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AN UPDATE ON THE GEOTHERMAL DEVELOPMENT IN EL SALVADOR

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ABSTRACT

The exploration of geothermal resources in El Salvador began in the mid-60's with the aid of the United Nations. The geothermal reconnaissance in the country provided 18 areas classified as low- and high-enthalpy areas. Technical studies were focused more on power generation.

The geothermal energy production in El Salvador dates back to 1975, with the first 30 MW unit in Ahuachapán. Today, there are two geothermal fields in operation: Ahuachapán and Berlín with an installed capacity of 95 MW and 109 MW, respectively. Geothermal power production has increased from 400 GWh in 1995 to 1293 GWh in 2007. The geothermal resources provide 25% of the electricity needs of the country.

1. INTRODUCTION

The main use of geothermal energy in El Salvador is power generation. Although there is some potential for direct use to dry grains and fruit, none is of significant economic value. Geothermal electrical power, on the other hand, has competed successfully in the local and regional markets for the last few years, and in fact, its use has increased from 400 GWh in 1995 to 1293 GWh in 2007.

The geothermal energy production in El Salvador dates back to 1975, when the operation of the first 30 MW unit in Ahuachapán field started. At present, there are two geothermal fields that have operating power plants: Ahuachapán and Berlín, both owned and operated by LaGeo, a spinoff privatized company of the government electric utility (CEL) and now jointly owned by both CEL and Enel Green Power of Italy.

The installed capacity is 95 MW in the Ahuachapán double-flash power plant, and in the 109 MW Berlín single-flash facility with bottoming cycle. In addition, two other fields (San Vicente and Chinameca) have been awarded in concession to San Vicente 7, a subsidiary of LaGeo, and exploration work is under way. Recent drilling results for San Vicente cast doubt on the economic viability of a power generation project.

Since 1996, El Salvador has adopted new electricity legislation aimed to open the market and introduce competition, so now prices for kWh are set by forces of supply and demand, rather than by executive decree. Several new organizations have been created to control and regulate the power market, which is becoming a very strong and has a dynamic role in the national economy.

2. ELECTRICITY MARKET

The Salvadorean electricity market was liberalized in 1998. Distribution was sold to foreign investors, as well as the thermal generation. The system operation was separated from CEL and given to a private entity, now known as Unidad de Transacciones S.A. de C.V. (UT), whose shares are owned by a group of market participants. The transmission company was also spun off from CEL, as was the geothermal generation.

Installed Capacity	**1,334**	**MW**
Maximum monthly demand	**892**	**MW**
Price MRS	**142**	**US$/MWh**

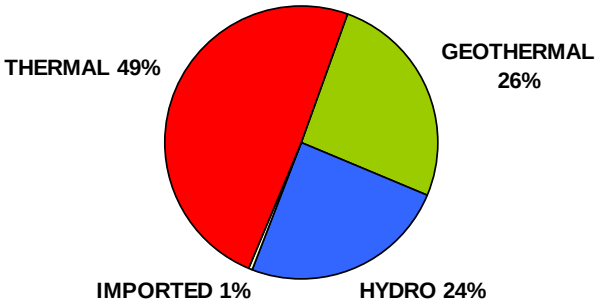

FIGURE 1: Energy supply mix in El Salvador

The wholesale market has two components: the contracts market (MC), and the system regulating market (MRS) or spot market. To participate in any phase of the MC, valid contracts are necessary, while in the spot market it is not. Charges for use of the transmission system are determined by the UT based upon the costs of investment, operation and maintenance associated with each component of the system. Dispatch is based on bid price, not variable cost, as in most other Central American countries.

