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Generation of market information of the Mexican Solar Industry under a model of strategic analysis and innovation

Generación de información de Mercado de la Industria Solar Mexicana bajo un modelo de análisis estratégico e innovación

RODRIGUEZ-CARVAJAL, Ricardo Alberto†*, ISIORDIA-LACHICA, Paula Concepción, TADDEI-BRINGAS, Jorge Luis and ROMERO-HIDALGO, Jorge Alberto

Universidad de Guanajuato, Departamento de Ingeniería Química, Departamento de Agronomía, Departamento de Relaciones Industriales
Universidad de Sonora, Departamento de Ingeniería Industrial

ID 1st Author: *Ricardo Alberto, Rodriguez-Carvajal* / **ORC ID:** 0000-0003-3105-9809, **CVU CONACYT ID:** 269292

ID 1st Coauthor: *Paula Concepción, Isiordia-Lachica* / **ORC ID:** 0000-0001-6403-3264, **CVU CONACYT ID:** 253334

ID 2nd Coauthor: *Jorge Luis, Taddei-Bringas* / **ORC ID:** 0000-0002-6960-7594, **CVU CONACYT ID:** 56486

ID 3rd Coauthor: *Jorge Alberto, Romero-Hidalgo* / **ORC ID:** 0000-0002-5804-3340, **CVU CONACYT ID:** 946094

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Abstract

The Mexican solar industry is being born because the existing mainly serves the commercialization of imported technology. Currently initiatives have been developed that seek to create this industry in Mexico, one of them is the Mexican Center for Innovation in Solar Energy, this Center was created in 2013 where the academic and research sector was invited to propose projects that could reach the market and generate innovation, giving way to a Mexican solar industry. The progress of this project is reflected in the generation of industrial property but without really addressing market needs, this is due to the fact that there is little formal and validated information that helps to make the best decisions to the academics who are conducting this research and to the sector. productive that motivates investment in these technologies. Derived from the above, this project strategically acquires the relevance to be able to provide information to the actors that are building the nascent solar industry. An analysis of the state of the art and the technique was carried out on market information generated regarding the solar industry in a global manner. The global information was analyzed and a study framework was proposed for the Mexican solar industry.

Solar Industry, Solar Market, Suply Chain

Resumen

La industria solar mexicana esta naciendo pues lo existente atiende principalmente a la comercialización de tecnología importada. Actualmente se han desarrollado iniciativas que buscan crear esta industria en México, una de ellas es el Centro Mexicano en Innovación en Energía Solar, este Centro fue creado el año 2013 donde se convocó al sector académico y de investigación a proponer proyectos que pudieran llegar al mercado y generar innovación, dando paso a una industria solar mexicana. El avance de este proyecto se refleja en la generación de propiedad industrial, pero sin atender realmente las necesidades de mercado, esto debido a que existe poca información formal y validada que ayude a tomar las mejores decisiones a los académicos que están realizando estas investigaciones y al sector productivo que motive la inversión en estas tecnologías. Derivado de lo anterior este proyecto adquiere de manera estratégica la relevancia para poder brindar información a los actores que están construyendo la naciente industria solar. Se realizó un análisis del estado del arte y la técnica sobre información de mercado generada referente a la industria solar de manera global Se analizó la información global y se planteó un marco de estudio para la industria solar mexicana.

Industria Solar, Mercado Solar, Cadena de Proveeduría

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* Correspondence to Author (email: rodriguez.ricardo@ugto.mx)
† Researcher contributing first author.

Introduction

Solar energy is the most generated source on earth, with approximately 885 million TWh falling on the surface of the planet each year, 6,200 times the primary commercial energy consumed by humanity in 2008 (SENER, 2017).

Global spending on renewable energy is breaking the trillion dollar barrier over the next few years, so nanomaterials are in commercial development as a means to reduce costs and make these sources of energy competitive. Achieving considerable progress in wind and solar energy, fuel cells, thermoelectric, batteries and supercapacitors, which today materialized into tangible products. Nanocoatings are enabling new paradigms in energy-friendly and low-cost energy conversion and storage systems (Nanocoatings, 2014).

