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LESSONS LEARNED FROM GEOTHERMAL DEVELOPMENT IN EL SALVADOR

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ABSTRACT

Geothermal exploration in El Salvador started during the 50's with the technical and financial assistance from UNDP to carry out the exploratory work in areas with geothermal interest. Foreign assistance aimed to train geothermal scientists in El Salvador has contributed to a better prospective of energy scenario. The development of Ahuachapán and Berlin projects provided a training ground for exploration and reservoir management, considering the different situations such as political, oil crisis, economic and technical issues.

The inclusion of foreign investors to the electrical sector, establishing a partnership agreement, gave way to more geothermal exploration, development and electricity production to upgrade the geothermal technology and increase the participation to international and national electrical market.

1. INTRODUCTION

The abundant geothermal manifestations in El Salvador and the possibility of converting their energy potential into electricity have been known since 1953. Due to the limited knowledge and experience of technical people in El Salvador, it was necessary to ask for the help of different experts to evaluate the resource and design the Ahuachapan and Berlín Projects.

In the sixties, the wells drilled in both fields proved the existence of a reservoir with commercial interest. Because of the accelerated growth of demand for electric power and the need to develop natural resources and minimize the oil dependence in El Salvador, Comision Ejecutiva Hidroelectrica del Rio Lempa (CEL), the electric executing agency, decided to pursue the development of Ahuachapan geothermal field. During the 1980's, a civil conflict in El Salvador together with the financial crisis throughout Latin America discontinued all new power projects by CEL.

Geothermal development was reinitiated after the civil war ended in 1992. A small wellhead geothermal power plant (two 5-MW units) was installed in Berlín, confirming the potential of a 56-MW condensing facility, which was completed in 1999. Exploration and field management have been a very rich learning experience for El Salvador and have improved with time. This paper describes the lesson learned taking into account the different historical period of the geothermal resources development in El Salvador.

2. GEOTHERMAL BACKGROUND

Geothermal exploration started in El Salvador during the 50´s, as a support of the United Nations development programs to Central American countries, due to the need to develop natural resources and minimize the oil dependence. Actually, even if the electricity generation in the country is distributed with 20% by geothermal and 40 % by hydro, it is still highly oil dependent with 40%. Since the 50´s up to now, it still remains the same scenario. However, the oil crisis forced the underdeveloped counties to focus on developing renewable energy resources.

As a result, 18 areas were found attractive and five of them continued more investigation (Ahuachapan , Berlin, Chipilapa, Parras Lempa and Santa Rosa de Lima). Several wells were drilled in these areas. The drilling result of AH-1 well provided the decision to develop the Ahuachapan geothermal field before the Berlin and Chipilapa geothermal fields and other interesting areas.

Due to the need of more technical knowledge and experience of the people in El Salvador, it was necessary to hire different experts to evaluate the resource and design the Ahuachapan Project.

A size capacity power plant was installed to adequate the real reservoir capacity, even if the initial concept of the experts, at that time, was to start developing Ahuachapan with a conservative capacity of a small 25 MW unit. The Italian company ELC, contracted in 1972 by CEL, recommended from the initial operation to install two medium steam pressure units of 30 MW, and to take advantage of the chemical and thermodynamic characteristics of the brine. It also recommended the increase of the capacity of the power plant up to 95 MW, by adding a 35 MW double pressure unit.

The commissioning was completed with less steam flow to generate at full capacity, reaching only a maximum power of 80 MW. Because of the civil war, it was impossible to continue with the normal development of the project and to complete the drilling program for the production wells to supply the mass flow for the third unit. The power plant was forced to generate at maximum capacity, causing a decline in reservoir pressure. As a result of this, the production capacity of field was evaluated due to the over exploitation of a small reservoir area. The total reservoir area was estimated to about 6 km^2 and the exploited area was only about 1 km^2. However, during the crisis of energy demand, the priority of the government investment was focused on the rebuilding infrastructures after war by maintaining and rebuilding the national transmission grid and guarantying the electricity supply through the installation of thermal power plants.

