CHALLENGES, OPPORTUNITIES AND INNOVATION IN THE MEXICAN GEOTHERMAL SECTOR

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ABSTRACT

This paper describes the geothermal activity that Mexico has been experienced due to the recent changes in the Mexican Legislation, among them are the new developments as well as the projects in program. It discusses the issues arising from the Mexican energy reform, as well as the structural changes that go through CFE. A description of the several opportunities in the sector is made, as well as the challenges and the innovation to be made in the geothermal sector to fit and succeed in the New Mexican Electric Market.

1. INTRODUCTION.

Mexico has been a geothermal country by tradition, beginning its activities in the 1950s with the iconic Pathé field in the state of Hidalgo. Through the time, the Federal Electricity Commission (CFE) explored several geothermal zones, commissioning the Cerro Prieto geothermal field in the 1960s, and then, in the 1970s, 1980s and 1990s, the geothermal fields of Los Azufres, Michoacán; Los Humeros, Puebla and Las Tres Virgenes, Baja California were commissioned.

During 2014, the Mexican Energy Reform was published, with which the Mexican State intends to develop more energy in all the resources of the Mexican Republic, with which both the oil industry and the electricity industry changed profoundly. From this, important regulations such as the Geothermal Energy Law (LEG) and Electrical Industry Law (LIE), among others were published too. Before this reforms, the Mexican government, through CFE, was in charge of the exploration and the development of the geothermal industry, as well as the operation or the geothermal power units, positioning Mexico as one of the leading countries in the sector.

As the first achievements of the energy reforms, two 5-MWe back-pressure units commenced operation in the Domo San Pedro geothermal field in February-March 2015. These are the first (and only) geothermal power plants owned and operated by a private company (Grupo Dragón) in Mexico. These plants had been previously used and were refurbished by the field operator. In 2016, Grupo Dragón also commissioned a new 25.5 MWe (net) flash-type power plant to be installed in the same field.

In the Electric Industry Law, the mechanisms to operate the new Mexican electricity market are establishes, encouraging electric energy generated with clean energy sources which, as a complement to this, was published the Energy Transition Law (LTE) and in which it is remarked the commitment of the federal government to include in the generation matrix a 35% share of clean energy by 2024. Particularly in the electricity industry, the Electric Market went from being a purely operated system by the CFE to a new Wholesale Electricity Market, where The National Energy Control Center (CENACE) controls and dispatches the electricity Energy. In this new plan, is where the geothermal energy faces new challenges and opportunities to continue its development.

2. THE GEOTHERMAL ACTIVITY IN MEXICO

As mentioned, Mexico has been a pioneer country with an important geothermal development. This can be seen in Figure 1, which illustrates the evolution of installed geothermal capacity over time.

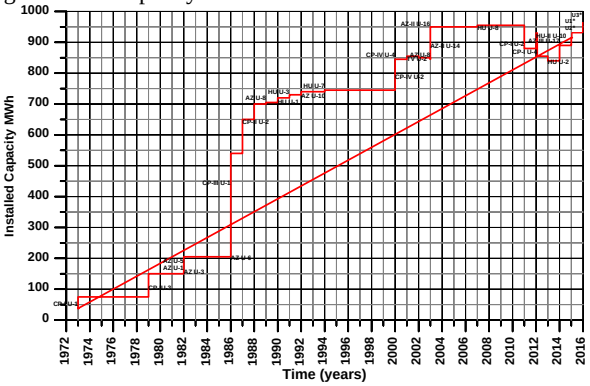

Figure 1: Figures the evolution of installed geothermal capacity in Mexico.

During 2015 there were 227 production wells and 34 injection wells, on average, in the five operating fields. These wells were distributed as follows:

- Cerro Prieto: 158 production and 23 injection,
- Los Azufres: 42 production and 6 injection,
- Los Humeros 22 production and 2 injection,
- Las TresVírgenes: 3 production and 2 injection, and
- Domo de San Pedro: 3 production and 2 injection.

Currently installed capacity in Mexico is distributed as follows in Figure 2.

