Geothermal El Salvador

By José Antonio Rodríguez and Ada Herrera - Geotérmica Salvadoreña, S.A. de C.V.

El Salvador is located in the heart of Central America, bordered by Guatemala and Honduras. The climate is tropical, with a rainy season (May to October) and a dry season (November to April). The terrain consists mostly of mountains, with a central plateau and narrow coastal belt. The country extends over an area of 21,040 km^2 (Fig. 1), with a population of about 6.3 million.

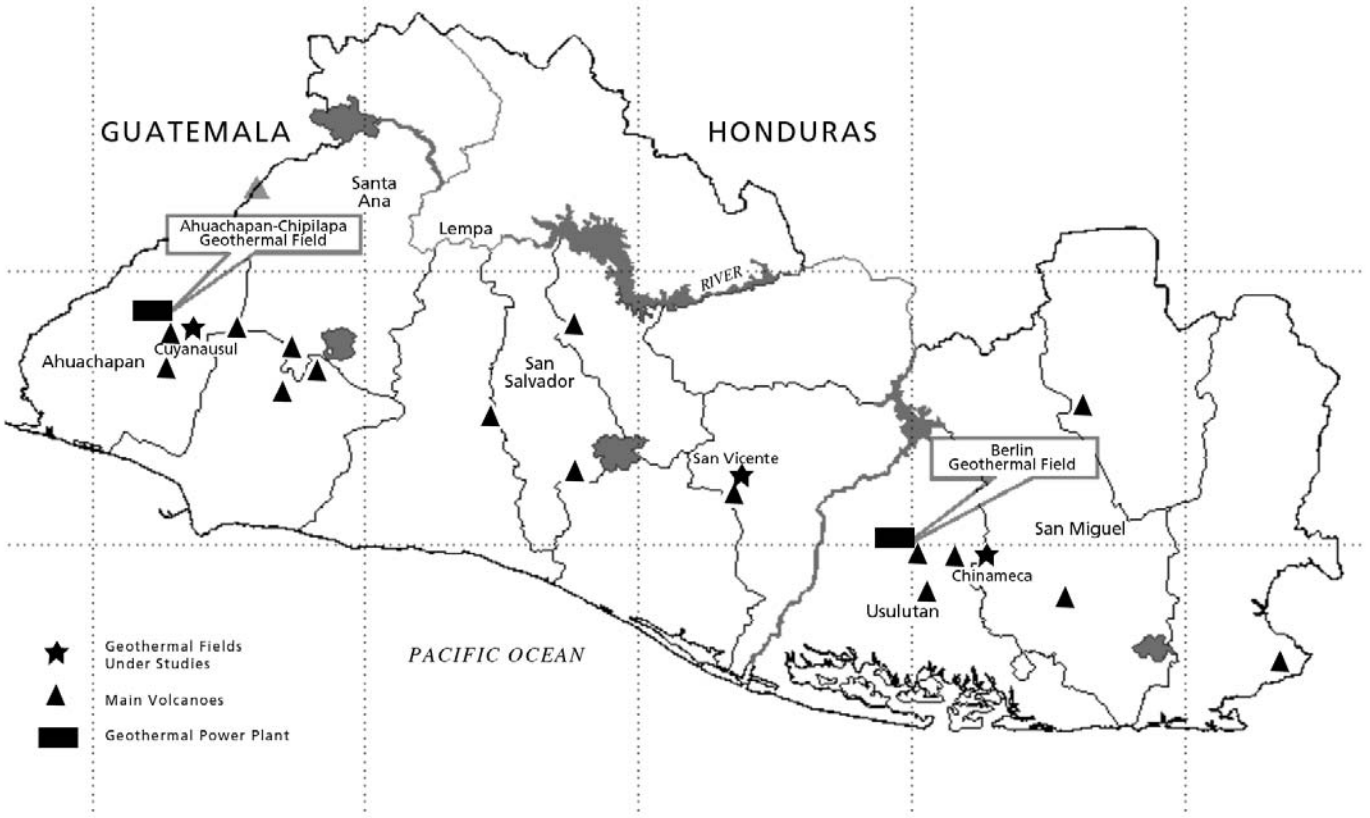
Geothermal energy is a plentiful resource in El Salvador, accounting for over 24 percent of the country's electricity output. In 2002, power generation from the Ahuachapán and Berlín geothermal facilities was 940 gigawatt-hours (GWh). This power was delivered to a newly deregulated, competitive market, mixed with 1,140 GWh of electricity from hydro projects, 1,805 GWh of electricity from thermoelectric operations, and 430 GWh of power imports from Guatemala (3,175 GWh total). Geothermal energy already claims a very high market share, which is projected to increase in the next few years as new projects come online (Fig. 2).