The geothermal electricity generation includes an adequate management and disposal of the separation water. El Salvador is one of the pioneers in reinjection disposal of brine from the beginning of the exploitation of the field. However, due to the cooling effect caused by an incorrect reinjection site selection, reinjection was switched to a canal to transport the residual water to the sea. Subsequently, because of the new legal environmental framework, the disposal water is presently reinjected to the existing wells in Chipilapa area, obtaining a recharge benefit to the Ahuachapan geothermal field. From 1988 to 1992, as a result of two agreements between El Salvador and France, and between El Salvador and Mexico, two projects were carried out at same time: the Chipilapa accelerated development and the feasibility of Chipilapa projects. The objectives were to confirm the existence of resource and to put into service two back pressure units of 5 MW each. Geoscientific studies were carried out and two turbo generators were supplied, however, the projects did not achieve their objectives.

At the eastern part of El Salvador, several wells were drilled in the Berlín Geothermal Field during the 70´s, leading to the discovery of another important resource. Reservoir depth at Berlín is between 2,000 m and 2,300 m with an estimate reservoir temperature of 280º – 300ºC.

Geothermal development in Berlìn was also reinitiated after the civil war ended in 1992, with help from the governments of France and Belgium. At that time, a small wellhead geothermal power plant

(two 5- MW units) was installed at Berlín. Operation of these backpressure units confirmed the geothermal potential with the commissioning of a 56-MW (two 28-MW units) condensing facility, which was completed in 1999 with funding from the Interamerican Development Bank (IADB).

The third geothermal unit at Berlín is part of ENEL's obligations as defined in the capitalization process. ENEL is undertaking ongoing activities to confirm the extension of the field's geothermal resource beyond currently exploited areas.

In the case of Berlin geothermal field, the strategy of development was implemented in a different way in comparison with Ahuachapan and the geothermal resource management had different objectives, such as:

• To minimize the operation cost of the geothermal reservoir
• To maximize the energy extraction from the resource
• To ensure the security of continuous energy delivery
• To minimize the environmental effects
• To avoid operational difficulties like scaling and corrosion

Some of the management options, which were applied in the Berlin geothermal resource management, were:

- Production strategy using Back Pressure Units (to get knowledge on the behaviour of the field at early exploitation stage (increased/reduced production))
- Application of injection and monitoring changes in injection strategy
- Make-up program through acidification and work-over programs and drilling of additional wells
- Changes in well-completion programs (casings etc.)
- Implementation of reinjection pumping station
- Search for new production areas or drilling targets
- Feasibility studies to use the separated water and the installation of a new 10 MWe Binary Plant Unit

3. LESSON LEARNED

3.1 Exploration

In the geothermal industry, as in many other businesses, experience is essential. Experience improved the exploration and development process of Ahuachapan and Berlin geothermal projects as well as their results.

Geothermal exploration in El Salvador started during the 50´s with technical and financial assistance from UNDP and with foreign assistance of expertise using some specific techniques. 18 areas were identified with possible potential for electric power generation.

Almost all techniques used in oil and mineral prospecting (geochemical, geological and geophysical methods) were applied with any limitations to construct a reliable conceptual model of the geothermal system under exploration. During the 60´s, some methods were used like geothermometry, structural geology and geophysical (schlumberger sounding and gravity) survey. During the 90´s, the Isotope techniques, Chemical modeling software, Dipole-Dipole, Head On, Misse la Masse, Seismic monitoring and Magnetotelluric (MT) methods was incorporated, improving the quality of the data and producing a more representative conceptual model of Ahuachapán and Berlín fields.

Because geothermal resources are complex natural systems, it was crucial to conduct a training of local personnel and to have a coordinated and integrated specialist team to elaborate a final integrated conceptual model.

At the beginning, the personnel did not have the expertise to carry out the exploration research studies. However, working together with foreign experts and participating in local and international training were very useful. The gained experience on exploration, utilization and assessment of geothermal resources was implemented using local human resources in new geothermal areas under exploration.

New techniques on surface exploration combined with those conventional have helped improve the results in identifying and discovering new fields and extending the existing fields. All of these provided betterment in the construction of conceptual models.

The present challenge of LaGeo is to develop a geothermal field and produce using the estimated power capacity from the result of the conceptual model, with success.

