, the commercial sector accounted for 14.3% (141.24 PJ) of total national energy consumption in 2022. Electricity consumption accounted for 42% (5.99 PJ), equivalent to 723.8 ktCO2e (BNE, 2023)(CRE, 2023). This reflects the importance of decarbonising electricity consumption in this sector. And where the use and integration of DER technologies becomes more relevant.

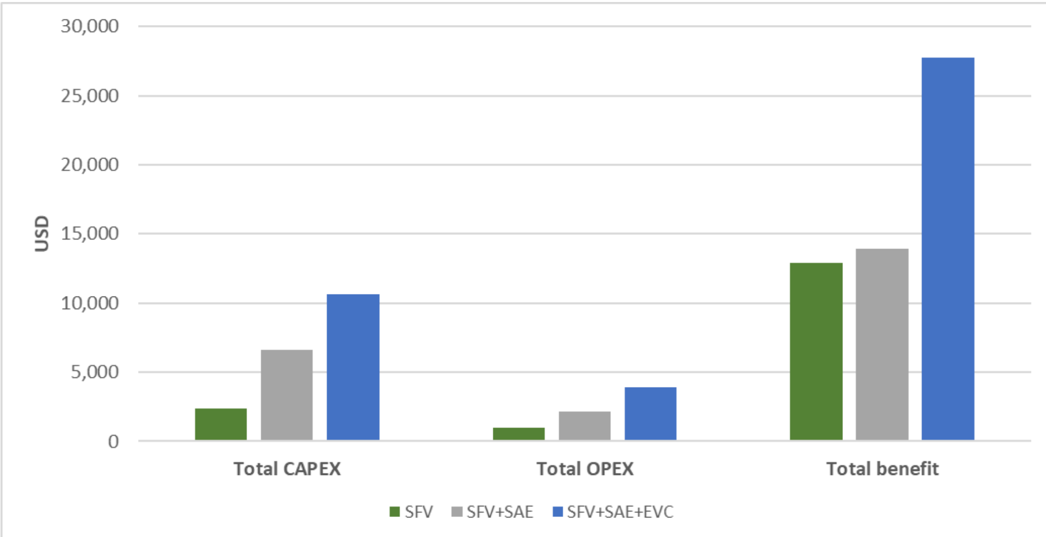
In line with the above, to determine both the economic and environmental benefits of the use of DER in the Mexican commercial sector, the analysis conducted focuses on the use and integration of three DER technologies, namely: solar photovoltaic (PV); lithium battery-based energy storage (BES); and electric vehicle chargers (EVC). These are integrated to analyse two case studies as follows: SFV+SAE and SFV+SAE+EVC. And finally compared with the use of SFV only, as a base case since it is the DER technology with the highest growth and penetration in the country. The model on the basis of which this analysis was designed can be found in the Annexes section.

The results obtained from the cost-benefit analysis carried out by tariff type for each integrated system (SFV+SAE and SFV+SAE+EVC), compared to the installation of a simple SFV, are shown below. The results are presented in terms of CAPEX, OPEX and average total benefits per tariff type. And in terms of payback period (years) and rates of return on investment (percentage) per tariff type per energy demand quartile.

PDBT Tariff

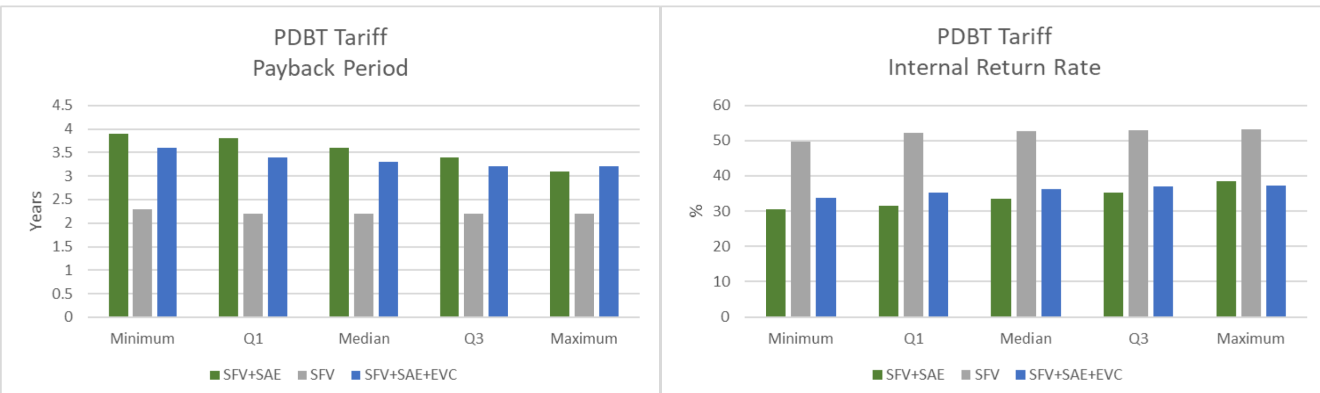
The PDBT tariff is the one with the lowest consumption demand with respect to the other types of tariffs, but not with respect to the number of users, since this tariff includes all the MSMEs and a large part of the country's SMEs. In terms of the CAPEX required for the incorporation of integrated DER technologies within this tariff sector, the installation of a PV system that also integrates an OSS (PV+OSS) requires 2.8 times more investment than the installation of a simple PV system. However, the total economic benefits are 1.1 times higher. This situation is repeated when integrating an EVC into the system (SFV+SAE+EVC), where the investment costs are 4.5 times higher compared to the installation of a simple SFV, but the benefits turn out to be 2.2 times higher, mainly due to the revenues derived from the recharging of external electric vehicles. As shown in Figure 1.

Figure 1. CAPEX, OPEX and Total Benefits of installing integrated DER systems within a PDBT tariff versus installing a VFS in Mexico.



Source: Own elaboration

Figure 2. Payback periods and IRR of installing integrated DER systems by quartile within a PDBT tariff versus installing a VFS in Mexico.