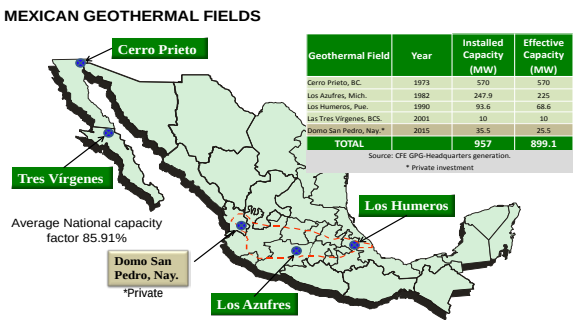

Figure 2: Installed geothermal capacity in Mexico.

As indicated in Figure 1, in 2012, 4 units installed in Cerro Prieto Geothermal Field, were decommissioned, reducing from 720 to 570 MW of installed capacity, partly because they reached their useful life and also due to the reduction of the steam availability.

In Los Azufres and Los Humeros, some of the backpressure units are out of operation (but not decommissioned yet), since they have been replaced by more efficient new condensing units: In the case of Los Azufres, those units are 4 x 5 MWe back-pressure and 2 x 1.5 MWe binary, and form Los Humeros those units refers to 5 x 5 MWe back-pressure. By October 2016 the geothermal-based installed capacity for electricity generation was 958MWe, and the running capacity was 899MWe. It is important to note that the total installed electric capacity in the country at December 2015 was 68,044 MWe and the electric generation for the 2015 year was 309,553 GWh.

In the international geothermal ranking, Mexico is located in the fifth placer worldwide.

Mexico has not stopped its geothermal activity, proof of this is that currently has two projects under construction, and multiple projects schedule in the PRODESEN government program , both private and public ones (see tables 1 and 2)

CFE Project	Los Humeros III Phase A CG CFE 02	Los Azufres II Phase II CG CFE 04
Capacity	25 MW	25 MW
Date of start up	oct-13	dic-15
Date of commercial operation	April-2017	jun-18
Location	Puebla	Michoacán

Table 1: CFE's projects under construction.

MEXICO´S Geothermal Projects (Source: PRODESEN 2016-2030)				
Project	**Capacity (MW)**	**Status**	**Operation**	**Located**
CG CFE 02	27	On construction	2016	PUE
CG CFE 03	2	Next to bidding	2017	BCS
CG CFE 04	27	On construction	2018	MICH
CG CFE 05	27	Next to bidding	2019	JAL
CG GCO 01	226	New project	2020	MEX
CG PP 02	1	New project	2020	PUE
CG CFE 09	27	New project	2020	BC
CG GCO 03	36	New project	2021	PUE
CG GCO 04	191	New project	2021	NAY
CG CFE 06	27	Next to bidding	2021	PUE
CG GCO 05	11	New project	2022	NAY
CG AUT 03	25	Next to construction	2022	JAL
CG PP 01	30	On construction	2022	NAY
CG CFE 07	27	New project	2023	JAL
CG GCO 06	27	New project	2023	NAY
CG GCO 07	15	New project	2024	JAL
CG GCO 08	1	New project	2024	NAY
CG AUT 01	25	Next to construction	2024	HGO
CG GCO 09	1	New project	2025	JAL
CG AUT 04	25	Next to construction	2025	JAL
CG GCO 10	44	New project	2026	JAL
CG GCO 11	11	New project	2026	JAL
CG CFE 08	27	New project	2027	JAL
CG GCO 12	36	New project	2027	JAL
TOTAL	**896**			

Table 2: PRODESEN Scheduled Mexican geothermal projects.

3. CHALLENGES FOR NEW GEOTHERMAL DEVELOPMENT IN MEXICO.

3.1 Competition

About 55.2% of the electricity produced in Mexico in 2015 was generated by the government-owned utility, Comisión Federal de Electricidad (CFE). 28.8% was generated by privately-owned companies that operate combined-cycle and wind power plants delivering their power to CFE, and the remaining 16% was produced by private operators as self-suppliers, co-generators, small-producers, exporters, and distributed generation or in rural systems isolated from the electric grid.

As part of the energy reform promoted by the federal government, CFE entered into a new market operation scheme. This implies that it will compete with private companies in both the generation and the commercialization of the electric energy, power and other ancillary services.