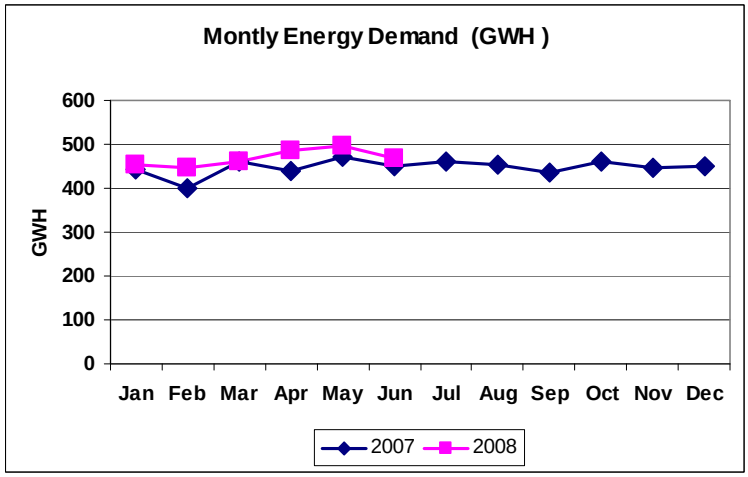

FIGURE 2: Monthly energy demand in El Salvador

The total installed capacity of electricity in El Salvador is 1,334 MW, with a maximum available capacity of 892 MW (variable). For the first semester of 2008, the generated energy was 2,811 GWh, with 720 GWh (26%) coming from geothermal power plants, 1,392 GWh (49%) produced from thermal plants, 679 GWh (24%) from hydro and the rest from imported energy. This total power generation addresses the energy demand growth rate of 5%/year. Figure 1 shows the energy supply mix and Figure 2 the monthly energy demand. The energy price in the MRS or spot market is US$ 142.00 per MWh, the price behaviour for the year 2007 and 2008 is shown in Figure 3.

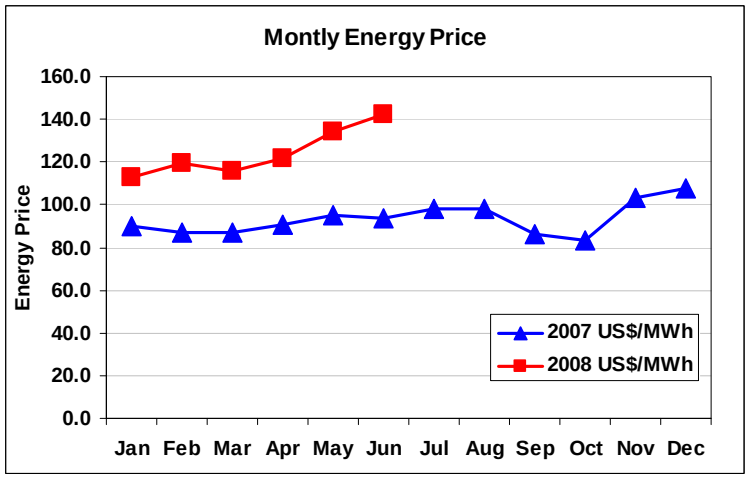

FIGURE 3: Energy price in the spot market

In 1998, the Telecommunications and General Electricity Superintendence (SIGET) became the regulator for power generation, transmission, distribution and electrical energy trading, which included provisions for public, private, and mixed sectors. Operation of any project to generate electricity is required to be registered in SIGET. The process for environmental compliance is according to

Agreement No. 39, which contains the document categorization activities or projects within the environmental law. This agreement was published in Official Journal No. 83, Vol. 375, on May 9, 2007. Project categorization will bring a more expeditious way for geothermal developers. On December 2007, the Decree 462 for the fiscal incentive law for renewable energy was approved. On July, 2008, three projects from LaGeo were qualified by SIGET for tax exemption according to this decree.

3. GEOTHERMAL DEVELOPMENT

3.1 Background

The exploration of geothermal resources in El Salvador began in the mid-60's with the aid of the United Nations. The geothermal reconnaissance of the country provided 18 areas classified as low- and high-enthalpy areas.

Figure 4 shows the geothermal areas in El Salvador. Five of these areas were investigated: Ahuachapán (exploratory well AH-1 1200 m deep), Chipilapa (exploratory well CH-1 900 m deep), Parras Lempa (exploratory well PL-1 940 m deep), Berlín (exploratory well TR-1 1450 m deep) and Santa Rosa de Lima in the eastern part of El Salvador.