The Secretariat of Energy (SENER), (2017) defines photovoltaic solar cells and modules as solid state semiconductor devices that convert sunlight into direct current electricity. It is important to mention that a cell is the minimum unit to acquire the energy of the sun and in which electric power is generated, while a module or solar panel is an array of cells with the objective of obtaining greater electrical power generation.

There is a wide range of photovoltaic materials available around the world and can be categorized by crystalline silicon technology, thin film technology and emerging technologies. The cells of crystalline silicon (c-Si) occupy 90% of the total produced, the rest are called "thin film" ("thin film").

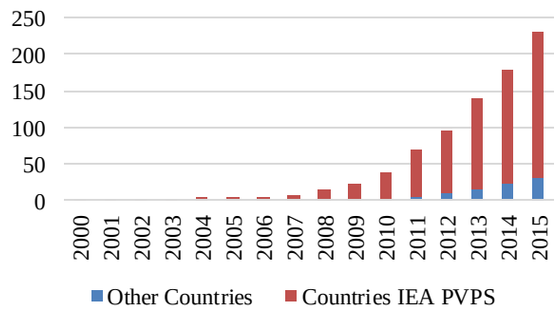
The solar light on impacting the semiconductor, there is the transfer of electricity through the union between two layers, thus obtaining direct current. The greater the intensity of the light, the greater the flow of electricity. It is important to mention that a photovoltaic system does not require bright sunlight to function, this is due to the phenomenon of reflection of sunlight, which also on cloudy days, energy is obtained.

A photovoltaic system takes advantage of incident solar radiation, to directly generate electricity in the form of direct or direct current.

When referring to photovoltaic technology all the components of the physical system that converts solar energy into electrical energy are integrated (SENER, 2017).

In the report of REthinking Energy 2017 it is mentioned that worldwide, photovoltaic solar energy; its photovoltaic capacity increased from 40 GW in 2010 to 219 GW in 2015, accumulating approximately 20% of the new installed capacity for electricity generation (SENER, 2017).

By the end of 2015, according to the International Energy Agency, installed capacity continued to increase to reach 227 GW of photovoltaic systems around the world (SENER, 2017), see Figure 1.



Graphic 1 Evolution of photovoltaic installations (GW)
Source: Trends in photovoltaic energy, SENER (2017 p.22)

This work shows an analysis of the market information available in Mexico, as well as the development potential of a nascent solar industry, making a study of the value chain, and not only focusing on the manufacture and installation of photovoltaic devices, but also a analysis of the potential of the technological developments of two national projects such as the National Laboratory of Concentration Systems and Solar Chemistry (LACYQS) and the Mexican Center for Solar Energy Innovation (CeMIE-Sol).

There is also an analysis of the industry installed in the State of Sonora, which shows the potential to be integrated into the value chain of this industry, and stop relying on technology acquisitions, this derived from the facilities that will be made emanated of the energy auctions that SENER has competed.

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Theoretical framework

The energy sector has become a condition for the economic growth of the countries, due to the close relationship that exists between the growth of the gross domestic product and the energy demand of each country. The increase in the standard of living of the population has generated a persistent increase in energy demand.

The finite nature of resources has forced us to seek greater efficiency in the production and use of energy, as well as to develop the potential of the use of non-fossil energy sources.

In this context, the use of renewable energies appears as an element that contributes to increasing the country's energy security, by diversifying its energy matrix in the face of the expectation of higher prices and the volatility of conventional energy sources (IEA, 2011), as well as how to mitigate greenhouse gas emissions and the serious consequences of climate change from the use of fossil fuels.

An energy balance provides a simple representation of an energy system using the basic ideas of accounting and is one of the basic frameworks for the analysis of energy systems, is a tool that has been used since the fifties in the United States and continues to be an essential part of energy planning today, mainly in models with an econometric approach (Bhattacharyya and Timilsina, 2009).

The energy balance represents the flow from the energy supply, the transformation to secondary energies, and the final demand, by sector and by type of energy, for this information to be able to monitor the energy needs in a region (Adams and Shachmurove, 2007).