Source: Own elaboration

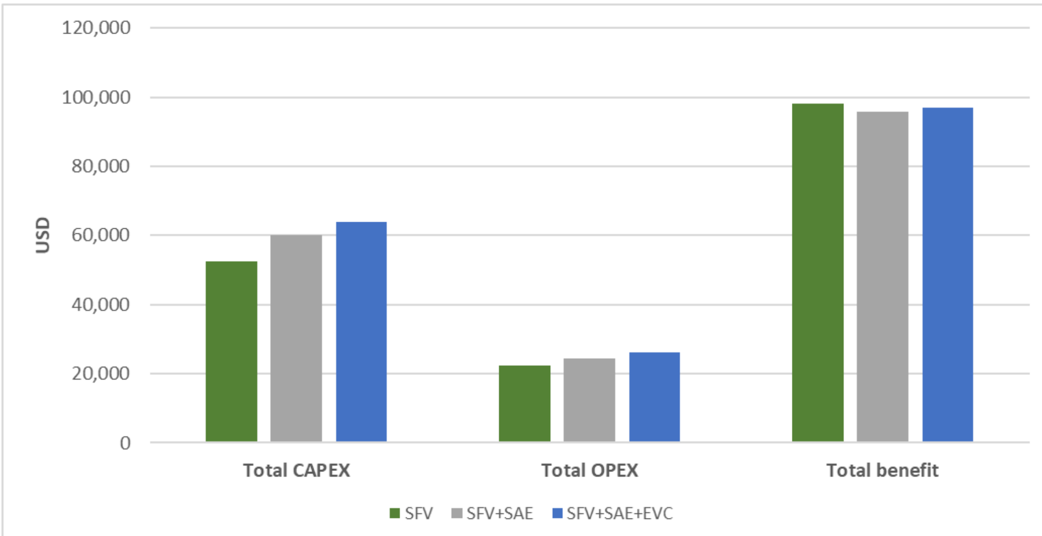
In terms of payback periods, as the investment cost of a simple SFV is lower, it can be recovered in an average of 2.2 years. This is 39% less compared to the installation of a SFV+SAE (3.6 years) and 33% less compared to the installation of a SFV+SAE+EVC (3.3 years). This is reflected in the internal rates of return on investment (IRR), where the IRR for the installation of a simple PVS is 1.5 times higher compared to the installation of a PVS+SHE and 1.4 times higher compared to the installation of a PVS+SHE+EVC. Figure 2 shows both payback periods and IRRs for each demand quartile of the PDBT tariff.

GDMTO Tariff

The GDMTO tariff is the second in terms of consumption demand. And with respect to the PDBT tariff, this tariff sector can consume between 9.7 and 30.2 times more electricity. Part of the country's SMEs and small industries can be found within this tariff. In terms of the CAPEX required for the incorporation of integrated DER technologies within this tariff sector, the installation of a PVS that also integrates a UPS (PVS+SPS) requires 1.1 times more investment than the installation of a simple PVS. However, the total economic benefits are 0.97 times lower. This is due to the investment cost of the UPS, which requires a higher storage capacity. This situation is repeated when integrating an EVC into the system (SFV+SAE+EVC), where the investment costs are 1.2 times higher compared to the installation of a simple SFV, but the benefits are 0.98 times lower, as the additional benefit of charging external electric vehicles is not enough to offset the cost of the SAE. As shown in Figure 3.

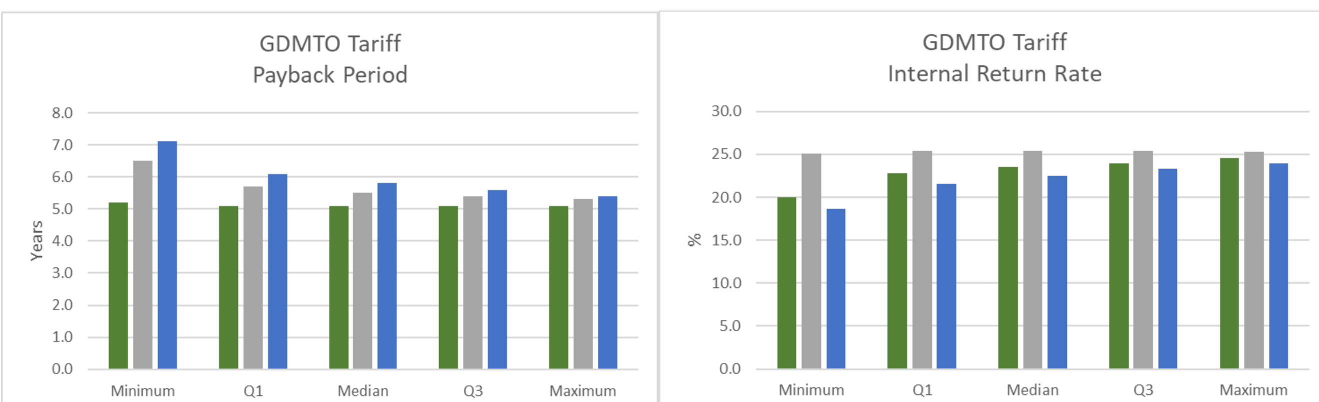
In terms of payback periods, as the investment cost of a simple SFV is lower, it can be recovered in an average of 5.1 years. This is 12% less compared to the installation of a SFV+SAE (5.7 years) and 18% less compared to the installation of a SFV+SAE+EVC (6.0 years). This is reflected in the internal rates of return on investment (IRR), where the IRR for the installation of a simple PVS is 1.1 times higher compared to the installation of a PVS+SHE and 1.2 times higher compared to the installation of a PVS+SHE+EVC. Figure 4 shows both payback periods and IRRs for each demand quartile of the GDMTO tariff.

Figure 3. CAPEX, OPEX and Total Benefits of installing integrated DER systems within a GDMTO tariff versus installing a VFS in Mexico.



Source: Own elaboration

Figure 4. Payback periods and IRR of installing integrated DER systems by quartile within a PDBT tariff versus installing a VFS in Mexico.