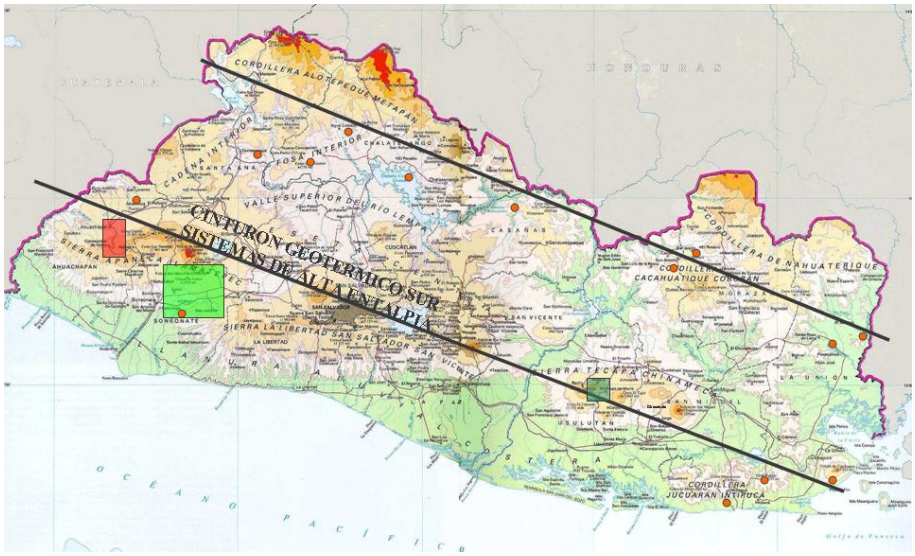

FIGURE 4: Geothermal areas in El Salvador

Temperatures found during the deep exploration were: a) 230°C in Ahuachapán, b) 300°C in Berlín and c) several resources below 200°C, all along the volcanic chain. Depths range from 800 m in the shallow areas of Ahuachapán to about 2800 m in Berlín.

The geothermal energy production in El Salvador dates back to 1975, when the operation of the first 30 MW unit in Ahuachapán field started. At present, there are two geothermal fields that have operating power plants: Ahuachapán and Berlín, both owned and operated by LaGeo. The second geothermal field, Berlín, started production in 1992 with two back-pressure units of 5 MW each. In 1999, the condensing units 1 and 2 were commissioned. Figure 5 shows the two back-pressure units in operation. At present, the total

FIGURE 5: Back-pressure units in Berlín

FIGURE 6: Ahuachapán power plant

FIGURE 7: Berlín power plant

installed capacity is 95 MW in Ahuachapán double-flash power plant, and 109 MW in Berlín single-flash facility with one binary cycle unit. Figures 6 and 7 show the power plants of the two fields.

3.2 Performance of the 1995 - 2008 programme

3.2.1 Goals and strategies

The primary goals of LaGeo for the period 1995 to 2008 were focused on financial performance, market share, human resources, social acceptability, investigation and research of other renewable sources of energy. The base line for the programme was a market share of 12% and the annual energy production of 400 GWh. Strategies to the timely implementation of projects and capital investment from the business cash flow and from external source on funds were pursued. CEL selected a strategic partner (ENEL) for LaGeo to invest in geothermal development. The geothermal power production increased from 400 GWh in 1995 to 1,293 GWh in 2007 and the market share from 12% to 25%. Figures 8 and 9 show the energy production and market share of LaGeo.