3.2 Drilling

During the beginning of the geothermal drilling exploration in El Salvador, it was usual to drill just one well in one platform like in Ahuachapan field. However, many separation stations and water and steam pipelines carrying the geothermal fluids to the power plants were constructed. Nowadays, in the new Berlin project, because of the land acquisition difficulties and steep terrain, the wellhead location was optimized, sharing a platform with several wellhead drilling deviated wells, and using just one separation plant for the wells in the same platform. Also, due to the lack of drilling water supply, a new technique using a combination of air, foam and mud was implemented. The network pipeline system was also improved and one pipeline to transport steam from these wells to the power plant and one water pipeline to the reinjection area, eliminating the spaghetti design like those in Ahuachapan and reducing the environmental impact in the fields and to the neighbors.

3.3 Reinjection

Even though El Salvador is one of the pioneers in the reinjection disposal brine from the beginning of the exploitation of the field, a cooling effect was observed because of an incorrect reinjection site selection. This forced to switch to a canal to transport the water to the sea, however due to the new legal environmental framework, the disposal water is presently reinjected to the existing wells in Chipilapa area, obtaining a recharge benefit to the Ahuachapan geothermal field,

The project in Berlin geothermal field was carried out assuming a zero surface discharge, which brought the design and implementation of a total reinjection water disposal during the construction and during the operation.

3.4 Reservoir Management

Field management has been a very valuable learning experience along the operation period. Firstly, the initial 95 MW estimated power capacity of Ahuachapan geothermal field and the decision to install three condensing units were appropriate. The idea to utilize the second flash steam to increase the power capacity allowed generating an additional 14 MW.

The training of personnel and the utilization of special software to implement numerical model in predicting future behavior of the geothermal system was useful for the strategy of field management.

3.5 Plant Construction

The general philosophy to decide on the acquisition of backpressure units in Berlin geothermal field was to procure a rapid utilization of the available steam from existing producing wells, to get a knowledge on the behavior at early stage of exploitation, generating low cost electricity and to obtain revenues for the years that the successful exploratory wells have to wait for a condensing power plant. Because of the low efficiency of this type of equipment, almost half of the condensing units, and the idea of an optimum exploitation of the geothermal resources, it is necessary to install with maximum efficiency like condensing units such as the unit already installed in both geothermal fields in El Salvador under exploitation.

On the other hand, to take advantage of the remaining energy from separated water, feasibility studies to use the separated water and the installation of a new 9.2 MWe Binary Plant Unit is now under construction.

3.6 Power Plant Operation

Taking into account the experiences during the execution of the Ahuachapan geothermal project, like developing a project without completing the project stages, i.e. not drilling sufficient wells to supply the mass flow to the third unit and not drilling the make up wells, at present, there is now a program to replace the geothermal mass reduction, a combination of acid injection and work over activities and drilling of new wells.

Increase in number of wells to optimize the exploitation of the reservoir was undertaken to generate the maximum power at the optimum mass extraction.

3.7 Environmental Impacts

Geothermal energy is a clean energy resource, discharging less gas emissions, including greenhouse gases, than the equivalent fossil-fueled generation.

Environmental monitoring and management program were implemented since the start of the geothermal exploitation with international agreements between Guatemala and El Salvador and regulations imposed by the IDB bank. During the construction of the Berlin first development project, the IDB bank required, as a part of the loan obligations, LaGeo to comply with IDB and El Salvador environmental law regulation framework. In 1998, the environmental law and regulatory framework were established in El Salvador with LaGeo complying and meeting all established procedures since its implementation.

From 1999 to 2002 a optional program was implemented, called "**SGA"** (Environmental management system), in order to control all the environmental parameters in the operation of the geothermal system like wells and gases discharge, noise control and mitigation, waste water and solid disposal methods, air, soil and water quality monitoring program, and operational risk evaluation.

In 2002, the achievement of the environmental award inspired LaGeo to continue working with the environmental management of the geothermal projects.

3.8 Social Responsibility

Working together with industries, municipalities, communities and landowners to develop geothermal resources are within the company's social policy, which has contributed to a mutual understanding among entities with social benefit projects mainly to the community within the vicinity of the geothermal field. Some of the community projects carried out in Berlin and Ahuachapan were: Temporary local employment, Productive domestic projects (Agriculture, fishing farm, fruit dehydration, irrigation using condensate geothermal water), improvement of infrastructure (Roads,

bridges, clinics and schools), Scholarships, English and informatics training to the neighbor communities.

