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■ ***Research Paper***

Solar Panel and Renewable Energy in Mexico: Development and Outlook for Photovoltaic

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Mexico has a great opportunity for the use of renewable energy RE), regardless of type energy is concerned, solar, geothermal, hydro, etc.., Because it is a country with diverse climate sea world, though little explored sparsely and it is necessary to identify the most suitable for promoting public policies and find the absolute advantage, given the international theories, we can use the same basis for rethinking the development of the sector, using as a guide the absolute advantage that Mexico has in its natural resources and climate types. We also see that international experience shows that it is possible to establish markets "green energy" where end users cover their costs and is a highly profitable emerging market, for both sides, provider and consumer, we also see as government programs exist that support the same , a fact that makes it tempting for the investment of national and international firms.

Keywords: Energy, Mexico, Development, lead, renewable;
JEL: M210, F230, O100, Q430, Q480, Q420, Q57

INTRODUCTION

Renewable energy (RE) currently occupies an increasing space in the energy landscape, and global economics. All developed countries and developing countries are changing their energy policies for the development of technologies that provide economic growth, and can meet the demands of its population. The technologies that use renewable energy are currently experiencing the highest growth rate in the world.

Mexico is no exception. Over the last decade and currently the energy reform led to the development of the energy sector, currently there are 10 major private companies engaged in the production of renewable energy, who sell both CFE (Federal Electricity Commission) as direct producers, and production equipment to businesses and individuals. Mexico has initiated a way to diversify fuels used in electricity generation. The intensive use of fossil fuels has impacts on energy security by the volatility of prices and availability of fuels, the environment by the emission of greenhouse gases and health.

It is for this reason that in Mexico recently, legislators and government have developed various policies, laws, rules and regulations to promote the rational use of non-renewable resources and increase the implementation of energy sources that cause less environmental impact, such as renewable energy. In the latter context, the use of solar energy could play an important role.

Various energy planning documents developed and / or supported by several national and international organizations and actors such as the

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Ministry of Energy (Secretaría de Energía), bilateral cooperation agencies, research centers, NGOs, associations and representatives of civil society and private industry, have highlighted the enormous potential for Mexico to take advantage of the solar resource, both for thermal applications such as electricity generation.

In the case of electricity generation, international experience shows that PV systems require some form of intervention by the authorities conducting energy policy to overcome the obstacles and create a market that will accelerate their development.

Objective

This paper analyzes the renewable energy industry, specifically solar and photovoltaic (PV) panels. While a new industry and an emerging market in Mexico, it is also a potentially growing market niche, making it a sector of business potential which is economically viable. The period of analysis oscillates between 2000 and 2013.

This work is focused on the review and analysis of the renewable energy sector since the operation of the technology, its application, its current market, and chronological development, immersing foreign and national investment as well as the sale and production of PV equipment. The present study investigates these aspects using techniques such as Herfindal-Hirshman Concentration Index (HHI) and Pascual concentration indices, also game theory.

The research questions are: What are the main features of the RE market in Mexico? What is the industry outlook both in development and production? And who are major investment companies in the photovoltaic industry in Mexico.

Background

According to the National Association of Solar Energy (ANES), until 2006, virtually all PV systems installed in Mexico, were in isolated applications of the grid and electrical network, rural electrification, communications, signage, water pumping and cooling. However, from the year 2007 there are records of applications connected to the grid and electrical network. This trend has continued in subsequent years so that in 2011, of 3.5 MWp installed in that year, about 94% were connected to the electricity grid systems. As shown in the figure below, the annual installed capacity, systems isolated and connected to the network, has shown a fluctuating behavior in the period 2005 -. 2011 In cumulative terms, the increased capacity of 16.5 MWp to 32 MWp. Regarding the annual electricity generation of 23,235 MWh is increased in the year 2005 to 44.974 MWh in 2010 (Figure 1).

Insert Figure 1 here

Description of technology

Although until the middle of last century, the use of solar energy to generate electricity materialized its first applications, mainly during the early space race between the U.S. and the former Soviet Union, the phenomenon that gave origin was observed by first time over 100 years ago. This phenomenon, called "photovoltaic effect," generally speaking, can be explained as follows:

A. When sunlight shines on two layers of semiconductor material, that is, those that conduct electricity only under certain conditions, this causes the release of electrons which flow from the bottom layer toward the top of the semiconductor;

B. On passing the electrons (electricity) through one or more electrical loads (e.g. a lamp) then they give up their energy;

Finally, the process is repeated to re-combine the electrons with the semiconductor material of the top layer (Figure 2).