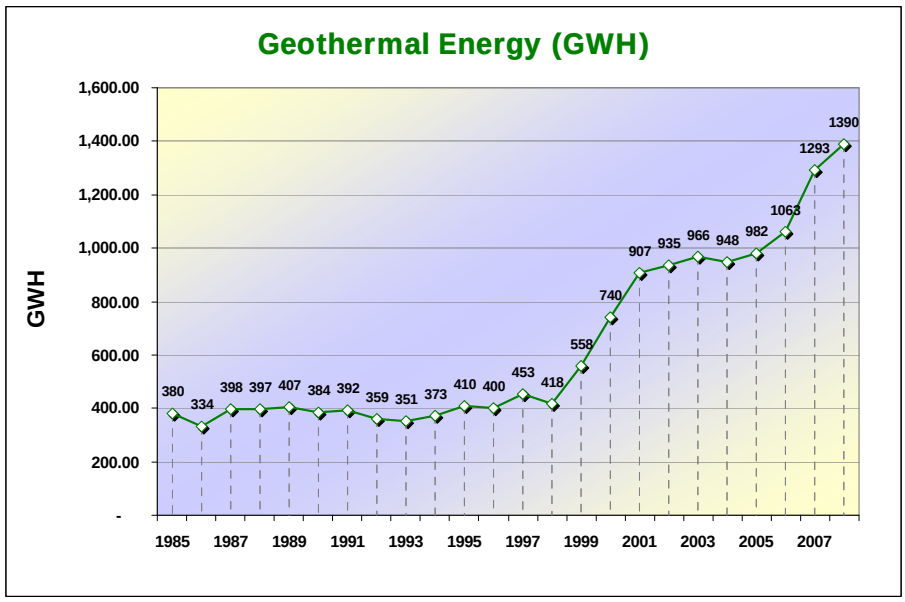

FIGURE 8: Energy production from geothermal

3.2.2 A "strategic partner" selected for geothermal

LaGeo, S.A. de C.V. (formerly called Geotérmica Salvadoreña) was separated from the government electric utility company, CEL, in November 1999, and received the geothermal assets in Ahuachapán and Berlín in ownership. However, LaGeo's shares were still 100% owned by CEL at this time. In 2001, a process began to select a strategic partner for LaGeo that would invest in geothermal (wells, investigation, power plants) then capitalize the assets in exchange for new shares. In June 2002, Enel

Green Power, a subsidiary of Enel S.p.A. of Italy, signed on as LaGeo's new strategic partner. Enel's obligations are to develop two projects: Berlín third condensing unit and Cuyanausul geothermal area.

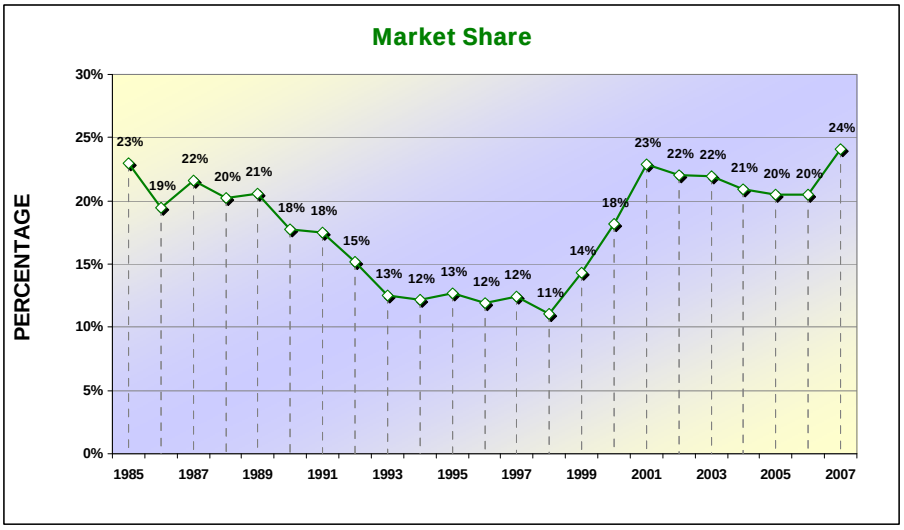

FIGURE 9: Market share of geothermal energy

The process followed what has been called "capitalization with risk", where the strategic partner evaluates the resource, drills wells, constructs a power plant and then transfers ownership to LaGeo in exchange for a new emission of shares. The amount of shares received for the new assets is not a function of the dollar amount invested, but rather a function of the effective power contributed (within certain quality standards), and hence the development risk is on the side of the strategic partner, who is thus given incentives to be efficient.

