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

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Abstract. Mexico has a great opportunity for the use of renewable energy (RE of all types, including solar, geothermal, hydro, etc., because it is a country with diverse climate and sea life that has not been thoroughly explored. It is necessary to identify the most suitable options for promoting public policies and finding an absolute advantage. Given international theories, we can use the same basis for rethinking the development of the sector, using the country’s advantage in terms of natural resources and climate types as a guide. We also see that international experience shows that it is possible to establish markets’ “green energy” where end users cover their costs and create a highly profitable emerging market for both provider and consumer. There are existing government programs that support the same, a fact that makes investment from national and international firms tempting.

Keywords. energy, Mexico, development, lead, renewable

1. 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 rates in the world.

Mexico is no exception. Over the last decade, energy reform has 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 due to the volatility of prices and availability of fuels, environmental impact of the emission of greenhouse gases, and health effects.

It is for this reason that in Mexico, legislators and government have recently 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 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 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.
2. Objective

This paper analyzes the renewable energy industry, specifically solar and photovoltaic (PV) panels. While Mexico is a new industry and an emerging market, it is also a potentially growing market niche, making it a sector of business potential that 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 as well as 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?

3. 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 of systems isolated and connected to the network has shown fluctuating behavior in the period from 2005-2011 In cumulative terms, the increased capacity is 16.5 MWp to 32 MWp. Annual electricity generation increased from 23,235 MWh in the year 2005 to 44,974 MWh in 2010 (Figure 1).

![Figure 1: Evolution of Installed Capacity and Power Generation PV Systems in Mexico; Source: SENER 2012](image-url)
4. Description of Technology

In the middle of the 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 for the first time over 100 years ago. This phenomenon, called the "photovoltaic effect," 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 to the top of the semiconductor.

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

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

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 a series and/or parallel, mounted on a support structure. This is called a 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):

A special feature of PV is that electricity is delivered as a direct (or continuous) stream, so that the connection to the main electrical networks is still necessary to transform in alternating current, the form how the CFE delivers electricity in homes. It is for this reason that harnessing solar energy, in most cases, 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 to 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 will 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

Interconnected systems to the electricity network are mainly found 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
3) Interconnecting devices, protection and measurement, switches, protection system and bidirectional meter.

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 inverter. Rev. Optional for alternating current loads

C. PV Isolated System

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

5. Solar Energy Industry in Mexico

Mexico is among one of the five countries considered the most attractive in the world to invest in PV projector. It is still behind China and Singapore because it is part of the Sun Belt. These are countries with latitude + -35 with respect to the Equator and exhibit higher levels of solar and sunlight radiation on the planet. For Mexico, there are areas where there is a greater than 5kWh per m² radiation. The 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 two decades, and its competitive cost of PV technology also cover electrical networks and their ease of distribution, among other factors (Figure 6).

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 same project has 100MW of installed capacity now in its first stage and who estimates that this would have a total of 400MW in the five years after its initiation (Figure 7).

6. 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, it is still above countries such as Chile, Brazil, and Argentina. Abengoa, Abener, Del Sol Systems, Microm, Iberdrola, and Silken are among the leading developers of photovoltaic.

High Solar-Thermal Concentration

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

Figure 6: Daily Solar and Sunlight Radiation; Source: IIE

Figure 7: PV Centrals in México; Source: CFE
The table looks like it has grown the national energy sector since early 2000 to late 2013 and can be seen as the sector photovoltaic energy barely appeared in the outlook in mid-2012 producing only 0.01 of energy and being less than 1% of its development potential (Figure 9).

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. For this year there were 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, which generated a total income of 522,313,705 million. Given the figures, we also see that there are 27 companies that dominate this market, contributing to 77.07% of it (Table 1).

Figure 9: Gross Power Generation; Sources: SENER
Table 1
Companies by Number of Employees

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<tr>
<th>Strata</th>
<th>Total Economic units</th>
<th>Total Gross production</th>
<th>Intermediate consumption</th>
<th>Total expenses by consumption of B and S</th>
<th>Total investment</th>
<th>Gross census aggregate value</th>
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Source: INEGI Census 2009

Table 2
Concentration Indexes

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<th>Strata</th>
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</table>

Source: INEGI Census 2009
C. Concentration Index Segment

In the table below, the participation of companies in the renewable energies sector is shown. 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 77.07% of the market, leaving only one 22.93% for all other companies.

Nonetheless, economic theory says that the market tends to move from a monopoly to oligopoly due to the size of companies and the influence they have in the market competition (Table 2).

This market is relatively new and 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 lower. It is known that the solar energy market in Mexico accounts for millions of dollars, of which 30 belong to photovoltaic.

Because it is an emerging market that is relatively new, it 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.

7. Costs

Photovoltaic systems in network connections in Mexico differ in cost depending on its capacity. In late 2011, SENER and GTZ conducted a survey of stakeholders and actors in the country to determine these costs. For the residential sector, 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 to 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 lifespan. It is estimated that the initial investment is recovered in the medium term between three and six years after purchase.

8. Regulatory Frameworks for Renewable Energy

Currently, the following legal and regulatory instruments allow the use of solar PV grid connections.

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: 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 on September 2, 2009, including more specific areas for compensation of renewable energy projects.


On April 8, 2010, the Energy Regulatory Commission (CRE) published these model contracts in the Official Gazette and 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 generating electricity, such as on 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 ERMT) 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, May 22, 2012).

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

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.

9. Conclusions

In the present work, it has been observed how the renewable energy market has been growing considering the potential as an emerging market. Mexico is considered one of the most attractive countries to invest in this sector and is considered the fifth country in terms of countries with the highest potential for development. Also it is seen that the HHI for 2009 is .60, which tells that it is a monopolistic competition with a tendency to be an oligopoly. The profitability of the sector is abundant, generating profits of more than double the investment for businesses.

This being the case, 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, we also see the growing legislative restructuring encouraged to develop different ways for both the private sector and the public.
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