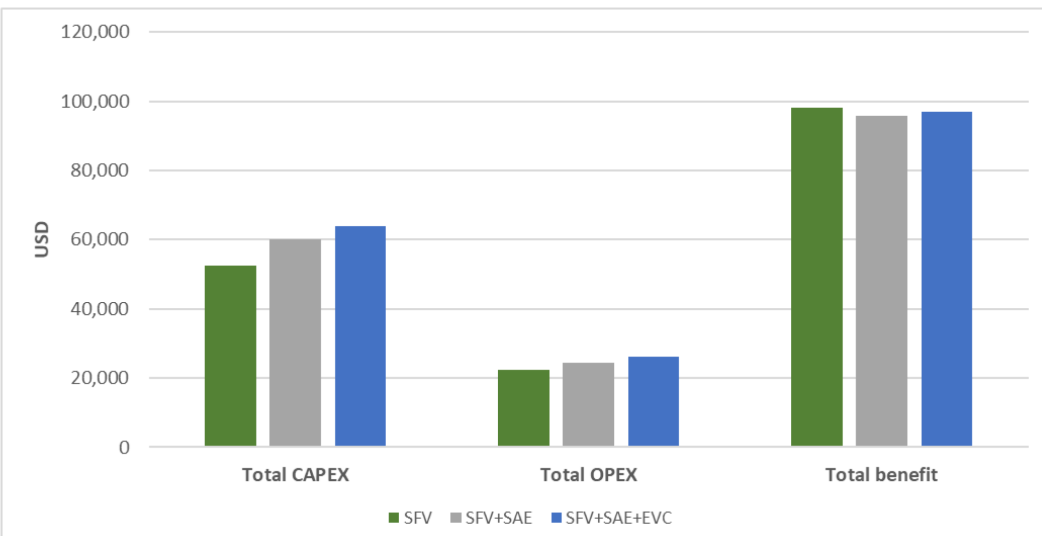


Source: Own elaboration

GDMTH Tariff

Finally, the GDMTH tariff is the tariff with the highest electricity demand in the country, and the lowest in terms of number of users, as this tariff is exclusive to large businesses (shopping centres, hotels and supermarkets) and medium and large industries. With respect to the PDBT tariff, this tariff sector can consume between 102 and 512 times more electricity. In relation to the CAPEX required, the installation of an SFV that also integrates a SAE (SFV+SAE) requires 1.03 times more investment than the installation of a simple SFV. However, the total economic benefits are 0.99 times lower. This is due to the investment cost of the FSS. However, as can be seen, the CAPEX is practically the same, since the GDMTH tariff is one of the most expensive in the country, and by using the energy stored in the SAE during night time, the benefits increase. This situation is repeated when integrating an EVC into the system (SFV+SAE+EVC), where the investment costs are 1.05 times higher compared to the installation of a simple SFV, but the benefits turn out to be 1.0 times higher, due to the additional benefit of charging external electric vehicles. As shown in Figure 5.

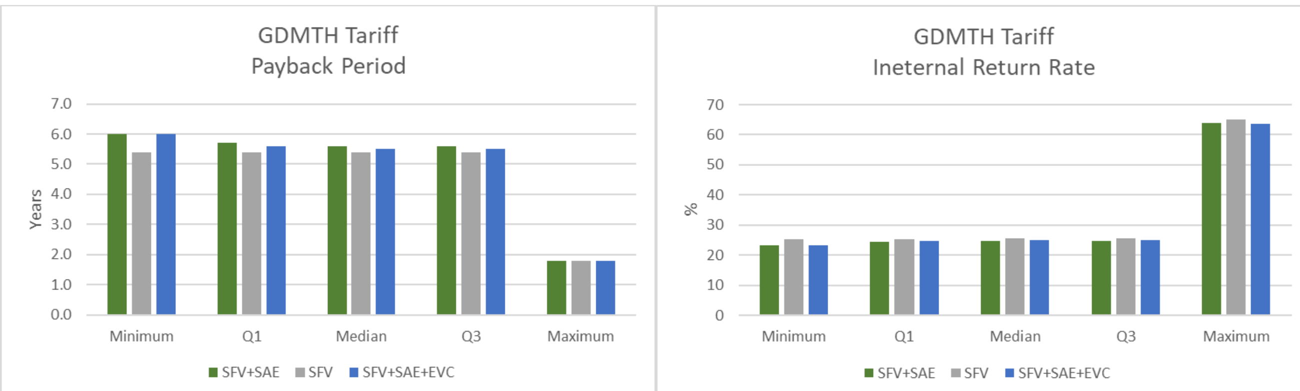
Figure 5. CAPEX, OPEX and Total Benefits of installing integrated DER systems within a GDMTH tariff versus installing a VFS in Mexico.



Source: Own elaboration

As mentioned in the previous paragraph, by not significantly impacting the integration of a SAE, the average payback periods for the integration of DER technologies versus the installation of a simple SFV are practically the same. 4.7 years for a SFV; 4.9 years for the integration of a SFV+SAE and 4.9 years for the integration of a SFV+SAE+EVC. This behaviour is reflected in the internal rates of return on investment (IRR), where the one corresponding to the installation of a simple SFV is 1.04 times higher compared to the installation of a SFV+SAE; and 1.03 times higher compared to the installation of a SFV+SAE+EVC. Figure 6 shows both payback periods and IRRs for each demand quartile of the GDMTH tariff rate.

Payback periods and IRR of installing integrated DER systems by quartile within a GDMTH tariff versus installing a VFS in Mexico.