Of the 161 MW of geothermal capacity currently installed in El Salvador (95 MW at Ahuachapán, and 66 MW at Berlín), only about 119 MW are available (63 MW at Ahuachapán, and 56 MW at Berlín). Geotérmica Salvadoreña (GESAL) estimates that it can increase effective capacity in the next three years by about 50 MW with the addition of one new 28-MW condensing unit at Berlín; reinstallation of the 10-MW wellhead power plant from Berlín to the Cuyanausul Geothermal Field; and a 12-MW upgrade of Ahuachapán installations. GESAL is also exploring possibilities to expand operations at other Central American geothermal fields.

Electricity Market Reform

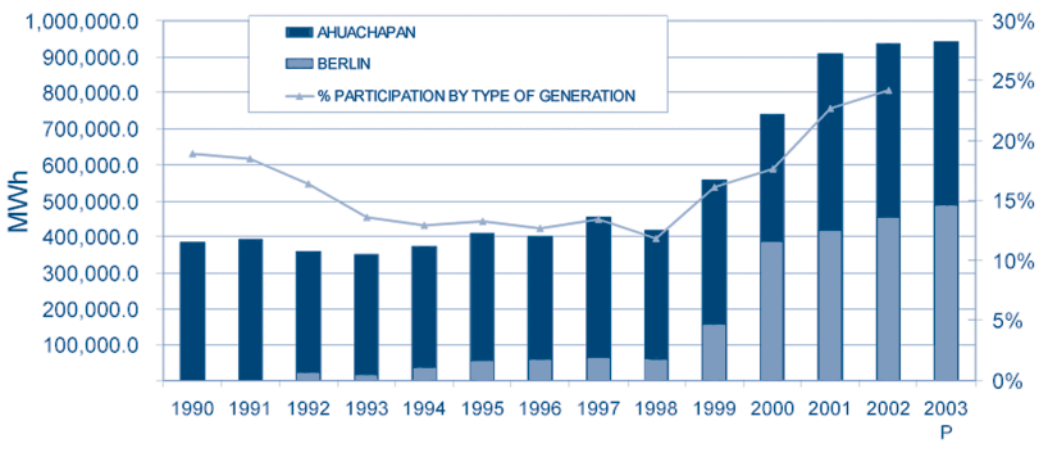
El Salvador passed electricity reform legislation in 1996, creating a free and open

Figure 1. General map of El Salvador and location of geothermal resources.