Inset Figure 2 here

Today this phenomenon is exploited by using small plates, called photovoltaic cells, which are made primarily of silicon, one of the most abundant elements on earth. The arrangement comprises a number of these cells encapsulated and electrically connected in series and / or parallel, mounted on a support structure, is called photovoltaic module or panel. A set of these panels are usually mounted on stands or structures, but today can be integrated as elements of shade, or even as part of the facades of some buildings.

The following figure shows an arrangement of a photovoltaic module assembly (Figure 3):

Insert Figure 3 here

A special feature of PV is that electricity is delivered as a direct (or continuous) stream, so that connection to the main electrical networks is still necessary to transform in alternating current, the form how the CFE delivers electricity in in homes. It is for this reason that in order to harness solar energy, in most cases, it requires an inverter, which along with other electric components form what is called a photovoltaic system. One of the main advantages of PV systems is that maintenance costs are low throughout life, approximately 20 years for PV modules. However, their initial investment costs are still high compared with other technologies; although the costs of operation and maintenance are virtually null compared to the costs of generating electricity. It is expected that both their investment and generation costs continue to decline significantly over the next few years.

There are two markets that can harness solar energy for electricity generation: the interconnected electric systems and network or autonomous isolated systems.

A. Interconnected systems to the electricity network

They are found mainly in urban or rural areas, which are interconnected to the National Electricity System (SEN). These systems consist of the following components (Figure 4):

1) Panel or PV array
2) Current inverter

Interconnecting devices, protection and measurement, switches, protection system and bidirectional meter.

Insert Figure 4 here

B. Isolated systems

Isolated systems are characteristic of rural or isolated areas, where it is not economically feasible to construct a grid interconnection with SEN. These systems consist of the following components (Figure 5):

1) Panel or PV array
2) Bank and battery charger
3) Interconnecting and protection devices.
4) Current invertor. Rev. Optional, for alternating current loads.

C. PV isolated system

Unlike the SEN interconnected systems, these do not require a measurement device. However, additionally require a battery bank and a controller to store the electricity that will be used at other times in the photovoltaic system cannot generate, for example, at night.

Insert Figure 5 here

Industry of solar energy in Mexico

Mexico is among one of the 5 countries with the most attractive in the world to invest in PV projector, still behind China and Singapore, because it is part of the Sun Belt. These are countries with latitude + -35 with respect to Equator and exhibit higher levels of solar and sunlight radiation of the planet. For Mexico, there are areas where there is a greater 5kWh per m² radiation. Attraction also includes other factors such as market potential, politics, business environment, financial stability and renewable energy policies. The size of the electricity market, its projected growth in electricity consumption in the next 2 decades and its competitive cost of PV technology also cover electrical networks and their ease of distribution, among others (Figure 6).

Insert Figure 6 here

A. PV Solar

Mexico currently has an installed capacity of 33 MW in solar PV projects, mainly in applications of rural and industrial electrification. Currently there are several construction and development projects of this kind that would have an installed capacity of 39.1 MW. In late 2011, a Spanish company called Siliken invested in a photovoltaic power project in Durango called La Manzana del Sol. The ame project has 100MW of installed capacity now in its first stage and who estimates

that this would to have a total of 400MW in the five years after its initiation (Fig. 7).

Insert Figure 7 here

Market structure

A. Major PV companies in Mexico

Mexico is the leading supplier of photovoltaic modules in Latin America, with an annual production capacity exceeding 276 MW still above countries such as Chile, Brazil and Argentina. Among the leading developers of photovoltaic are: Abengoa, Abener, Del Sol Systems, Microm, Iberdrola and Silken.

1). Solar Thermo high concentration

Today in Mexico there are no operating plants using such technologies harnessing solar energy. However, in the state of Sonora is developing the project 171 CC Agua Prieta II, by CFE same that consists of a combined cycle hybrid system, 477 Mwe, and a thermal solar field trough parabolic channels with a power of 14 MWe. It is expected that this central enter into operations in 2014-2015 (Figure 8).

Insert Figure 8 here

The table looks like it has grown the national energy sector since early 2000 to late 2013 and can be seen as the sector photo voltaic energy barely appeared in the outlook in mid-2012 producing only 0.01 of energy and being less 1% of its development potential (Figure 9).