Source: Own elaboration

Conclusions

Based on the results obtained, the following conclusions can be drawn:

1. As could be observed, the Mexican commercial sector is composed of 3 different tariffs, PDBT, GDMTO and GDMTH, which vary according to the electricity consumption of the end user. And the benefits of integrating DER technologies can be extrapolated to any type of end user in any sub-sector of the commercial sector.
2. The benefits of incorporating integrated DER technologies are directly dependent on the energy demand of the user, generating greater benefits to those who consume more energy, and therefore have a greater chance of generating greater savings through avoided electricity costs. And where initial investment costs are no longer a factor, as the total benefits are much greater.
3. Depending on the type of tariff and type of technology integration, average payback periods range from 6.0 to 1.8 years. With average net benefits equivalent to USD 1.7 million.
4. In general terms, the current context of the Mexican commercial sector and electricity market opens the door to the future development of a distributed energy resources market in the country. As can be seen, the integration of DER technologies applied to the commercial sector generates significant economic benefits for any end user belonging to this sector. These benefits may increase in the future, since it is expected that the investment costs of the technologies associated with DERs will decrease considerably in the coming years, as their demand increases.

Obstacles and needs for the development of a DER market in Mexico

This section presents the identification of the main obstacles and needs faced by the DER market for its development in Mexico.

Among the main obstacles identified is the regulatory uncertainty. This uncertainty is due to the fact that the current regulation is old and does not include new technologies such as batteries for energy storage. This creates loopholes that prevent the integration of PV systems with other technologies. However, it is expected that this will change in the future, due to the international momentum and growing demand.

Specialised training is another obstacle that could impede the accelerated growth of DER technology in the country. Training the engineers who will install integrated DER technologies is essential to build consumer confidence.

Likewise, socialisation and financing are two market obstacles that need to be overcome for the accelerated growth of technologies in Mexico in the short term. It is recommended to carry out campaigns to raise awareness of the available technologies, as well as the models and financial institutions that facilitate their acquisition. Although in general, acquiring funding today is easier than before, programmes that finance private sector DER projects are not sufficient or are difficult to obtain. Contrary to what happens in the public sector, where government programmes for installing DER have more opportunities to obtain funding. In this way, the market could quickly penetrate other sectors of interest sectors such as the agri-food sector.

However, one of the most important obstacles to the scaling up of DER technology in the country is the modernisation of the transmission and distribution grid infrastructure, which may limit these social projects at the state level.

Finally, the study shows that these technologies have not yet penetrated the agri-food sector as in other sectors, due to the lack of socialisation of new technologies in the agri-food sector, as well as the lack of financing models that allow companies to obtain these technologies in an accessible way. In addition, other types of technology are used in the food sector, such as solar pumping systems, which are less known and more expensive than photovoltaic systems alone. In contrast, the commercial sector is driven by the private sector, which has a higher penetration of these technologies, so the financial models and technologies are better known and well regarded for the economic returns they provide.

Annexes

A.1. Market study methodology

The methodology used for the development of the market study is given below:

- **Stakeholder mapping.** A mapping of all possible national stakeholders that may be involved in the development of the project was carried out, including technology suppliers and developers; project developers; associations related to the photovoltaic and electromobility sectors; chambers and associations representing members of the hotel, restaurant, and food industry sectors, among others; financial institutions; academia; subnational governments and regulatory bodies.

- **Interviews.** Following the stakeholder mapping, primary research was carried out by conducting direct interviews, based on the stakeholder mapping, to gather information on the current context of the RED market in Mexico. The interviews were conducted on the basis of the statistical establishment of a representative sample selected from the universe of actors obtained in the secondary research. This representative sample indicates the minimum number of interviewees to ensure a standard margin of error (confidence interval) of 5%, a confidence level of 95% and a data dispersion (standard deviation) no greater than 0.5. Therefore, this sample was obtained from the statistical analysis of the z-score. A z-score (also called a standard score) gives an idea of how far a data point is from the mean. The equation from which a representative sample of a finite universe is obtained, based on the Z-score, is as follows:

$$Sample = \frac{(Universe)(Z - score)^2\ (standard\ deviation)\ (1 - standard\ deviation)}{(margin\ of\ error)^2(Universe - 1) + [(Universe)(Z - score)^2\ (standard\ deviation)\ (1 - standard\ deviation)]}$$

  The interviews were designed to cover the following aspects:

  - **Regulatory framework.** Based on the secondary research, the interviews sought to ascertain the opinion of the experts on the barriers or opportunities identified in the regulatory framework for the development and implementation of RED in the country. As well as their opinion on the proposals for new regulations that could be added to the current regulatory framework to promote and allow for an adequate development of RED in Mexico.
  - **Characterisation of suppliers.** The interviews were used to identify the type of technology supplier and project developer companies in Mexico. As well as the solutions and

technologies they offer, the skills needed to develop a market based on these technologies, the risks they face and their vision of the RED market.

- **Consumer characterisation.** Through the interviews, focused on industries, companies and SMEs in the agri-food, hotel and restaurant sectors, essential information was obtained on their knowledge of DER technologies, the solutions they offer, their attractiveness and experiences as end users of these technologies. As well as their perspective on the development of the DER market in Mexico.
- **Technology availability.** Information was obtained through secondary research on the RED technologies available and marketed worldwide. Subsequently, this information was cross-checked through interviews with technology providers and project developers to explore which technologies can be implemented in Mexico, which are being or can be introduced, and which are unknown and why. In addition, information was obtained on which technologies are being integrated and which solutions are attractive to suppliers and consumers (focusing on the characterisation of consumers), considering their energy consumption needs. Information was also obtained on the investment cost of these technologies, their installation and operation and maintenance costs.
- **Business models.** Through interviews, it was possible to identify the different business models offered by suppliers, how they work, their level of penetration, their profitability once implemented and their risks.
- **Financing.** The interviews provided information on what credits or financial tools are offered, whether there is a predominant type of customer (e.g. large industry, SMEs, a specific sector such as shopping malls, offices, restaurants, tourism, etc.), whether financial institutions influence (positively or negatively) the development of a DER market in Mexico, and whether they help customers to become prosumers. Information was also obtained from the perspective of financial institutions about DER technologies and their attractiveness, as well as what kind of incentives and financial mechanisms could increase the adoption of DER and develop their market and the barriers and needs to implement such incentives.