Specifically for geothermal, with the Mexican Energy Reform, the Geothermal Energy Law (LEG) was published and entered into force, then CFE is no longer the only company to develop geothermal energy in Mexico, that is, now many companies can potentially and actually are doing exploration and exploitation of the geothermal resources. This implies a new role for CFE, as the before utility

company, to solve, to compete, to reduce operation and development cost and to create more and better value in the new market conditions.

At present there are no special economic incentives for geothermal power generation in Mexico or an economic recognition for being base load above solar or wind energy. Power generation from geothermal energy is considered conventional in Mexico, and thus it competes on the same basis as fossil-fuel, conventional hydro and nuclear technologies. Therefore, it is fair to say that the main constraint for further geothermal development in this country is its market competition against modern fossil-fuel as well as against lower risk and investment intermittent clean generation technologies. So far, the only available instrument to incentive geothermal new projects is the market for Clean Energy Certificates (CEL), which applies only form renewable energy generation as define in the Electric Industry Law, hydro, geothermal, solar, wind, nuclear, biomass and cogeneration among others. We will discuss this later in more detail, but prices resulted in the first and second auction during this 2016 for clean energy resulted in a very competitive energy and CEL prices especially for new solar and wind projects, which also make more difficult that new geothermal projects can be developed under those market conditions.

3.2 New CFE business structure

CFE in under the most intensive and important restructure of its history. Bing a company that controlled the entire electric generation, transmission, distribution and marketing process, will become a productive company of the state with different subsidiaries and filial. On January 11, 2016, the Secretary of Energy (SENER) decreed the terms of the strict legal separation of CFE. Now CFE is made up of six subsidiary generation companies, one of transmission, one of distribution, one of basic supply, one of qualified supply, one of energy and international affairs and one of intermediation of legacy contracts. The new scheme of operation, after the legal separation of the CFE is shown in Figure 3.

As far as the dispatch is concerned, CENACE will be responsible for managing commercial transactions to meet the demand for power, energy and clean energy certificates in the National Electricity System (SEN), through the linking of the different electricity suppliers and generators.

The company is right now moving into the new organizations, so understanding the new organization and market context and moving as fast as possible with all this inertia is fundamental and mandatory to operate and succeed in the new conditions.

3.3 Wholesale Electrical Market (MEM)

A natural result of all the above changes is that CFE went from being the only company that controlled the electrical system, to one participant in the new electricity market. Figure 4 shows the operation of CFE before the energy reform, and Figure 5 shows the role of CFE in the new electricity market.

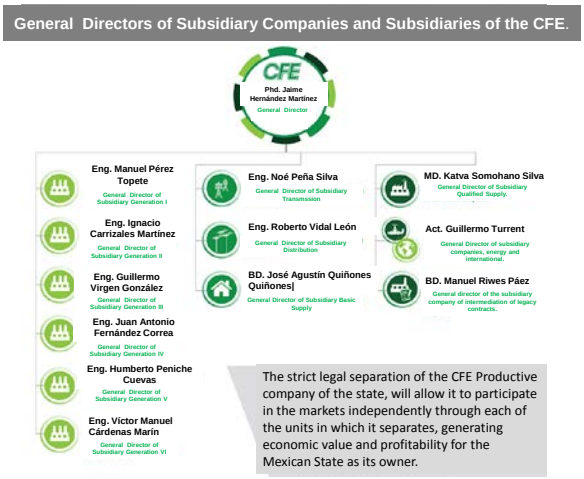

Figure 3: The new CFE's organization.

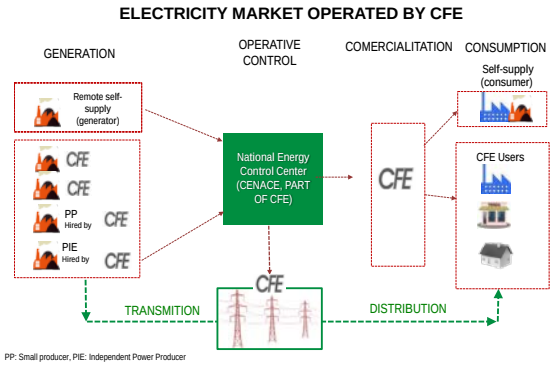

Figure 4: The CFE's operation, before Energy Reform.