Insert Figure 9 here

B. Share of renewable energy companies in Mexico

The following table shows the number of companies participating in the market for 2009, according to INEGI. IT can be appreciated that for this year are 65 companies involved in this market segment. Gross production for 2009 amounted to a total of 450,968,876 units, with a total investment of 29,504,562 bp generated a total income of 522 313 705 million, and given the figures we also see that there are 27 companies that dominate this market goes to 77.07% of it (Table 1).

Insert Table 1 here

C. Concentration index segment

In the table below it is shown the participation of companies in the renewable energies sector, also there are calculations of the Herfindal-Hirshman Concentration Index (HHI). For 2009 were also calculated by size of enterprise, the data give an HHI of 0.60 that is a monopolistic competition because 27 of the 65 companies control the market hogging the 77.07% of the market, leaving only one 22.93% for all other companies.

Nonetheless, economic theory tells that the market tends to be from monopolistic to oligopoly due to the size of companies and the influence they have in the market competition (Table 2).

Insert Table 2 here

This relatively new market and little taken into account is a tempting niche for the large firms because consumers are almost all the same, houses, apartment buildings, hospitals, businesses, hotels, sport clubs, government projects, solar parks and even the producers themselves would benefit because costs would be lowering. It is known that the solar energy market in Mexico ascents amount millions of dollars, of which 30 belong to photovoltaic.
Because it is an emerging market that is relatively new, turns out to be extremely profitable for all companies making the development and growth of this focus solely on their production costs, and market strategy.

Costs

Photovoltaic systems in network connection in Mexico differ in cost depending on its capacity. In late 2011 SENER and GTZ conducted a survey to stakeholders and actors in the country to

determine these costs. For the residential sector where the average investment for PV systems with a capacity between 0.24kWp to 1.65kWp is U.S. $ 4.851 / kWp with leveled costs of U.S. ¢ 17.8/kWh. Meanwhile costs for systems with capacities between 2kWp to 10kWp are reduced U.S. $ 3,000 / kWp - 4,200 / kWp and leveled generation costs range from U.S. ¢ 10.9/kWh (Mx $ 1.3) and U.S. ¢ 15.4/kWh (Mx $ 1.8). By early 2014 these costs were reduced to 1100 dlls.

It is estimated that the average lifespan of photovoltaic panels is 25 years useful to 100% and up to 35 years total lifetime. And it is estimated that the initial investment is recovered in the medium term between 3 and 6 years after purchase.

Regulatory frameworks for renewable energy

Currently the following legal and regulatory instruments allow the use of solar PV grid connection

A. General Law on Climate Change

On June 6, 2012 this law was published in the Official Gazette Diario Oficial de la Federación, which has among its purpose to ensure the right to a healthy environment and to establish the occurrence of powers of the three branches of government in the development and implementation of public policy on two guiding themes: Climate change adaptation and mitigation of emissions and greenhouse compounds.

B. Law on the Use of Renewable Energies and Financing of Energy Transition (LAERFTE) and its regulations.

In late 2008 this law was published in the Official Gazette Diario Oficial de la Federación, which has the purpose to regulate the use of renewable energy for electricity generation for purposes other than the provision of public service. Its regulation was published in the Official Gazette of September 2, 2009, including more specific areas for compensation of renewable energy projects.

C. Interconnection Agreement for Renewable Energy and Power Cogeneration System in Small and Medium Scale.

On April 8, 2010, the Energy Regulatory Commission (CRE) published these model contracts in the Official Gazette, and is intended to establish the rights and obligations of a user that connects a source of renewable energy to SEN. These interconnection agreements are based on the principle of "net metering".

D. Interconnection Agreement for Renewable Energy of Collective Source or Collective System Small Scale Cogeneration contract (to be published by the CRE)

This type of contract applies to everything related to Small Scale generation described in the previous paragraph. With the characteristic that the collective source of electricity generation belongs to a group of generators, besides, the energy generated by the collective source. It is divided, for billing purposes, between the owners depending on the percentage of investment made by each of the owners.