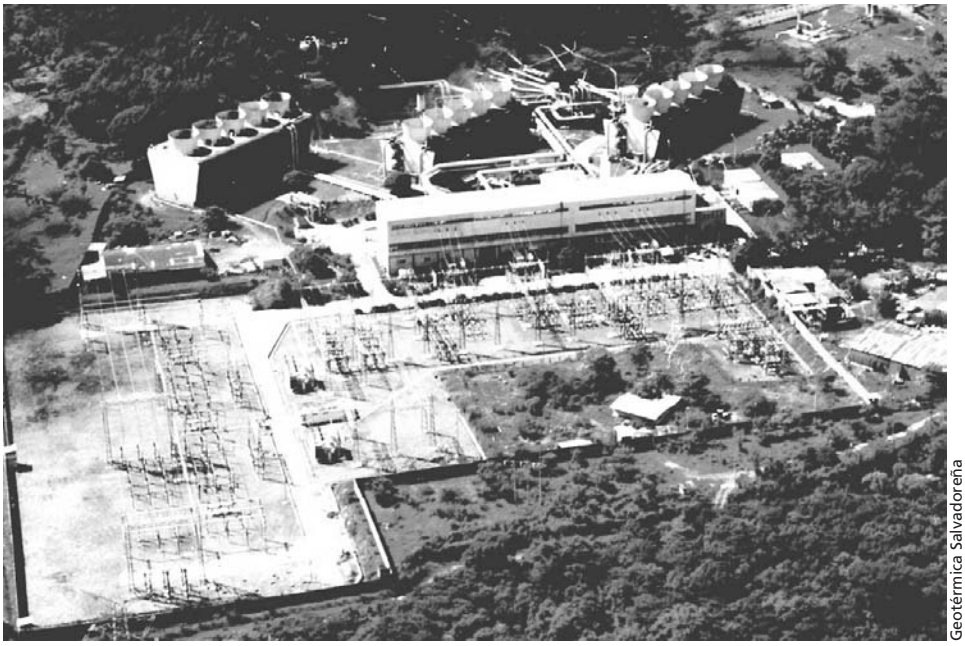


power market. A regulatory agency (SIGET) was created to oversee the market, and the country's state-owned electricity company, CEL, was split into several distribution, transmission and generation companies, some of which were sold to private foreign investors. CEL now directly controls only hydropower. Geothermal generation assets were spun off from CEL in 1999 into GESAL, which now competes in the open market against CEL, private generators and importers (all private power agreements have since ended). The annual, average spot market price for power generated in El Salvador, after transmission losses and other charges, is about $55 per megawatt-hour.

Figure 2. Geothermal generation and market share.



To strengthen GESAL's position in the market and spur new geothermal developments, a search for a strategic partner was carried out in 2001-2002. The process was defined as an "earn-in," with new project shares issued to the partner in exchange for capitalization of new power generation assets. In April 2002, the process brought in fresh private equity from ENEL GreenPower SpA (ENEL – Pisa, Italy), which has extensive knowledge of geothermal resource development. ENEL promised to explore and develop feasible geothermal resources at two pre-defined projects, which includes installation of a third condensing unit at Berlín, and wellhead generation development at the Cuyanausul Geothermal Field, east of Ahuachapán.



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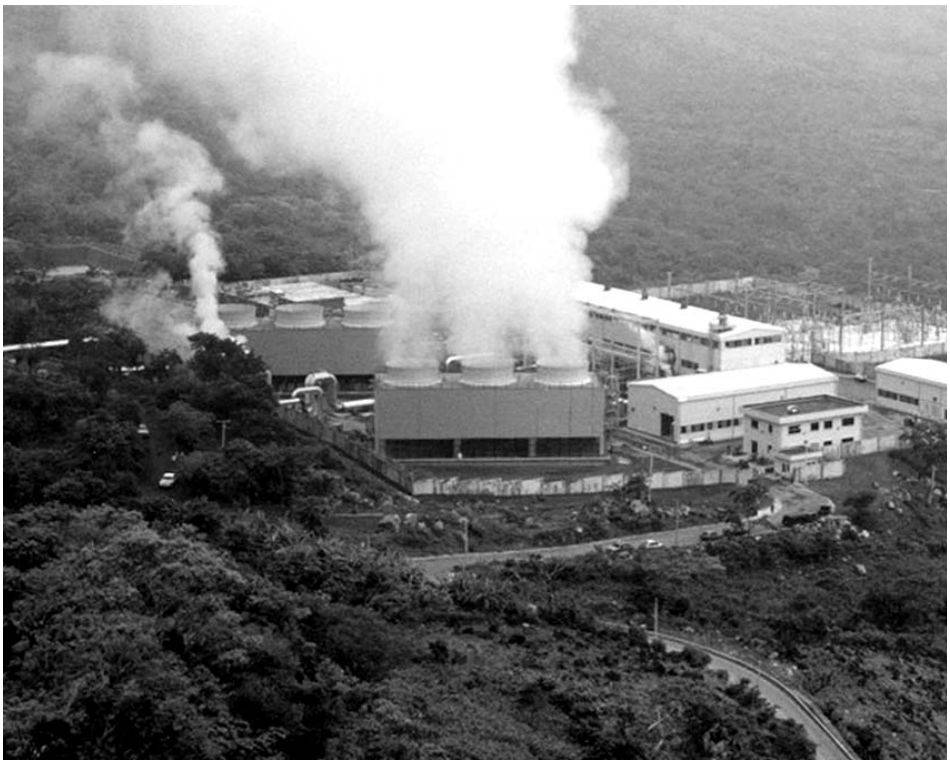
Aerial view of Ahuachapán power plant in western El Salvador.