3.2.3 Implemented projects

Ahuachapán geothermal field

There are three condensing units installed in Ahuachapán: two 30 MW single-flash units, and one 35 MW double-flash unit. The ex-ante conditions in the operation of Ahuachapán power plant before the execution of the projects were: a) maximum instant power production of 45 MW, b) one single-flash unit running with the double-flash unit and c) the separated water from the field being dumped into the sea via a 71 km long canal. Table 1 shows the main projects executed in Ahuachapán.

TABLE 1: Main projects implemented in Ahuachapán

Item	Project	Program	Target	Period	Power Plant Status after the project
1	Stabilization Ahuachapán	Addition of 20 MW	20 MW	1995 -1999	65 MW
		Reinjection of the Brine	50% Brine		50% Reinjection & 50% to tha ocean
2	Total re-injectión Ahuachapán	Reinjection 500 l/s Brine	560 l/s	2002-2004	100% Brine reinjection
3	Optimization Ahuachapán	Addition of 25 MW	20 MW	2003-2008	Production 85 MW Reinjection capacity 650 l/s
4					

The ex-post conditions in the operation of Ahuachapán power plant after the execution of the projects were: a) maximum instant power production of 85 MW, b) two single-flash units runing with the double-flash unit, and c) the separated water from the field totally injected into the Chipilapa area.

In August 2004, the canal to the sea was destroyed and two 6 km long pipelines built to Chipilapa and reinjection of the brine started by a pumping station. Figure 10 shows the gross power production of

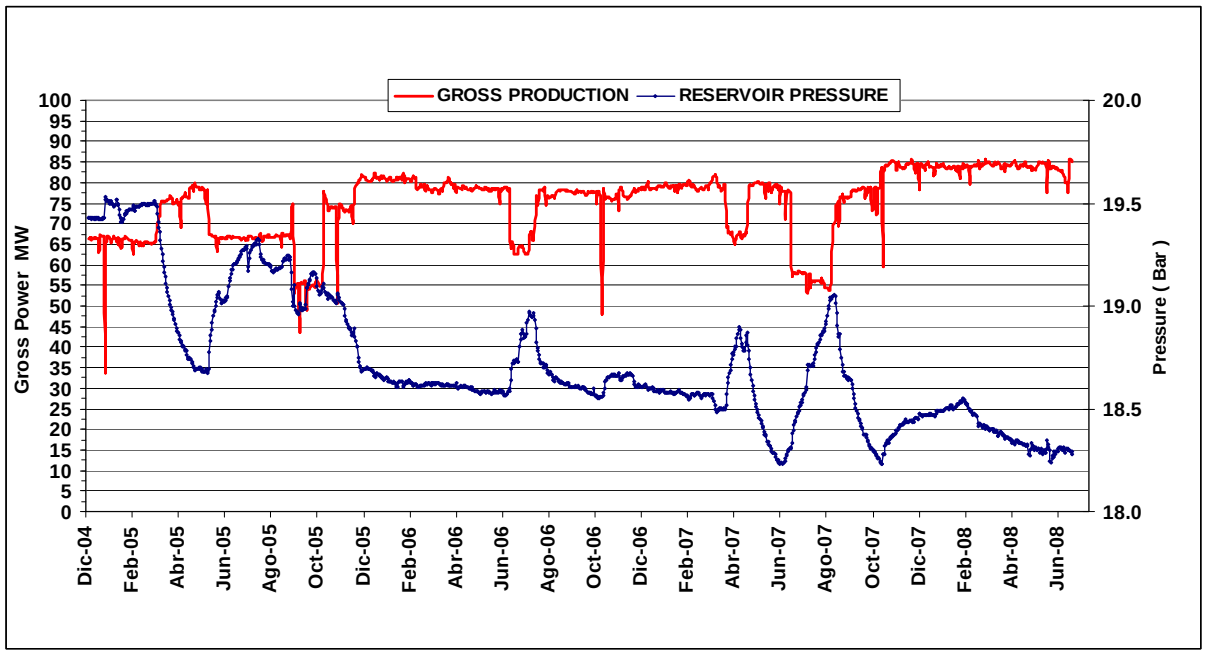

FIGURE 10: Gross production of Ahuachapán

Ahuachapán, Figure 11 the pump station system and Figure 12 the decommissioning of the canal to the sea.