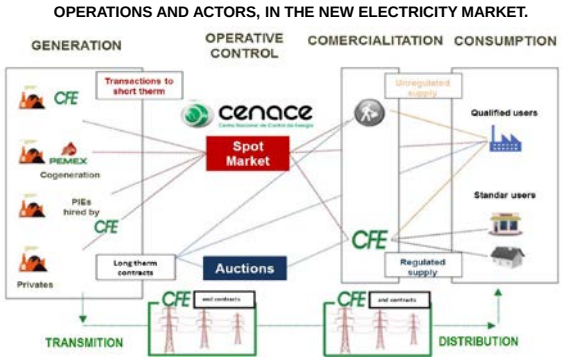

Figure 5: The CFE's operation, after Energy Reform.

The mechanisms to achieve these operations were established and will be regulated by SENER, through: the spot market (real time), the market of the day in advance and the long-term auctions, among others. The products to be marketed will be: power, cumulative electric energy and CELs, as well as ancillary services. A CEL is a title issued by the Energy Regulatory Commission (CRE) equivalent to a Megawatt-hour generated with clean energy power plants, such as geothermal, hydroelectric, nuclear, solar and wind, among others. These CELs serve to meet the requirements associated with the consumption of the consumption Centers. In Long Term Auctions, the duration of the contracts will be 15 years for generation and power and 20 years for CEL.

On January 29, 2016, the Wholesale Electricity Market (MEM) was launched, whose objective is to promote the

National Electric System (SEN) development in conditions of efficiency, quality, reliability, continuity, safety and sustainability.

Existing geothermal power stations will be able to participate in this new market scheme, as legacy power plants and some, where appropriate, under the legacy generation contract. For the exploration fields, the development of new geothermal projects under the Law of the Electrical Industry (LIE) will be allowed, ie they will participate in open competition within the electricity market.

Substantial changes in the new electricity market can be seen in the following conceptual map (figure 6).

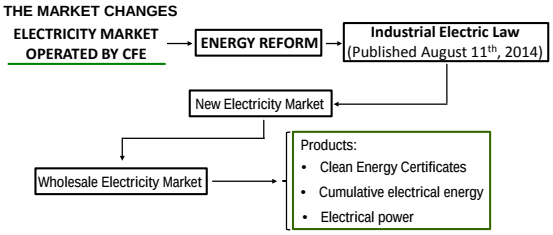

Figure 6: Substantial changes in the new electricity market.

3.4 Environmental and social aspects

For new projects in the electricity sector, the elaboration and management of the Social Impact Assessment is required, which is a challenge since this requires a cultural change in the public, private and community stakeholders. In this way the acceptance of the projects and the distribution of benefits and responsibilities are achieved.

The LIE states that when it is possible to affect the rights of an indigenous community, a prior, free and informed consultation must be carried out for the development of the project. In this way the acceptance of the development of the same will be achieved, thus avoiding social conflicts.

In environmental matters, Mexico has a broad regulatory framework that has been the result of an evolutionary process, reflected by international policies, which regulates the conditions under which the projects will be developed.

New commitment to the development of geothermal projects is to adhere to the environmental criteria established in the legislation, including the techniques or tools to design the best mitigation, prevention and / or restoration measures in project planning.

In addition, the companies will seek to ensure that its geothermal projects are compatible with environmental programs for the use, conservation and restoration of ecosystems and thus guarantee the environmental services they provide.

In conclusion, Mexico joins the global commitment to internalize environmental and social externalities in the planning and development of its geothermal power projects.

4. OPPORTUNITIES

4.1 Allocation of geothermal permits and concessions

In 2015, the Energy Secretary (SENER: Secretaría de Energía) awarded CFE five geothermal concessions and 13 geothermal permits, based in the 2014 Geothermal Energy Law. The geothermal concessions are for the four geothermal fields that CFE have been exploiting (Cerro Prieto, Los Azufres, Los Humeros and Las TresVírgenes) and a new field that it expects to develop in the near future (Cerritos Colorados, with a forecast minimum potential of 75 MW). The permits are for exploring 13 new geothermal zones within the next 3-6 years which have to some extent already been previously explored by CFE. These permits represent about 1,591 km² with a minimum estimated potential of 448 MWe.

In total, SENER has granted 18 exploration permits and 6 operating concessions, including the operating concession already mentioned first private investment geothermal field in the state of Nayarit, see figure 7.