Ahuachapán Geothermal Project

After early geothermal exploration efforts in the mid-1960s, Well AH-1 was drilled in 1968 in Ahuachapán, in the western part of El Salvador. It confirmed the existence of a water-dominant reservoir that could be commercially exploited for power generation. The reservoir's depth is between 600 m and 1500 m, and wells at the field operate at around 6 bar-g WHP, with total mass flow rates ranging from 30 to 100 kg/s.

Further exploration and aid from the United Nations started the Ahuachapán Geothermal Project in 1972, with funding from the World Bank. The field's 30-megawatt (MW) Unit 1 was commissioned in 1975, Unit 2 (30 MW) in 1976, and Unit 3 (35 MW, double-flash) started up in 1981. When the third generating unit came on line, Ahuachapán supplied 41 percent of El Salvador's electricity, a figure that to this day stands as a record. Unfortunately, a sharp drop in reservoir pressure demanded that generation be scaled back from its maximum capacity.

An upgrade at Ahuachapán will inject 100 percent of separated fluids (currently about 70% are injected and the rest are channeled to the ocean); improve the gathering system to reduce pressure losses; modify turbogenerators in the existing power plant to improve efficiency; and install a fully computerized operating system. Some project components are already installed, and the expected result is to produce an additional 12 MW (in stages) from the Ahuachapán resource. The goal is to modernize the power plant while ensuring long-term production sustainability.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Aerial view of Berlín power plant in eastern El Salvador.

Berlín Geothermal Project

In the eastern reaches of El Salvador, several wells were drilled in the Berlín Geothermal Field in the 1970s, leading to the discovery of another important resource. Reservoir depth at Berlín is between 2,000 m and 2,300 m, and wells typically operate at approximately 10 barg WHP with total mass flow rates ranging from 50 to 100 kg/s.

During the 1980s, civil conflict in El Salvador combined with the "Lost Decade" financial crisis throughout Latin America essentially stopped all new power projects by CEL. Geothermal development was 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 potential of building 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 performing ongoing work to confirm the extension of the field's geothermal resource beyond currently exploited areas, including: 1) integration of all geoscientific and well data in the field; 2) development of an updated numerical reservoir model; and 3) drilling of "step out" wells to the southeast and southwest of existing wells. Once this work is completed and the extent of the resource is confirmed, a new, third condensing power unit will be installed at Berlín to optimise sustainable use of the geothermal resource.