FIGURE 11: Pumping station for brine injection in Ahuachapán

Berlín geothermal field

There are three condensing units installed in Berlín: two 28 MW single-flash units and one 44 MW single-flash unit, and one 9.2 MW binary unit. The ex-ante conditions in the operation of the Berlín power plant before the execution of the projects were: a) maximum instant power production of 9 MW, b) two back-pressure units, and c) the separated water from the field being reinjected to the northern part of the field. Table 2 shows the main projects executed in Berlín.

FIGURE 12: Decommissioning of the canal to the sea in August 2004

The ex-post conditions in the operation of Berlín power plant after the execution of the projects were: a) maximum instant power production of 100 MW and b) reinjection of the brine to the northern and eastern parts of the field. Figures 13 and 14 show the binary plant and the pumping station in TR-1 pad.

TABLE 2: Main projects implemented in Berlín

Item	Project	Program	Target	Period	Power Plant Status after the project
1	Firts Condensing Units	Addition of 56 MW	56 MW	1995 -1999	56 MW
		Reinjection of the Brine	100% Reinjection		100% Reinjection
2	Third Condensing Unit	Addition of 44 MW	44 MW	2002 -2007	44 MW
		Reinjection of the Brine	100% Reinjection		100% Reinjection
3	Binary Unit	Addition of 9.2 MW	9.2 MW	2005-2008	9.2 MW
4	Total re-injectión Berlín	Reinjection 220 l/s Brine	220 l/s	2005-2008	Injection a high pressure and temperature

FIGURE 13: Binary plant in Berlín

FIGURE 14: Pumping station in wellpad TR-1

4. OTHER AREAS OF DEVELOPMENT

Besides the increase of power generation by means of geothermal, LaGeo has developed other technical areas such as:

- *Drilling:* implementation of directional drilling;
- *Reservoir management:* conceptual and numerical modelling of the fields, acid stimulation in production and re-injection wells, real time monitoring of the fields;
- *Environmental:* implementation of environmental management system, winner of environmental award 2002;
- *Clean development mechanism***:** two projects certified for carbon credits;
- *Social:* fishing farm, English and computer education, medical campaign, greenhouses, improvement of infrastructure, roads, bridges, clinics and schools; and,
- *Research of other energy sources:* thermosolar, biofuels, modelling of the energy from the sea, hydrogen production.

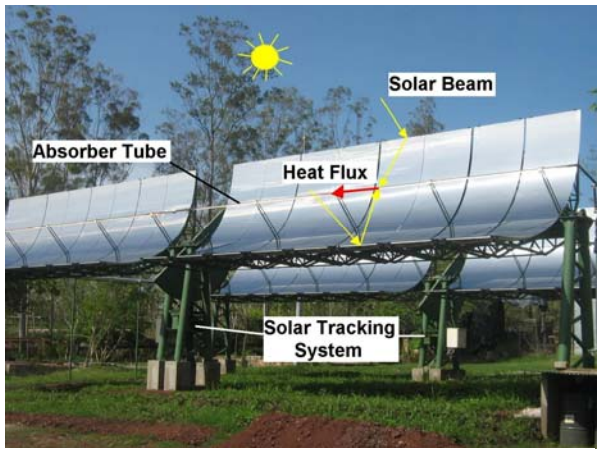

FIGURE 15: Solar Collectors of the pilot project in Ahuachapán

Figure 15 shows the pilot solar system installed in Ahuachapán.

5. FUTURE PROJECTS

For 2009 – 2013, the projects that LaGeo will work on are: 28 MW unit 5 for Berlín, 5-9 MW, re-powering of unit 2 of Ahuachapán, 50 MW Chinameca development, 5–9 MW binary plant for Berlín and feasibility studies for low-enthalpy areas.

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