Bazán and Ortiz (2010) describe the energy system in general and the parts that make up this system as: demand, which in the balance is detailed by sector, subsector, end uses and equipment; transformation, where an evaluation is made detailed structures for the generation of secondary energy, such as refineries, power plants, etc.; and supply of primary energy, simple representation of renewable and non-renewable resources that are used as supply.

According to the National Inventory of Renewable Energies (INER), Mexico has abundant resources for the generation of energy from renewable sources, with a proven potential of up to 13,167 GWh / year, estimates that increase substantially if reserves are considered probable, as indicated in table 1.

Potential of Electrical Generation with Renewable Energies (Gwh / Year)

Resources	Geothermal	Mini hydraulics	Wind	Solar	Biomass
Possible	16,165	-	87,600	6,500,000	11,485
Probable	95,569	1,805	9,597	-	391
Probable	892	1,365	9,789	542	579

Table 1 Prospective of Renewable Energies 2013-2027
Source: National Inventory of Renewable Energies, SENER

Solar Manufacturing

The potential of manufacturing components for the solar industry is very great since it has a highly developed industrial ecosystem, this derived from a large number of companies that have integrated supply chains in other industries such as medical, automotive, electrical, electronic, aerospace and others.

Together with a good industrial ecosystem, technological scientific initiatives have been developed, such as the National Laboratory of Concentration Systems and Solar Chemistry (LACYQS), a project funded by the National Council of Science and Technology of Mexico and led by the Institute of Renewable Energies of the University Autónoma de México, in this project the University of Sonora actively participates being the headquarters of the Experimental Field Installation of Central Tower (CEToC) of this national laboratory.

The LACYQS project, which frames several important linking results, has developed several technologies that have been protected through patent applications, which have been sought to be transferred to the productive sector to impact on economic development and generate mitigation impacts greenhouse gases, because when they are adopted they stop consuming fossil fuels for the production of electrical energy.

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In this sense, the technology that has been transferred to a local company dedicated to the automotive sector, whose expertise is the work of metalworking, manufactures solar tracking structures of two axes, which opens a business unit dedicated to the manufacture of fixed structures and solar tracking to serve the photovoltaic and solar power concentration market, since it serves both solar technologies.

This shows the potential of the scientific developments carried out by universities and research centers.

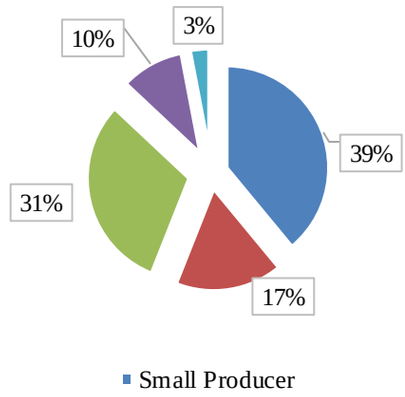
Another of the projects that have been generated nationally, are the initiatives of the Mexican Centers in Innovation in Energy, Solar, Wind, Geothermal, Ocean, among others, with the financing of the Energy Sustainability Fund, of the Secretariat of Energy in Association with the National Council of Science and Technology (CONACYT).

In particular, the Mexican Center for Solar Energy Innovation (CeMIE-Sol) has promoted 22 strategic projects, as shown in Table 2.