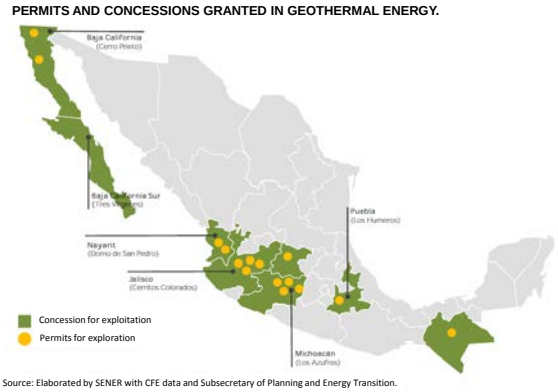

Figure 7: Permits and concessions granted by SENER.

The geological, geochemical and geophysical exploration campaigns to be carried out in the geothermal areas, from which CFE obtained exploration permits, must be carried out within three years of obtaining them, and may be extended up to three years, totaling a maximum of six years. All investment costs involved in the activities mentioned in the previous paragraph must be solved by CFE or shared with any partner with whom it intends to develop the projects. This has opened a huge opportunity for CFE to form joint-ventures or enter agreements with private national and/or foreign developers to explore these areas.

One of the objectives is to invest enough in exploration, so that the risks of this, either own or shared, are minimized at the time of the test drilling (ESMAP), see figure 8. After this, drilling for production purposes can be started to development of the necessary infrastructure for electricity generation.

Companies can be associated to develop new geothermal projects, even existing ones, with the aim of reducing costs, making its processes more efficient and developing the assigned areas.

4.2 Clean Energy Certificates

All of the above converges in an important point, any electric project that develops after the publication of the LIE, must be framed within this, and therefore compete in the new electric market. That is, in the case of geothermal energy that is clean, it must seek to sell its products: Power, Accumulable Electric Energy and Certificates of Clean Energy (CEL'S), in any of the available markets in MEM.

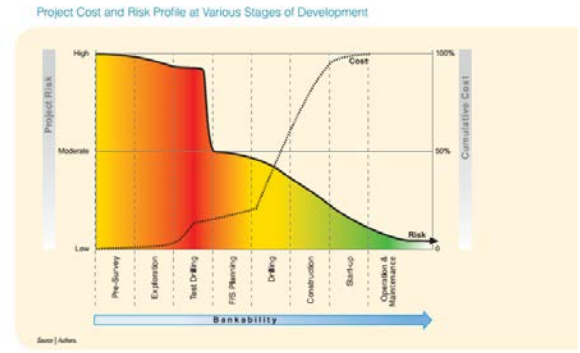

Figure 8: Cost and risk profile.

Geothermics can be framed within clean energies and therefore can participate in Long Term Auctions and bilateral contracts, in which it would sell its three products (Power, cumulative Electric Power and CEL's), directly to a basic or qualified supplier (MEM participant) or through a bilateral contract.

CFE participated in the long term actions that were announced by CENACE in 2015 and 2016. During the second one, CFE has participate with two plants, one of them geothermal: Central Los Azufres III of 25 MW, becoming the first geothermal power station to win this type of event in Mexico. This project was able to offer the three requested products for the Auction:

• Clean Energy Certificates

• Cumulative Electric Energy

• Electrical Power

Being one of the highest price in the auction, none of the other technologies could offer that trinomial, which places CFE at the energetic vanguard and able to participate in the new energy market of the country. It is corroborated that one of the reasons that makes a geothermal development strong, with respect to other resources is the:

• Plant availability (plant factor) greater than 90%.

• Complies with the power requirements within the critical hours of the National Electrical System (SEN).

Because of the above, it is considered a base load and has advantages over other sources like the sun and wind, since they are intermittent and handle maximum plant factors of 50%.

4.3 Research

In 2014 the federal government launched the Mexican Center for Innovation in Geothermal Energy (CeMIEGeo), which is led by the Center for Scientific Research and Higher Education in Ensenada B. C. (CICESE), with participation from academic institutions, and private and public (CFE) companies involved in geothermal energy in Mexico. CeMIEGeo has been developing 30 specific technical projects, a national system of specialized geothermal laboratories, and a program to promote education and the development of human resources. CeMIE-Geo uses federal funds allocated for each project and has budgeted funding up to 2018. After that the Center should be self-funding.