Since PV systems can reduce or stop suddenly generate electricity, for example, partially cloudy days, it is also necessary to establish a series of technical rules to avoid discomfort or harm to other users. For this, the CRE and CFE have developed a specific regulatory framework for interconnection technologies based on renewable sources such as photovoltaic systems:

1) Specification for low voltage interconnection of photovoltaic systems with capacity up to 30 kW (CFE G0100-04).
2) Annexes to the Interconnection Agreement in Medium Scale: Characteristics of measuring equipment and communication (Annex E-RMT) and technical requirements for interconnection (Annex ERD-T).
3) General Rules for Interconnection to SEN or permit generators with renewable energy or efficient cogeneration (published in the Official Gazette by the CRE, the May 22, 2012).

In more graphic form below is shown how is composed the regulatory and policy framework for PV in Mexico (Figure 10), which consists of the following legal structure

Insert Figure 10 here

In addition to public institutions (CRE and CFE) there are private institutions for issuing standards in the electricity sector such as the National Association for Standardization and Certification of the electricity sector that have issued Mexican Standards.

CONCLUSION

In the present work it has been observed how has been growing this renewable energy market considering the potential as an emerging market. Mexico is considered one of the most attractive countries to invest in this sector being considered as the 5th country with more possibility of development. Also it is seen that the HHI for 2009 is 0.60 which tells that it is a monopolistic competition with a tendency to be oligopoly. The profitability of the sector is abundant, generating profits of more than double the investment for businesses.

This being concluded it can also determine that the investment for consumers becomes profitable from the 3rd and 6th year, with costs ranging between 1000 and 10000 dollars according to their size. Within the regulatory framework also see the growing legislative restructuring encouraged to developing different ways for both the private sector and the public.

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Table 1
Companies by Number of Employees

Stata	Economic units	Total Gross production	Intermediate consumption	Total expenses by consumtion of B and S	Total investment	Gross census aggregate value	Total remunerations	Total revenues
Total	65	450968876	233857943	298861814	29504562	217110933	35520658	522313705
From 0 to 2	5	10284205	8485161	8486788	-32356	1799044	300	10451433
3-5	1	2100	1157	1186	0	943	0	2100
6-10	1	92538	79036	79036	0	13502	1021	92538
11-15	3	620686	620686	494161	20	4119	0	97966
16-20	3	99667	95548	94112	20		0	
21-30	2	2859872	2132179	2132179	47609	727693	0	2580730
31-50	12	33293082	24408760	24409601	-127987	8884322	53907	30346885
51-100	1	243083	220004	233195	0	23079	0	243083

101-250	1	536132	231202	311708	1417	304930	49448	430398
251-500	2	20050472	11308700	12706982	119680	8741772	100219	1561760
501-1000	7	35295345	15597663	18240301	1771641	19697682	1691959	24897558
1001 and more	27	347591694	170804372	231672565	27593151	176787322	33623804	451020425
Total	65	450968876	233857943	298861814	29504562	217110933	35520658	522313705

Source: INEGI Census 2009.

Table 2
Concentration Indexes

Strata	Economic units	Participation/ Market share	%	**P²(IHH)**	**HH**	**ID(HH²)**
Total	65	1				
From 0 to 2	5	0.022804689	2.2804689	0.000520054	0.000855074	7.31E-07
From 3 to 5	1	4.66E-06	0.0004657	2.17E-11	0.608197431	0.369904115
6-10	1	0.000205198	0.0205198	4.21E-08	6.92E-08	4.79E-15
11-15	3	0.001376339	0.1376339	1.89E-06	3.11E-06	9.70E-12
16-20	3	0.000221006	0.0221006	4.88E-08	8.03E-08	6.45E-15
21-30	2	0.006341617	0.6341617	4.02E-05	6.61E-05	4.37E-09
31-50	12	0.073825676	7.3825676	0.00545023	0.008961285	8.03E-05

51.100	1	0.000539024	0.0539024	2.91E-07	4.78E-07	2.28E-13
101-250	1	0.001188845	0.1188845	1.41E-06	2.32E-06	5.40E-12
251-500	2	0.044460878	4.4460878	0.00197677	0.00325021	1.06E-05
501-1000	7	0.07826559	7.826559	0.006125503	0.010071569	0.000101437
1000-and more	27	0.770766482	77.076648	0.59408097	0.976789672	0.954118064
Total	65	1	100	0.608197431	1.608197431	1.32421522

Source: INEGI Census 2009.