# of Project	Project name
P03	Production of solar electricity using parabolic disk systems, from photocells
P16	National Inventory of the Solar Resource (Map of the Solar Resource)
P21	National Inventory of the Solar Resource (Map of the Solar Resource)
P22	Design and development of photovoltaic devices in CIACYT UASLP: based on cubic InGaN and multi-band cell structures of GaNAs
P25	Development of prototypes of CdTe / CdS photovoltaic modules in an area of 100 cm2 with efficiency in the range of 10%, and associated systems for its manufacture for efficiency in the 10% range, future technology transfer
P26	Processing of solar cells of CdS / Cu (InGa) Se2 and CdS / Cu2ZnSnS4 for their technological transfer to the industrial sector
P27	Development and manufacture of solar cells modules of TiO2 sensitized with dye (DSC) and quantum dots (QDs), and of photovoltaic organic (OPVs)
P28	Nanotechnology applied in the development of thin films and prototype solar cells
P29	Development of a national laboratory for the evaluation of the compliance of modules and components of photovoltaic systems and installations LANEFV
P31	Advanced nanostructured materials for high efficiency organic / inorganic hybrid photovoltaic cells
P32	Nanoantenas thermoelectric with high efficiency for the use of solar energy
P35	I+D of solar cells with novel materials
P37	Development of new photovoltaic devices and semi-superconducting materials
P39	Development of a permanent inventory of PV systems installed at the national level
P50	Low-capex manufacturing routes coupled to heat treatments for high performance of novel thin film materials

Table 2 Strategic projects driven by the CeMIE-Sol
Source: Own Elaboration from. PROMÉXICO, 2018

In Mexico, there is an installed capacity per modality as shown in Figure 2.



Graphic 2 Installed capacity of Photovoltaic Energy by mode (MW)
Source: PROMÉXICO, 2018

Value chain of the photovoltaic industry

Regarding photovoltaic technology, we have the following supply chain that can be seen in figure 1, this chain poses as a challenge to develop Mexican interconnected investors, since the tracking and fixed structures can be manufactured and serviced by Mexican companies.

In terms of electrical equipment, there are already several Mexican companies that will provide the materials to the plants that could be developed. Photovoltaic panels are a technology that requires large investments to produce them, so it is better to import this technology, although there are Mexican companies that are manufacturing panels.

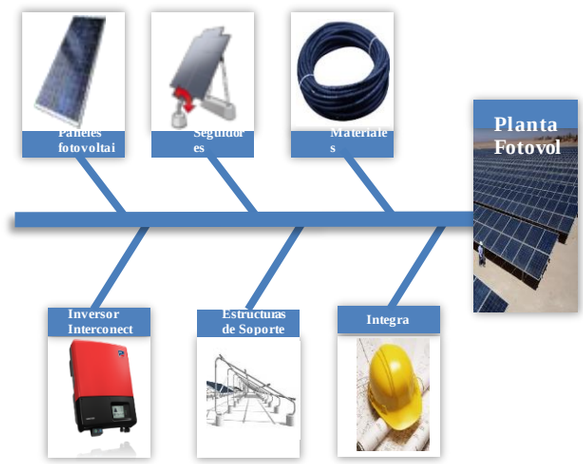


Figure 1 Value chain of the photovoltaic industry
Source: Own Elaboration

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When presenting this analysis of supply chains in photovoltaic technology it is clear that the great opportunity for Mexican companies to generate products such as: solar tracking structures, electrical materials, investors and microinverters, marketing of photovoltaic panels, development of new materials, integration and engineering in large-scale and residential generation projects among others. Each of these links have a national and international market value that is growing due to the number of facilities projected in Mexico and the World.

Characterization of Sonoran companies with potential for integration into the value chain of the solar industry

A survey was carried out of the Sonoran companies dedicated to the metal-mechanic manufacturing for the automotive and aerospace industry. The following were found: 61 companies (see table 3) dedicated to this line of business, with diverse capacities and clients, the most consolidated serving as a priority to the automotive sector, offering several products and services. These 61 companies are distributed in the state of Sonora, with their main activity distributed as follows:

Location	What is the main activity of the Company			Total
	Production	Sales and / or trade	Service	
Hermosillo	61.1	5.6	33.3	100.0
Cd. Obregón	7.7	7.7	84.6	100.0
Navojoa	10.0	0.0	90.0	100.0
Guaymas - Empalme	0.0	0.0	100.0	100.0
Nogales	50.0	12.5	37.5	100.0
Total	27.9	4.9	67.2	100.0

Table 3 Classification of companies by municipality and main activity
Source: Own Elaboration

The composition of its sales is presented as follows (see table 4).