Preliminary estimates indicate that a 28-MW unit at Berlín is feasible, but even larger expansion is possible. Additional wells will be drilled, and a gathering system for steam and separated brine will be installed. In concert with current field operations, all separated brines and condensate from the new unit must be injected back to the reservoir to comply with environmental regulations. On July 16, *El Diario de Hoy* reported that ENEL and GESAL will drill 10 new wells at the Berlín geothermal project. Work started on July 5, and is expected to be completed by early 2004. If successful, the news wells will supply steam to ENEL's third power unit at the geothermal field (Marcelo Lippmann, Lawrence Berkeley National Laboratory - Berkeley, CA).

An interesting research and development project is also being carried out at Berlín by Shell International, which will hydraulically stimulate a hot, tight well (TR-8A) to create an extensive network of fractures occupying a volume of 0.1–1.0 km^3 at a depth of 2,000 m. The goal is to enhance the amount of recoverable energy from an "engineered" reservoir. This newly developed reservoir could then be used to produce energy by circulating water through the fracture network to additional production wells.

Advantages of performing the Shell project at the Berlín Geothermal Project instead of a new, "greenfield" area include: 1) a dry, hot well is available to accept the water necessary to fracture the rock; 2) separated water from current operations is available; 3) existing power generation installations can utilize any additional produced steam; 4) an on-site seismic network has already been extended, and can provide historical data for calibration and monitoring of the hydraulic fracture process; and 5) a wealth of subsurface data from the project planning phase is available. If the project is successful in producing electricity for commercial use, this industrial "proof of concept" by GESAL and Shell may allow extensive use of "Hot Dry Rock" (HDR), and/or Enhanced Geothermal System (EGS) methods at other sites to produce geothermal electricity with small power plants.

GESAL has successfully worked to improve permeability of the geothermal resource at Berlín by chemical stimulation. Stimulations are done with a mixture of HCl and HF, injected at the mouth of the formation through a 3" drill pipe. Injection wells have seen improvements in permeability ranging from 30 to 300 percent, and production wells have increased production by as much as fourfold. These chemical stimulations have substantially reduced the overall cost of geothermal development, and positively impacted the competitiveness of geothermal electricity in the Salvadorean power market.

Cuyanausul and Other New Geothermal Projects

Another important energy project for El Salvador is development of the Cuyanausul Geothermal Field, about 8 km east of Ahuachapán. Geothermal potential at Cuyanausul was detected by regional geoscientific studies (geology, MT and geochemistry) for the Ahuachapán field and the Chipilapa area now used for injection. There is a prominent 1 ohm-m anomaly associated with a graben that may indicate the existence of a geothermal reservoir with an area of about 2 km^2.

Geothermometer temperatures from fumaroles in the area indicate the existence of a resource with temperatures above 250 ° C. Exploration of the Cuyanausul area is another of ENEL's commitments to obtain shares in GESAL. The exploration project will consist of developing a geoscientific model of the field and drilling two exploratory wells. If the wells intersect a commercially exploitable reservoir, then two of GESAL's 5-MW wellhead units will be installed, and other wells will be drilled to begin power production at Cuyanausul.

In May 2001, SIGET awarded concessions at the San Vicente and Chinameca geothermal fields to Orpower 7, a subsidiary of ORMAT International, Inc. (Sparks, NV). The concession agreement specifies development of a 50-MW geothermal power plant in each field.

Central America Power Transmission Interconnection

In September 2002, El Salvador interconnected with Honduras via a 230-kilovolt (kV) transmission line, the final link establishing a Central America grid. Power is now traded from Panama to Guatemala in the Regional Electricity Market (MER). This open power marketplace provides new opportunities for geothermal energy, as well as competition from other sources. The capacity to trade power is still fairly weak, but will be strengthened by the new 230-kV SIEPAC Transmission Line stretching from Guatemala to Panama, scheduled for completion by 2006. As this additional transmission capacity is placed in operation, larger, regional hydro and thermal generation projects with improved economies of scale will be possible. The result will be a more competitive power market for all of Central America, and the benefits of lower priced power for El Salvador and all of the region's electricity consumers. ■