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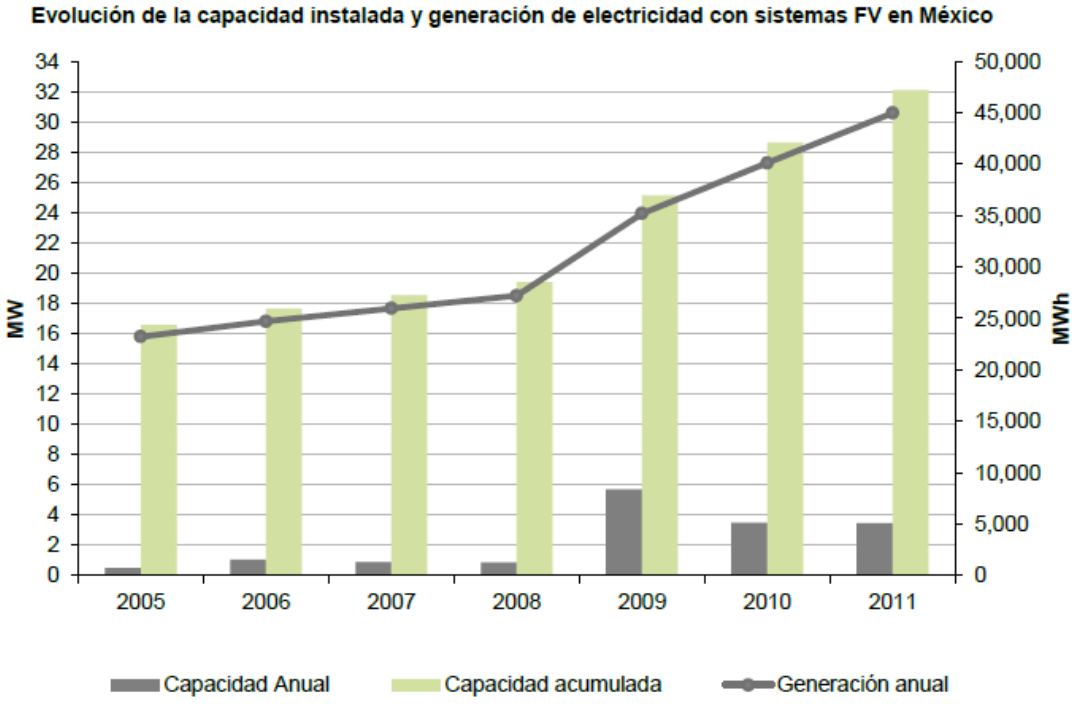
APPENDIX

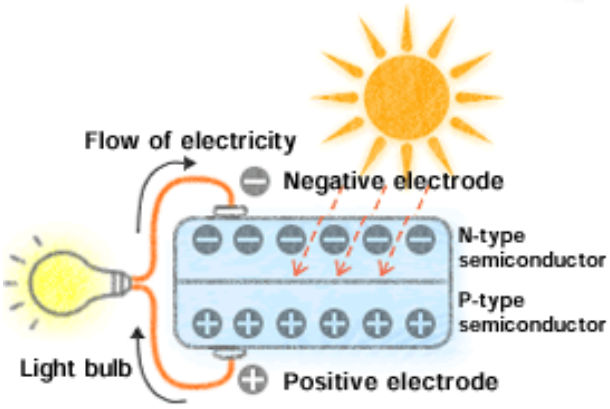
Figure 1
Evolution of installed capacity and power generation PV systems in Mexico



Fuente: Elaboración propia con datos de SENER, 2012

Source: SENER 2012.