What percentage of your sales are	What is the main activity of the Company			Total
	Production	Sales and / or trade	Service	
Local	61.4	78.3	87.1	79.5
Nationals	10.3	11.7	8.7	9.3
Foreign	28.4	10.0	4.3	11.3

Table 4 Percentage of sales and main activity
Source: Own Elaboration.

As can be seen, the highest concentration of sales are local, with the solar industry turning out to be a potential, as it would allow it to export its production to the US border states with Mexico.

The level of education of the employees of these companies is varied as presented in table 5.

Percentage of employees and level of education	What is the main activity of the Company			Total
	Production	Sales and / or trade	Service	
Without studies	0.6%	4.3%	0.1%	0.5%
Primary school	6.9%	14.5%	6.6%	7.1%
Secondary school	22.3%	24.8%	36.4%	31.9%
High school	24.9%	4.3%	17.2%	18.7%
Technical	24.4%	39.5%	24.7%	25.4%
Bachelor's degree completed	16.4%	12.6%	13.2%	14.0%
Postgraduate	4.4%	0.0%	1.7%	2.3%

Table 5 Percentage of employees according to level of education
Source: Own Elaboration

Being the highest concentration staff with baccalaureate and technical level, however, the level of undergraduate and graduate is present and concentrates a good percentage of employees in the production area.

The composition of its clients currently served is as follows (see table 6).

Customer relationship	What is the main activity of the Company			Total
	Production	Sales and / or trade	Service	
Percentage of National Clients	64.2	83.3	84.3	78.6
Percentage of Transnational Clients	35.8	16.7	15.7	21.4

Table 6 List of customers with company activity
Source: Own Elaboration

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Where it is seen that national clients are the ones that occupy the highest percentage of clients, this is due to the type of clients they currently manage, that if they turn to the solar industry, the composition will change since the largest consumer of solar technology is the United States, and the products and / or services that these companies can attend are the metalworking for fixed structures and solar tracking.

Among the products and services that companies registered as their main ones, a total of 70 was obtained, since not all companies already have on the market the results of the approved projects or because they still do not obtain profits and therefore do not consider them your main products / services.

Some of the products mentioned by the companies whose main activity is production are instrumentation, equipment installation, pre-cooling systems semifix and others. Likewise, the service companies had answers such as services to instruments and equipment, consulting services, preventive and corrective maintenance, among others.

Linking companies with the academy

Table 7 shows the companies that have had links with higher education institutions (HEIs) and / or Research Centers (CIs).

It shows how the Sonoran companies decide to have links with IES or CI outside of the state because there is no State of Sonora institution.

Name of the institution outside of Sonora with whom you have links	Main activity of the Company		Total
	Production	Services	
Center for Industrial Engineering and Development (CIDESI)	0	1	1
Advanced Materials Research Center (CIMAV)	0	2	2
Postgraduate School (COLPOS)	1	0	1
National Institute of Cardiology	0	3	3
National Institute of Astrophysics, Optics and Electronics (Inaoe)	1	0	1
National Institute of Nutrition	0	3	3
National Polytechnic Institute	2	1	3
Veracruz University Institute	0	3	3
University of Development (udd)	1	0	1
National Autonomous University of Mexico	1	0	1
La Mar University	1	0	1
Polytechnic University of Sinaloa	1	0	1
Total	8	13	21

Table 7 Linking IES or CI with companies
Source: Own Elaboration

The linkage activities that have been carried out for these companies are principally the development of services, which are provided by the different laboratories of the IES or CI (see Table 8).

Reason	Production	Services	Total
Technical Capabilities	0	7	7
Laboratory equipment	0	1	1
Product development	1	3	4
Project development	16	12	28
Thermal / Mechanical Engineering	0	1	1
Practitioners	5	2	7
I+D projects	10	1	11
Technological Transfer and Biotechnology	2	0	2
Bonding	2	0	2
Software development	1	0	1
Brand registration and patent initiation	1	0	1
Home	1	0	1

Table 8 Linkage activities by quantity and type of companies
Source: Own Elaboration

Other linking activities are shown in figure 3. The R & D projects and product development are the activities that are carried out most between the companies and the IES or CI.