3.9 Political Decisions over Technical Decisions

The normal development of geothermal projects in El Salvador was affected by the political problems during 1980-1992, which forced the overexploitation of the Ahuachapán field. During this crisis of energy demand, the priority of the government investment was focused on rebuilding infrastructure by maintaining and reconstructing the national transmission grid and guarantying the electricity supply by installing thermal power plants.

This socio-political civil conflict seriously decelerated the development of the geothermal sector. All investment in geothermal projects were suspended and the development of the Berlin geothermal field was in stand-by for more than 10 years.

The high risk in the preliminary stages of the geothermal development, the long period of investment return and installation time forced the government to provide facilities for the thermal power plant investors.

After the end of the civil war in 1992, financing for geothermal projects, particularly from multilateral organizations, was readily available. In 1994, the Inter American Development Bank (IDB) and the Overseas Economic Cooperation Fund (OECF) of Japan financed over 80% of the $332 million Electric Power Sector Program. The plan included the construction of the 56MW geothermal power plant at Berlín as well as the stabilization and rehabilitation of the Ahuachapán power plant.

3.10 Private Sector (Investor's participation)

The inclusion of foreign investors to the electrical sector, establishing a partnership agreement with the Italian company Enel Green Power gave way to more geothermal exploration, development and electricity production (Berlin new production-reinjection wells and 3rd Unit) and upgrade the geothermal technology and increase the participation into international and national electrical market.

4. A NATIONAL POLICY

The government plays a key role in providing incentives to the full development of geothermal energy in El Salvador. However, some barriers have been found:

- The marketplace needs to support the continued development of geothermal resources.
- There is a need of a law to give incentive to the renewable resources not only for less than 20 MW producers. State tax credits are important to reduce the risk and high capital cost of new projects. Other conceptions are necessary with respect to environmental aspects, insurance conditions, and future power prices, if not fixed under Power Purchase Agreements (PPA).
- VAT on production real state (land, wells, etc) is not deducible from sales.
- State laws and regulations should provide incentives for utilities and others to enter into long-term contracts for renewable power. At present, there are no long term contracts available. There is no dispatch priority to geothermal generators when system requires reduction of supply.
- Exploration risk cost is not deducible from taxes.
- Municipal taxes are not uniform.
- Lengthy procedures to give concessions to new geothermal fields. Geothermal projects should be prioritized and should not have complicated mechanisms on the agreement with the national environmental policy, in a timely and efficient manner.

- Government ministries and other electricity agencies should regulate the resources and requirements.

5. CONCLUSIONS

To conclude, the following should be emphasized:

The oil price crisis and dry season phenomenon pushed the government to reduce the dependence on fossil fuels and focus on other renewable energy sources. However, the oil crisis will always exist and because of this, it is important to continue searching and developing renewable alternative sources of electricity production.

Since 1950, services from foreign expertise were necessary to help design the exploration and development program of geothermal areas in El Salvador. In the 90´s, experts from International Development Bank (IDB) formed the Consultative Panel to evaluate the project plans for Ahuachapán and Berlin Geothermal fields and to recommend strategies to handle the geothermal resources. Due to local and international extensive training of LaGeo personnel, the dependence on foreign specialist was reduced. At present, the company has its own local expertise in different geothermal aspects.

The feasibility studies of Ahuachapan geothermal field provided an extent of the field potential and the power plant design. A 95 MW power plant was installed to adequate real reservoir capacity. However, the installation was completed without enough steam flow to generate at full capacity.

An important element of geothermal resource management involves controlling energy extraction from a geothermal system so as to avoid over-exploitation of the underlying resource. When geothermal systems are over-exploited, production has to be reduced drastically.

Environmental aspects should be inherent to geothermal projects and it is an obligatory component for the normal operation of the geothermal power plants. This has permitted to put CO2 emission bonds in the international market.

Ahuachapán became the training ground for many Salvadorean professionals and technicians in different aspects of geothermal project development. From the reinjection experience, it is important to take into consideration the selection of best sites, cost of drilling and operation of the wells, as compared with other methods of disposal and operational aspects.

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