Figure 2
Photovoltaic



Source: Solarpooltech

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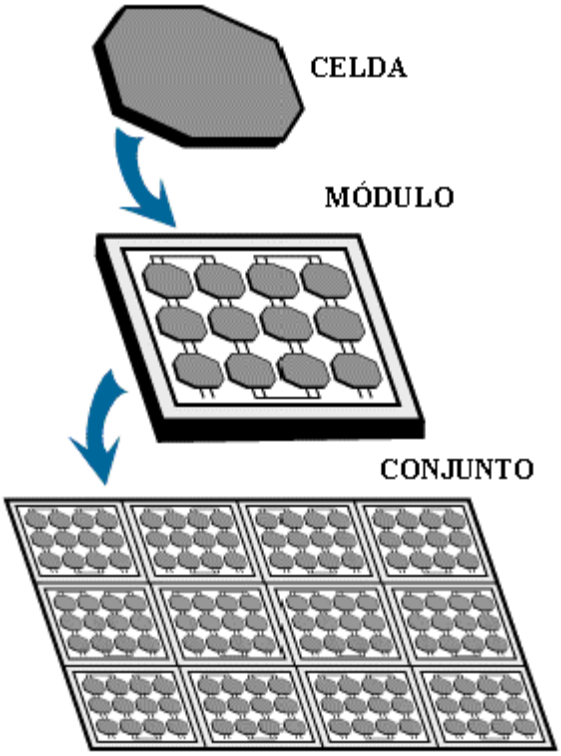
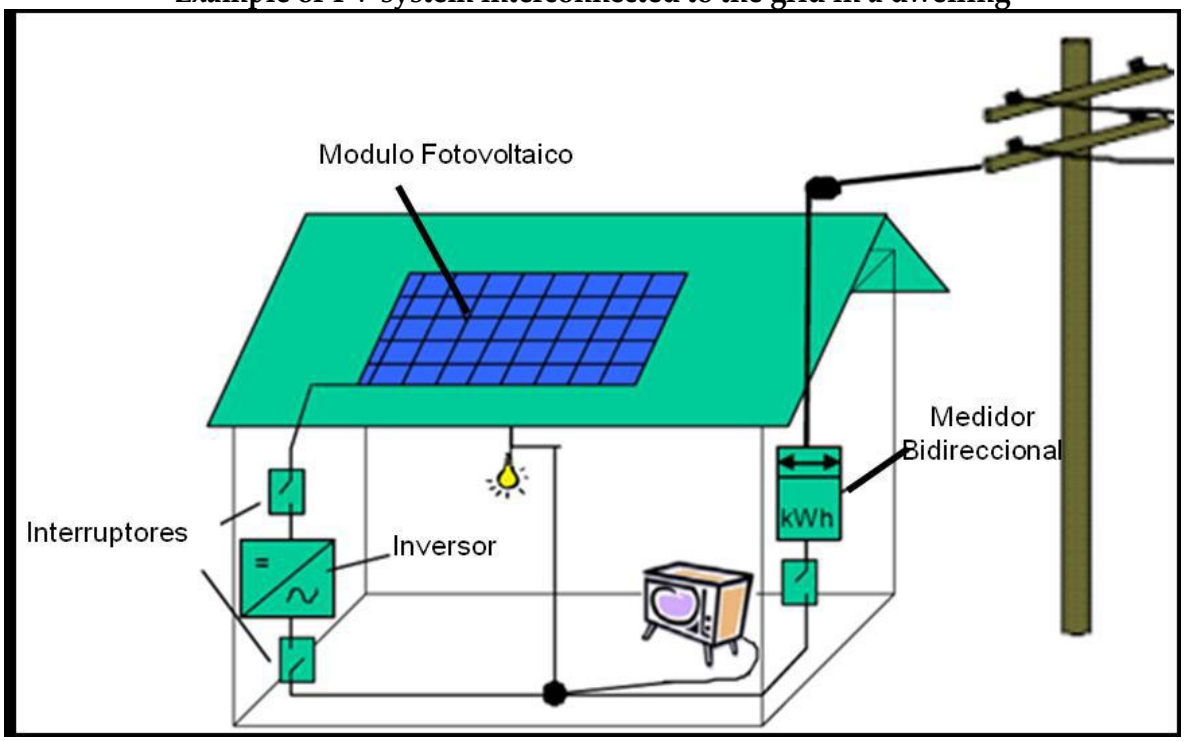
Figure 3
Assembly of a PV module