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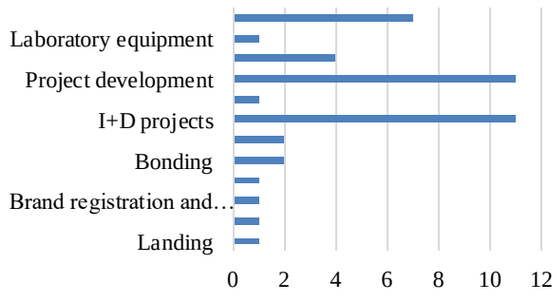

Graphic 3 Other bonding activities
Source: Own Elaboration

Methodology to be developed

With the previous characterization, what can be observed in the State of Sonora is a business ecosystem with important links with the academy, with strong capacities for the development of new products and with export capacities.

These companies have technically well-trained employees, and the lack of skills or competences solves them with the link with the IES and CI.

In this way, integrating into the productive chain of the solar industry, it is potentially a step that has to be taken, derived from the prospects for growth of the photovoltaic solar energy sector that, if not served by national companies, will be occupied by transnationals, as has happened in other industries.

With the reform of the energy law, the forms that limited the growth of the market have been modified, opening the possibility of being able to generate and market in an open market, although the transmission lines will be mostly from the Federal Electricity Commission (CFE) (see Figure 2).

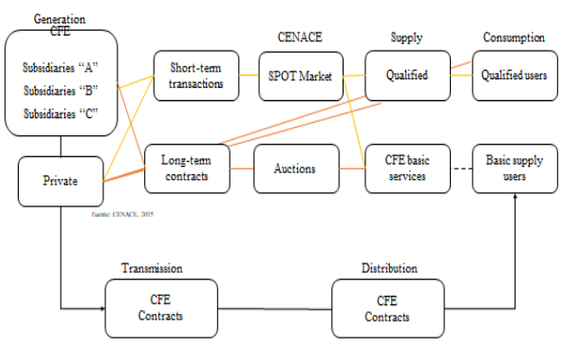

Figure 2 New model of the electric industry in Mexico
Source: CENACE, 2015

The LTE and the LIE -which are set as minimum goals for the participation of clean energy in the generation of electric power 25% for 2018, 30% for 2021 and 35% for 2024- are key instruments for the impulse of the generation of electricity from clean energies.

These country goals will make it possible to comply with the policy on the diversification of energy sources, energy security and the promotion of clean energy sources. (PROMEXICO, 2018).

In the year 2016 in Mexico permits for generation were granted as shown in table 9.

No.	Central	Federal entity	Scheme	Authorized capacity (MW)	Authorized energy (GWh)	Entry into operation
1	Autoabastecimiento renovable, S.A. de C.V.	Aguascalientes	Self-supply	0.8	1.8	2011
2	Coppel, S.A. de C.V.	Sinaloa	Self-supply	1.0	2.3	2014
3	Generadora Solar Apaseo, S.A.P.I. de C.V.	Guanajuato	Self-supply	1.0	2.1	2013
4	Plamex, S.A. de C.V.	Baja California	Self-supply	1.0	1.9	2014
5	Iusasol Base, S.A. de C.V.	Estado de México	Self-supply	0.9	1.9	2015
6	Iusasol 1, S.A. de C.V.	Estado de México	Self-supply	18.3	37.2	2016
7	Santa Rosalía (CFE)	Baja California Sur	Generation	1.0	2.0	
8	Cerro Prieto (CFE)	Baja California	Generation	5.0	11.0	2012
9	Servicios Comerciales de Energía S.A. de C.V. (Aura Solar)	Baja California Sur	PP	30.0	86.0	2012
10	Tai Durango Uno, S.A.P.I. de C,V,	Durango	PP	15.6	32.4	2013
11	Tai Durango Dos, S.A.P.I. de C,V,	Durango	PP	6.3	12.1	2016
12	Tai Durango Tres, S.A.P.I. de C,V,	Durango	PP	3.5	6.8	2016
13	Tai Durango Cuatro, S.A.P.I. de C,V,	Durango	PP	6.3	12.1	2016
14	Tai Durango Cinco, S.A.P.I. de C,V,	Durango	PP	30.0	57.9	2016
Total				**120.7**	**267.5**	

Table 9 Permits granted during the year 2016 in Mexico for power generation
Source: Energy Regulatory Commission

In Mexico, auctions have been carried out by SENER so that companies can generate energy and sell it to the CFE. The National Center for Energy Control (CENACE) shows the information of the energy auctions presented in table 10.