A.2. Cost-benefit analysis model design

A technical-economic model was designed in Excel that considers the electricity demand of the commercial sector, according to tariff type, to estimate the costs and benefits of the use and integration of the different DER technologies considered. Both costs and benefits were evaluated through an updated cash flow that takes into account the electricity generation of the systems, electricity demand, investment costs, operation and maintenance costs and revenues (both avoided cost and energy surpluses) for a period of 25 years, within which the life cycle of the DER technologies is considered. This is done through the following assumptions and considerations:

1. It is assumed that the technologies, in addition to being integrated, are interconnected to the General Distribution Network (RGD) in a net metering scheme (explained in the previous section), which allows the surplus energy generation (if any) to be delivered to the grid, and generate an additional economic benefit. In this sense, in Mexico there are four tariff schemes in force, for which the cost varies depending on the geographic location and the contracted demand (kW) by the user for the full operation of its equipment, as shown in Table 1 below.

Table 1. Current tariffs for the commercial sector in Mexico.

Tariff	Demand (kW)	Description	End-user to which it applies	Average cost
Small Demand Low Voltage (PDBT)	≤ 25 kW-month	Applies to all services that use low voltage energy for any use, with a demand of up to 25 kW. With a constant cost per variable energy consumption ($/kWh).	It is normally applied to small businesses (MSMEs).	0.2306 USD/kWh
High Demand Low Voltage (GDBT)	≥ 25 kW-month	Applies to all services that use low voltage energy for any use, with a demand greater than 25 kW. With a constant variable energy consumption cost ($/kWh).	It is normally applied to small self-service shops, SMEs, restaurants or small hotels.	0.1029 USD/kWh
High Demand Ordinary Medium Voltage (GDMTO)	≤ 100 kW-month	Applies to services that allocate energy to any use, supplied at medium voltage, with a demand of less than 100 kW. With a constant cost for variable energy consumption ($/kWh).	It is normally applied to self-service shops, SMEs, restaurants or hotels.	0.0871 USD/kWh
High Demand Medium	≥ 100 kW-	Applies to services that use	It is normally applied to	Off-peak:

Voltage Hourly (GDMTH)	month	energy for any purpose, supplied at medium voltage, with a demand greater than 100 kW. With a variable energy consumption cost ($/kWh) that varies according to the time of day when the energy is consumed. There are three levels: Base, Intermediate and Peak.	large supermarkets, hotels and shopping centres.	0.0647 USD/kWh In-between: 0.1100 USD/kWh Peak: 0.1265 USD/kWh

Source: Own elaboration based on information from CFE.

2. Electricity demand was estimated from the number of users and their electricity consumption by tariff type for each state in the country. Given the dispersion of the data, this demand was distributed in quartiles, in order to consider all users in the commercial sector as part of the analysis. The result of this analysis is shown in Table 2 below.

Table 2. Average electricity demand by tariff type for the commercial sector in Mexico.

Quartile	Type of tariff and average annual consumption (kWh)				
	PDBT	GMTO	GDMTH		
			Off-peak	In-between	Peak
Minimum	2,130.3	20,593.1	43,551.4	152,430.0	21,775.7
Q1	2,828.7	46,699.1	90,177.1	315,619.8	45,088.5
Medium	3,433.5	66,849.5	136,178.6	476,625.1	68,089.3
Q3	4,038.4	87,000	173,061.8	605,716.3	86,530.9
Maximum	4,960.7	149,832.6	507,523.9	1,776,333.7	253,762.0

Source: Own elaboration based on information from CFE.

3. The capacity of both the base system (SFV) and the integrated systems (SFV+SAE and SFV+SAE+EVC) was estimated from the energy demand of each tariff type for each quartile (Table 2). Considering that the SAE receives energy from the SFV, and once it has completed its storage capacity, it delivers the stored energy when the SFV is not generating. Whereas in the case of the EVC system, the energy is considered to come directly from the grid, matching its consumption with

the energy provided by both the SFV and the SAE; and its use for electric vehicle charging has a cost of 0.058 USD/kWh (equivalent to the cost of consuming 1 kWh in the residential sector). Adding economic benefits to the owner of the integrated system.

4. In relation to the CAPEX and OPEX by type of DER technology within the country, these were obtained through interviews conducted with project developers and technology suppliers. In addition to the above, as part of the cost-benefit analysis, the replacement of those technologies that complete their life cycle before the 25-year analysis period is considered. The costs used are shown in Table 3 below.

CAPEX and OPEX (USD/W) for various DER technologies in Mexico.

Level	SFV		SAE		EVC	
	CAPEX	OPEX	CAPEX	OPEX	CAPEX	OPEX
Maximum	1.53	0.031	3.27	0.065	0.53	0.011
Average	1.06	0.053	2.70	0.135	0.47	0.024
Minimum	0.65	0.065	2.08	0.208	0.4	0.040

Source: Own elaboration

5. Finally, Table 4 below shows further general technical and economic considerations for the analysis.

Table 4. General techno-economic considerations

Variable	Value
Average solar peak hours	5.5 h
Average thermal efficiency	90%
Total energy efficiency	86%
Annual SFV degradation	0.5%
Life cycle of PV panels	25 years
Life cycle of investors	13 years