Most geothermal research activities in Mexico are focused on development and exploitation of resources for power generation.

In the other hand, European and Mexican researchers will work together on tapping into new sources of geothermal energy in the context of GEMex, an international project that was selected in a joint call launched by the European Union and Mexico. The EU and Mexico contribute equally to the €20 million project. The EU's share comes from Horizon 2020, its €77 billion research and innovation funding programme (2014 – 2020), and the other from Mexico's Fondo de Sustenibilidad Energética (SENER) - Consejo Nacional de Ciencia y Tecnología (CONACYT).

GEMex will develop innovative methods for accessing the earth's vast resources of heat now trapped in variable geological formations. The ultimate objective is to make this renewable energy source cost-effective and affordable both for electricity and heat production. The project will adhere to the strictest environmental standards and address issues around social acceptance of the technology.

The three-year project will start in the autumn of 2016. It is an example of successful international cooperation under the Bilateral Agreement for Science and Technology Cooperation EU-Mexico. The coordinated call was launched by Secretary Coldwell and Commissioner Moedas during his visit to Mexico in November 2015.

4.4 Insurance risk instrument

The Ministry of Energy of Mexico, Nacional Financiera (NAFIN) and the Inter- American Development Bank (IDB) supported the development of a risk mitigation program for private geothermal energy projects in the country, in which the company Munich RE was involved in the development of an insurance mechanism.

The risk mitigation and financing program will apply innovative geothermal financing schemes - such as guarantee and insurance mechanisms - to reduce the risks associated with the exploration of geothermal energy, one of the main obstacles to the development of this clean energy source in Mexico and in the rest of Latin America. The proposed geothermal secondary law in the context of the Mexican energy reform would further support the successful development of the program reducing the risk perception of investors and setting the rules for exploration and exploitation of this clean energy source more clearly.

As a result, the program is expected to generate 300 MW of clean energy in a period of six years and thereby reduce emissions of greenhouse gases in the country.

The financial scheme of the program is a revolving fund to ensure sustainability beyond the six-year project duration. In addition to insurance mechanisms in development, the project will include the possibility of granting guarantees and loans convertible into non-refundable financial support, depending on the different stages of project development.

The project is funded with $54.3 million from the Clean Technology Fund (CTF), $54.3 million of IDB resources, channeled through NAFIN, and $11.5 million of Mexico's Energy Secretariat (SENER).

5. INNOVATION

CFE must reinvent itself, looking for ways to reduce costs and risks. To do this, it must use its geothermal experience as well as its brotherhood countries in geothermal energy. The strategies that are being implemented are, among others, the following:

• Best practices in exploration and exploitation.

• Alliances with private companies and academic sector, for the development of own and private areas.

• Development of competencies for the provision of engineering services.

• Develop geothermal and solar fields as a unique project.

Technical and non-technical challenges are many, including difficulties in new exploration, social and environmental aspects, economic and legal issues. However, benchmarking can be carried out in other countries that have been able to develop geothermal in the legal and technological framework under which Mexico is located, as it is the case in New Zealand and other countries that have traveled the paths that now it is up to Mexico to transit

6. CONCLUSIONS

The actual installed capacity in Mexico is 957 MW, but with two geothermal plants under construction.

The new power stations of Domo San Pedro, Los Humeros III Phase A and the Los Azufres III Phase II, and the scheduled projects are going to contribute with clean energy in the electricity system and increasing the installed capacity.

The electricity market in Mexico has changed from CFE as a unique controller company to CFE as a participant among many participants (New Electricity Market).

Wholesale Electricity Market: In the second one auction, CFE participated with a geothermal power station of 25 MWe, becoming in the first power unit of this class which obtained this kind of contract in the country.

Due to the characteristics of geothermal power plants: clean, efficient and reliable, geothermal is competitive, but we must improve all processes.

New exploration projects are under progress, but creativity and innovation is needed to probe that geothermal can also be competitive against other clean energy sources.

With all the government support, showed by the Mexican innovation center and insurance risk instruments, it is expected that geothermal energy development will continue in 2016 and beyond.

ACKNOWLEDGEMENTS

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