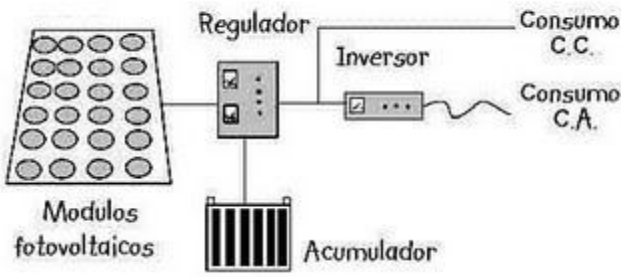
Source: Organización Anes

Figure 4
Example of PV system interconnected to the grid in a dwelling



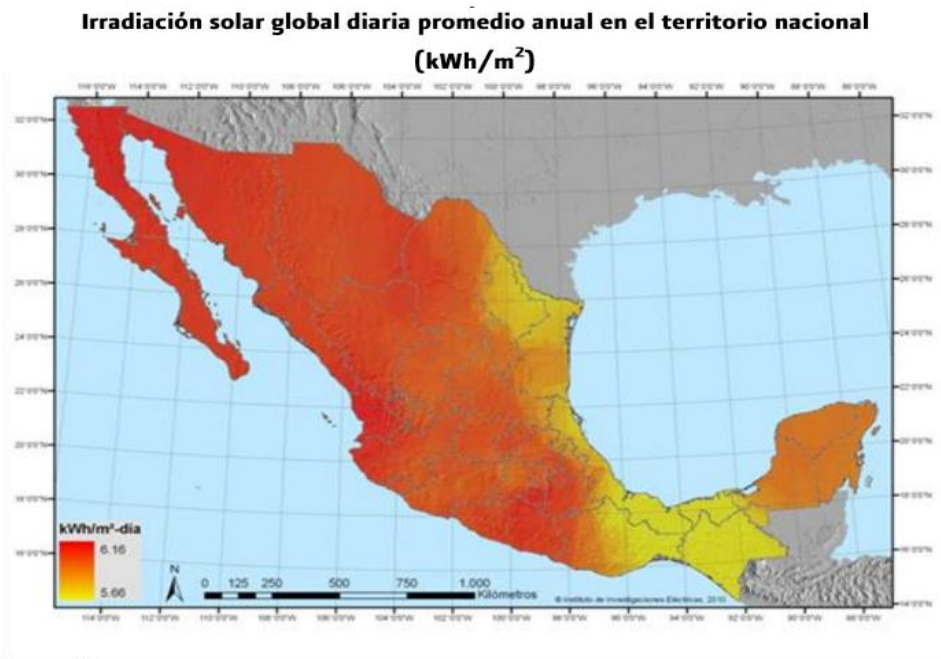
Source: CONUEE/ GTZ, 2009*Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Figure 5
PV isolated system



Source: alternativasnuestras

Figure 6
Daily solar and sunlight radiation



Fuente: IIE.

Source: IIE.

Figure 7
PV centrals in México

Centrales solares fotovoltaicas para la generación de electricidad

Central / permisionario	Estado actual	Capacidad instalada (MW)	Ubicación	Tipo de servicio
Contratos de pequeña y mediana escala	En operación	32.0	-	Privado
Central Piloto, Santa Rosalía	En operación	1.0	Baja California Sur	Público
Total	-	**33.0**	-	-
Proyecto fotovoltaico, Durango	Por iniciar operaciones	0.5	Durango	Privado
Proyecto fotovoltaico (autoabastecimiento)	En construcción	3.8	Aguasca-lientes	Privado
Proyectos fotovoltaico (pequeño productor)	En construcción	29.8	Jalisco	Privado
Central Piloto, Cerro Prieto	En construcción	5.0	Baja California	Público
Total		**72.1**		