Battery life cycle	10 years
Inflation	4%
Discount rate	10%
Real rate	6%

Source: Own elaboration

A.3. Actor mapping matrix

		Stakeholder type					Services						Company Bussines Model			
Name	**Sector**	**Association**	**Financial Services**	**Manufacturer**	**Supplier**	**Project developer**	**Solar PV**	**Storage**	**Solar PV + Storage**	**EV**	**EV Infraestructure**	**After-sales service**	**Traditional Financing**	**Leasing**	**PPA**	**Qualified Supplier**
CRE- Comisión Reguladora de Energía	Regulator															
CENACE - Centro Nacional de Control de Energía	ECC															
CFE- Comisión Federal de Electricidad	ESCO				X											
ANES - Asociación Nacional de Energía Solar	Solar PV	X														
ASOLMEX - Asociación Mexicana de Energía Solar	Solar PV	X														
AMIF - Asociación Mexicana de la Industria Fotovoltaica	Solar PV	X														
CPEF - Consejo de Profesionales de la Energía Fotovoltaica	Solar PV	X														
ANVES- Asociación Nacional de Vehículos Eléctricos y Sustentables A.C.	Electromobility	X														
AEM - Alianza por la Electromovilidad en México	Electromobility	X														
AMDA - Asociación Mexicana de Distribuidores de Automóviles	Electromobility	X														
ATB - Alianza por la Transición a un Transporte de Carga de Bajas Emisiones	Electromobility	X														
IMT - Instituto Mexicano del Transporte	Electromobility	X														
RCAM - Red de Clusters Automotrices de México	Electromobility	X														
AMIA - Asociación Mexicana de la Industria Automotriz	Electromobility	X														
IEC- Comisión Electrotécnica Internacional	Electromobility	X									X					
CFE- Comisión Federal de Electricidad	Electromobility				X						X		X			
TESLA	Electromobility			X				X		X	X		X			
EV Ready	Electromobility			X							X			X		
EDRIVE	Electromobility				X	X					X					
EverGo	Electromobility				X	X					X					
Solar Beat	Electromobility					X					X					
EV Ready	Electromobility					X					X	X				
Marketify	Electromobility					X					X					
Schneider Electric	Electromobility				X						X	X				
ASINELEC	Electromobility				X	X					X	X				
CapWatt	Electromobility				X	X					X	X		X	X	
Ecovalue	Electromobility				X	X					X		X			
Ecoss Circular	Electromobility					X					X	X	X			
Krannich	Electromobility					X					X	X				
RER Energy Group	Electromobility				X						X	X	X	X	X	
Solar Inter	Electromobility					X					X					
Kiin Energy	Electromobility				X	X					X		X			
Growatt	Electromobility					X					X					
Huawei México	Electromobility				X						X	X	X			
GRUNER	Electromobility			X	X						X	X	X			
BYD	Electromobility				X					X		X				
Element	Electromobility			X	X	X				X		X		X		
Ford	Electromobility				X	X				X		X	X	X		
Foton	Electromobility			X	X					X		X	X	X		
JAC	Electromobility				X					X		X	X	X		
MegaFlux	Electromobility				X					X		X	X			
Renault	Electromobility				X	X				X		X	X	X		X
Volkswagen	Electromobility				X					X		X	X	X		

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		Stakeholder type					Services					Company Bussines Model				
Name	**Sector**	**Association**	**Financial Services**	**Manufacturer**	**Supplier**	**Project developer**	**Solar PV**	**Storage**	**Solar PV + Storage**	**EV**	**EV Infraestructure**	**After-sales service**	**Traditional Financing**	**Leasing**	**PPA**	**Qualified Supplier**
SEAT	Electromobility				X					X		X	X			
Italika	Electromobility			X	X					X		X	X	X		
ARMOTOS ELÉCTRICAS	Electromobility			X	X					X			X			
Ecomoto Puebla	Electromobility				X					X		X	X			
Mandarina Bike	Electromobility			X	X	X				X		X	X			
Schneider Electric	PV & Electromobility			X		X	X		X		X	X				
ANTAD - Asociacion Nacional De Tiendas De Autoservicio Y Departamentales	Commercial & Services	X														
AMPC - Asociación Mexicana de Plazas Comerciales	Commercial & Services	X														
AMR - Asociación Mexicana de Restaurantes A.C.	Restaurant	X														
AFRPM | AFRPM, Asociación de Franquiciatarios de Restaurantes Preferidos de México	Restaurant	X														
AMHM - Asociación Mexicana de Hoteles y Moteles	Hotel & Food Service	X														
Asociación de Hoteles de México	Hotel & Food Service	X														
Asociación de Hoteles de la Ciudad de México	Hotel & Food Service	X														
Asociación de Hoteles de la Riviera Maya	Hotel & Food Service	X														
Asociación Nacional de Cadenas Hoteleras (Hoteles por México)	Hotel & Food Service	X														
Asociación Mexicana de Hoteles de Nuevo León	Hotel & Food Service	X														
Asociación de Hoteles de Cancún, Puerto Morelos & Isla Mujeres	Hotel & Food Service	X														
Asociación de Hoteles de Los Cabos	Hotel & Food Service	X														
Asociación Mexicana de Hoteles y Moteles de Tabasco, A.C.	Hotel & Food Service	X														
Asociación Mexicana de Hoteles y Moteles del Estado de Chihuahua	Hotel & Food Service	X														
Asociación Mexicana de Hoteles y Moteles de León	Hotel & Food Service	X														
Asociación Mexicana de Hoteles y Moteles de Bahías de Huatulco	Hotel & Food Service	X														
Asociación Mexicana de Hoteles en Yucatán	Hotel & Food Service	X														
Asociación Queretana de Hoteleros	Hotel & Food Service	X														
CANIRAC – Cámara Nacional de la Industria Restaurantera	Restaurant	X														
CNA - Consejo Nacional Agropecuario	Agroafoods	X														
Alternativa Energética SA de CV	Solar PV					X	X									
Alverde	Solar PV					X	X	X				X				
Ammper	Solar PV					X	X	X	X				X		X	X
Avitar	Solar PV					X	X						X			
Caliza	Solar PV					X	X					X	X		X	
Canadian Solar	Solar PV			X			X									