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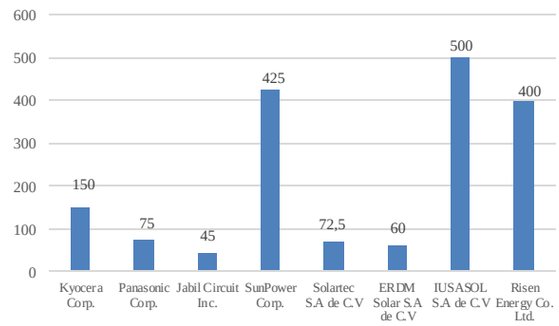
First Auction	Second auction
	- Acciona (180 MW)
	- Ienova (41 MW)
- Sunpower (100 MW)	- Zuma Energy (148 MW)
- Enel (787 MW)	- OPDE (112.17 MW)
- Recurrent (63 MW)	- Fisterra Energy (125 MW)
- Sunpower (500 MW)	- Gestamp Solar (X-Elio) (150 MW)
- Jinko (188 MW)	- ENGIE (126 MW)
- Alter Enersun (30 MW)	- Ienova & Trina Solar (100 MW)
	- Fotowatio Renewables (300 MW)
- Thermion (23 MW	- Hamwha Q-Cells (101.08 MW)
	- Alten Renewable Energy (290 MW)
	- EDF (90 MW)

Table 10 Information about energy auctions
Source: CENACE

The new installed capacity of photovoltaic solar energy will be concentrated mainly in seven states of the country: Coahuila, Aguascalientes, Yucatan, Sonora, San Luis Potosi and Chihuahua, which will cover, overall, 93% of the new capacity resulting from the first and second auctions (3,310 MW); the remaining 7% will be installed in the states of Jalisco, Morelos, Baja California and Baja California Sur (see Figure 3).

Figure 3 Location of projects to develop derived from energy auctions
Source: Solar Industry, 2018

In addition to the above, in Mexico there is an installed capacity of photovoltaic panel factories as shown in Figure 4.



Graphic 4 Installed capacity of photovoltaic panel manufacturing
Source: PROMÉXICO, 2018

Results

In this work we have shown in a general way the predicted energy production potential in Mexico, this denotes a growing market in the coming years.

This market demands inputs that must be provided by companies that are integrated into the value chain of the solar industry; In this sense, an analysis and characterization of companies from the north of Mexico, the state of Sonora was carried out, selecting a sample of those that can be users but also have the capacity to integrate into the value chain of the solar industry.

Added to this is the impact of public policies regarding energy generation, where Mexico has acquired an international commitment to produce a high percentage (30% to 35% by 2030) of the energy used in the country with renewable sources, giving a great opportunity to solar energy.

SENER has competed several auctions of energy production and in Mexico there are at least 18 projects to be installed that total 3,454.25 GW in the coming years, giving the opening of the market on a large scale.

Acknowledgement

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Conclusions

The analyzed companies have the capacity to develop the knowledge and skills to be able to diversify their turn and to attend quickly the business that the solar industry means.

Failure to do so will happen as in other industries, where transnational companies come to meet the needs, and Mexico would be only a consumer of foreign technology.

The projects of scientists and technological development that are being carried out by the IES and CI, give a great opportunity to generate technology and frontier knowledge to meet the needs of the solar industry.

The companies have taken confidence with the IES and CI, so that they have the conditions to generate this ecosystem of innovation and technological development, in order to generate social, environmental and economic benefits that take the Mexican solar industry to a position competitive, and that later is exporting technology to the world.

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