Fuente: CFE/CRE/ SENER/ medios electrónicos

Source: CFE

Figure 8
Growth potential of solar thermal energy in Mexico

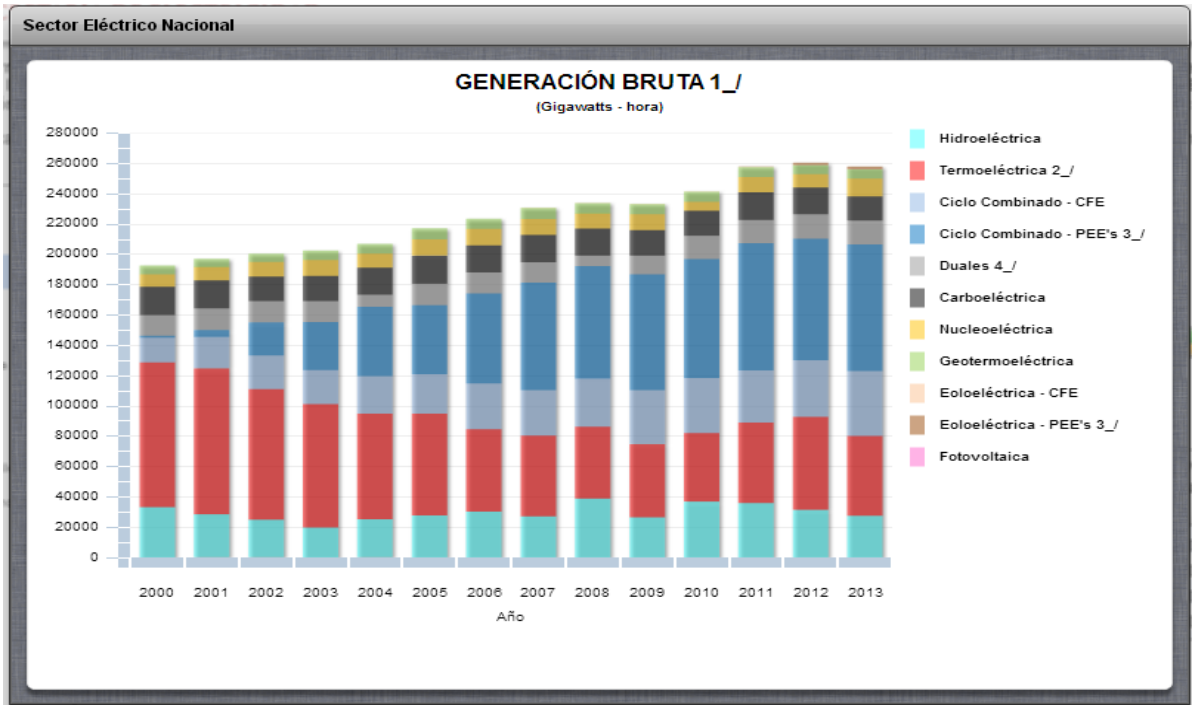
Potencial de penetración de las tecnologías termosolares de concentración en México
Período 2010-2015

Región	Escenario	Potencia media (MW)
Norte	Bajo	0
	Medio	816
	Alto	1,413
Noroeste	Bajo	417
	Medio	837
	Alto	1,431
Total	Bajo	417
	Medio	1,653
	Alto	2,844

Fuente: IIE.

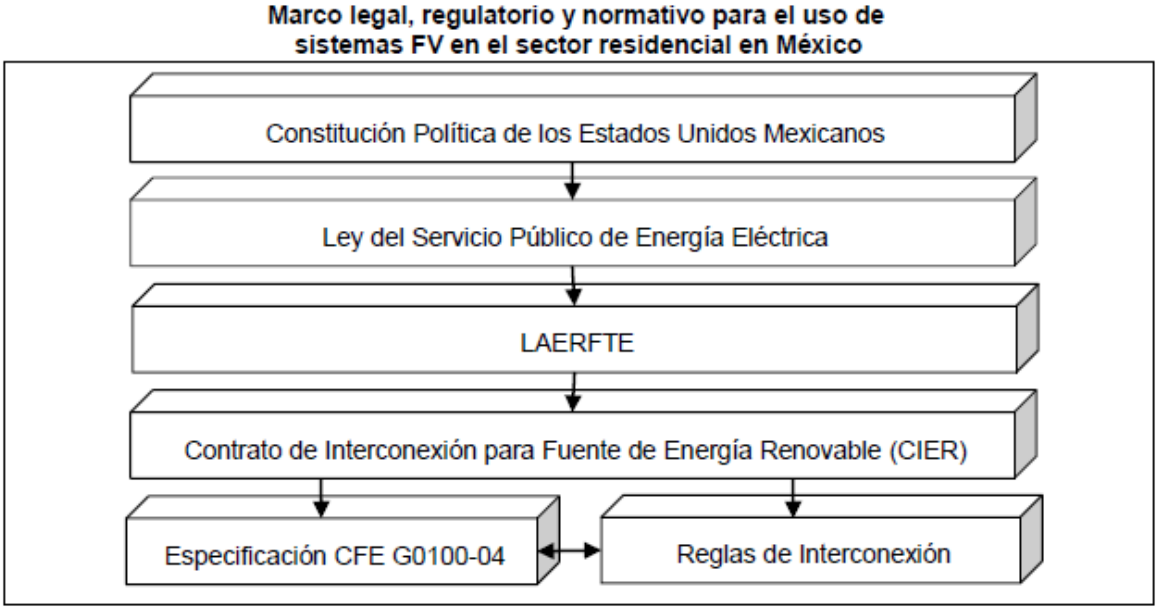
Source IIE

Figure 9
Gross Power Generation



Sources: SENER

Figure 10
Legal structure



Source: PROSOLAR SENER