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		Stakeholder type					Services						Company Bussiness Model			
Name	Sector	Association	Financial Services	Manufacturer	Supplier	Project developer	Solar PV	Storage	Solar PV + Storage	EV	EV Infraestructure	After-sales service	Traditional Financing	Leasing	PPA	Qualified Supplier
Canadian Solar	Solar PV			X			X									
Capital Energy	Solar PV					X	X	X	X							
CapWatt	Solar PV				X	X	X	X	X		X	X		X	X	
Cometer	Solar PV					X	X					X	X			
Conermex	Solar PV				X		X	X	X							
Coproin Energía	Solar PV				X		X									
Citrus	Solar PV					X	X	X	X					X	X	
Corporativo Soles	Solar PV				X											
Createch Energías	Solar PV					X	X					X				
CSier Renovable	Solar PV					X	X					X	X			
Deg Energy	Solar PV					X	X									
Desmex	Solar PV			X	X	X	X									
Ecopotencia	Solar PV				X	X	X	X	X			X				
Ecovalue	Solar PV					X	X		X		X		X			
Econosolar	Solar PV				X	X	X	X	X			X				
Ecoss Circular	Solar PV					X	X				X	X	X			
Energía Real	Solar PV					X	X								X	
Energía Renovable de América	Solar PV				X		X									
Energía Solar del Golfo	Solar PV					X	X		X							
Energy Saver	Solar PV					X	X					X	X			
Enphase	Solar PV			X			X									
Enersing	Solar PV					X	X	X	X		X			X	X	
Solar Depot	Solar PV				X		X									
Corporativo ERSU	Solar PV					X	X					X				
Etesla	Solar PV					X	X					X	X			
Exel Solar	Solar PV				X		X	X								
Energon Solar	Solar PV					X	X						X			
Keymex Energy	Solar PV					X	X						X			
Grupo Corell Energía Solar	Solar PV					X	X						X			
Fortaleza Energy	Solar PV		X			X	X					X	X	X	X	X
Fronius	Solar PV			X	X		X	X								
Fuva Solar	Solar PV					X	X					X	X			
Gasadi	Solar PV					X	X					X	X			
Genergy	Solar PV					X	X									
Green Power Solutions	Solar PV					X	X					X				
Heliomex	Solar PV					X	X					X				
Iisol	Solar PV					X	X	X	X							
Iluméxico	Solar PV					X	X							X		
Forefront Power	Solar PV					X	X	X				X				
Jinko Solar LTD	Solar PV			X			X									
Krannich	Solar PV				X		X	X	X		X	X				
Latin American Rainmakers	Solar PV		X			X	X						X	X	X	
Mexilight	Solar PV					X	X									

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		Stakeholder type					Services						Company Bussines Model			
Name	Sector	Association	Financial Services	Manufacturer	Supplier	Project developer	Solar PV	Storage	Solar PV + Storage	EV	EV Infraestructure	After-sales service	Traditional Financing	Leasing	PPA	Qualified Supplier
Mexico Energy LLC	Solar PV					X	X	X	X	X	X	X	X		X	X
Natural Project	Solar PV					X	X					X	X			
Nova Group	Solar PV					X	X					X				
Prodeco	Solar PV					X	X					X	X			
Solarix	Solar PV				X		X	X								
Poder Solar	Solar PV				X	X	X					X				
Photoenergy	Solar PV					X	X									
Rennergy	Solar PV					X	X									
Solaris Renewables de México	Solar PV					X	X		X							
Solartech HMO	Solar PV				X		X		X							
Energía Solar y Proyectos Sustentables	Solar PV					X	X									
PYCEM Ingeniería de Tijuana	Solar PV					X	X									
Red Girasol	Financial		X				X	X	X	X	X		X	X		
RER Energy Group	Solar PV					X	X	X	X		X	X	X	X	X	
SICES Solar	Solar PV				X		X									
Solar Plug	Solar PV					X	X									
Solar Inter	Solar PV				X	X	X		X	X	X					
Solar Power Group	Solar PV				X		X	X	X							
Kiin Energy	Solar PV					X	X				X		X			
Solarever	Solar PV			X	X		X	X								
Solarama	Solar PV				X		X									
Solart	Solar PV					X	X		X			X	X		X	
Solarvatio	Solar PV			X		X	X		X				X			
Sunpower	Solar PV			X		X	X									
Tecnoligente	Solar PV					X	X						X			
Trinasolar	Solar PV			X	X											
Tupanel.solar	Solar PV					X	X									
Ksab Solar	Solar PV					X	X					X	X			
Mexicali Solar	Solar PV					X	X									
Solartec Renovables	Solar PV					X	X					X	X			
Solea	Solar PV					X	X	X	X			X	X	X	X	
Stream Solutions & Associates	Solar PV					X	X					X				
Sun Day	Solar PV					X	X					X				
Suncore	Solar PV					X	X					X	X			
Tresol	Solar PV					X	X						X			
Growatt	Solar PV				X		X	X	X		X					
Iusasol	Solar PV			X			X									
ERDM Solar	Solar PV			X			X									
Bright	Solar PV					X	X							X	X	
Energía Era	Solar PV					X	X									
Verisol Energía Limpia	Solar PV					X	X									
Vivesolar	Solar PV					X	X									
Leasol	Solar PV					X	X		X			X				

		Stakeholder type					Services						Company Bussines Model			
Name	**Sector**	**Association**	**Financial Services**	**Manufacturer**	**Supplier**	**Project developer**	**Solar PV**	**Storage**	**Solar PV + Storage**	**EV**	**EV Infraestructure**	**After-sales service**	**Traditional Financing**	**Leasing**	**PPA**	**Qualified Supplier**
Luminasol	Solar PV					X	X									
Orosol	Solar PV					X	X									
Solar Tapatía	Solar PV					X	X						X	X	X	
Energytec	Solar PV					X	X					X				
KDS Energía + Ingeniería	Solar PV					X	X	X	X							
Sol y Ahorro Sustentable	Solar PV					X	X						X	X	X	
Energía Libre	Solar PV					X	X									
Solarium	Solar PV					X	X		X				X			
Grupo RIMOLDI y Asociados	Solar PV					X	X						X			
Grupo Amerali	Solar PV					X	X									
Grupo SIE	Solar PV					X	X						X			
Tecnoproyectos Avanzados	Solar PV					X	X		X							
Elecon	Solar PV					X	X									
Solarbay	Solar PV					X	X						X			
Enilso	Solar PV					X	X					X				
Osolec	Solar PV					X	X					X				
Sun Energy	Solar PV					X	X						X			
Dari Ingenierías	Solar PV					X	X									
Notend Energía Solar	Solar PV					X	X					X	X			
Morenergy	Solar PV					X	X					X	X			
Bolt Energy	Solar PV					X	X					X	X			
Marsam	Solar PV					X	X					X	X			
Mayan Solar	Solar PV					X	X									
Luv Terra	Solar PV					X	X						X			
Solaren	Solar PV					X	X									
Sienergy	Solar PV				X		X									
Energía Infinita	Solar PV					X	X									
StellaSolar	Solar PV					X	X		X			X	X			
Solarsafe	Solar PV					X	X					X				
GS Solar	Solar PV					X	X					X	X			
Greenlux	Solar PV					X	X					X	X			
SOLEX Paneles Solares	Solar PV					X	X									
Agrosolar	Solar PV					X	X						X			
Cal y Gar Smart Energy	Solar PV					X	X						X			
Eco Soluciones	Solar PV					X	X						X			
GRUNER	Solar PV					X	X						X			
FIMER	Solar PV			X		X	X						X			
Strip Steel	Solar PV			X		X	X						X			
Huawei México	Solar PV			X	X			X			X	X	X			
Industronic Solar	Solar PV			X		X	X						X			
Suneco	Financial		X				X						X			
Cash Volt	Financial		X				X									
Alianza Caja Popular Cerano	Financial		X				X	X	X	X	X					

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		Stakeholder type					Services						Company Business Model			
Name	Sector	Association	Financial Services	Manufacturer	Supplier	Project developer	Solar PV	Storage	Solar PV + Storage	EV	EV Infraestructure	After-sales service	Traditional Financing	Leasing	PPA	Qualified Supplier
Luminasol	Solar PV					X	X									
Orosol	Solar PV					X	X									
Solar Tapatía	Solar PV					X	X						X	X	X	
Energytec	Solar PV					X	X					X				
KDS Energía + Ingeniería	Solar PV					X	X	X	X							
Sol y Ahorro Sustentable	Solar PV					X	X						X	X	X	
Energía Libre	Solar PV					X	X									
Solarium	Solar PV					X	X		X				X			
Grupo RIMOLDI y Asociados	Solar PV					X	X						X			
Grupo Amerali	Solar PV					X	X									
Grupo SIE	Solar PV					X	X						X			
Tecnoproyectos Avanzados	Solar PV					X	X		X							
Elecon	Solar PV					X	X									
Solarbay	Solar PV					X	X						X			
Enilso	Solar PV					X	X					X				
Osolec	Solar PV					X	X					X				
Sun Energy	Solar PV					X	X						X			
Dari Ingenierías	Solar PV					X	X									
Notend Energía Solar	Solar PV					X	X					X	X			
Morenergy	Solar PV					X	X					X	X			
Bolt Energy	Solar PV					X	X					X	X			
Marsam	Solar PV					X	X					X	X			
Mayan Solar	Solar PV					X	X									
Luv Terra	Solar PV					X	X						X			
Solaren	Solar PV					X	X									
Sienergy	Solar PV				X		X									
Energía Infinita	Solar PV					X	X									
StellaSolar	Solar PV					X	X		X			X	X			
Solarsafe	Solar PV					X	X					X				
GS Solar	Solar PV					X	X					X	X			
Greenlux	Solar PV					X	X					X	X			
SOLEX Paneles Solares	Solar PV					X	X									
Agrosolar	Solar PV					X	X						X			
Cal y Gar Smart Energy	Solar PV					X	X						X			
Eco Soluciones	Solar PV					X	X						X			
GRUNER	Solar PV					X	X						X			
FIMER	Solar PV			X		X	X						X			
Strip Steel	Solar PV			X		X	X						X			
Huawei México	Solar PV			X	X			X			X	X	X			
Industronic Solar	Solar PV			X		X	X						X			
Suneco	Financial		X				X						X			
Cash Volt	Financial		X				X									
Alianza Caja Popular Cerano	Financial		X				X	X	X	X	X					

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		Stakeholder type					Services						Company Bussines Model			
Name	Sector	Association	Financial Services	Manufacturer	Supplier	Project developer	Solar PV	Storage	Solar PV + Storage	EV	EV Infraestructure	After-sales service	Traditional Financing	Leasing	PPA	Qualified Supplier
Sunwise	Solar PV				X		X					X	X			
Baywa R.E.	Solar PV					X	X						X			
AMARAE	Solar PV					X	X						X			
SECING	Solar PV					X	X						X			
Grupo Encanto	Solar PV					X	X						X			
Quartux México	Solar PV					X	X	X					X			
Enlight	Solar PV					X	X		X			X			X	
Zunne	Solar PV					X	X					X	X			
Galt Energy	Solar PV						X	X	X				X	X	X	
Grupo Luxun	Solar PV					X	X						X	X	X	
Solarpro	Solar PV					X	X						X			
Agencia de Energía del Estado de Campeche	Subnational Energy Agency	X														
Agencia Estatal de Desarrollo Energético	Subnational Energy Agency	X														
Agencia Estatal de Energía de Hidalgo	Subnational Energy Agency	X														
Agencia de Energía del Estado de Jalisco	Subnational Energy Agency	X														
Agencia para la Promoción y Aprovechamiento de Energías Renovables (creation feb-2023)	Subnational Energy Agency	X														
Agencia Estatal de Energía de Puebla	Subnational Energy Agency	X														
Agencia Estatal de Energía de Querétaro	Subnational Energy Agency	X														
Agencia Estatal de Energía de Veracruz	Subnational Energy Agency	X														
Comisión Estatal de Energía de Baja California	Subnational Energy Agency	X														
Instituto para el Medio Ambiente y Desarrollo Sustentable del Estado de Colima	Subnational Energy Agency	X														
Instituto Estatal de Energía y Cambio Climático	Subnational Energy Agency	X														
Clúster de Energía de Sonora	Industry	X														

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