Proceedings 24th New Zealand Geothermal Workshop 2002

CHILE: PROSPECTS, MARKET, AND REGULATION IN THE GEOTHERMAL INDUSTRY

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SUMMARY - The Chilean government enacted a Geothermal Law in January 2000, establishing a framework to acquire geothermal exploration and development concessions. The state-owned oil company, the Empresa Nacional del Petroleo (ENAP), working with both public and private partners, has initiated an aggressive exploration effort, conducting geologic and geophysical surveys in key prospects directed at different markets in the north and south. Three exploration wells of 2000m to 2500m will be drilled in late **2002** and early 2003. At the same time, a combination of market conditions, a healthy national economy, limited fuel alternatives, and strong government support have made geothermal development in Chile a viable energy choice for the long term. Geothermal has recently received additional support from the adoption of the Clean Development Mechanism under the Kyoto Protocol.

1. INTRODUCTION

Chile has all of the components for a successful, dynamic geothermal industry (Salgado & Raasch **2002):**

- numerous attractive exploration opportunities
- well-defined geothermal legislation
- a growing electric market driven by an expanding economy.
- a renewed national interest in fuel diversity and fuel security; and
- growing awareness of the global effects of CO_2 emissions.

Under the leadership of President Ricardo Lagos, Chile continues to maintain its enviable position as the regional leader in economic reform. With the lowest country risk in Latin America and a Standard and Poor's rating of A-, Chile is poised for continued economic growth. To avoid energy shortages in the coming decade, Chile's growing energy market will require new sources of electricity. Geothermal energy is an ideal solution as the country contains over **10%** of the world's active land volcanoes and there are numerous attractive prospects associated with more than **300** thermal and mineral springs (Hauser, **1997).**

Geothermal exploration activity has increased rapidly since 2000, when the Geothermal Law was enacted. This law permits the exploration and development of geothermal resources, and provides open access to the electricity market. Driven by continuing economic growth and the need for energy security and fuel diversity, there has been a renewed interest by the Government to encourage the development of this national resource. In response, ENAP and its partners have recently accelerated geothermal exploration programs directed at the mining market in northern Chile and the more general power market in southern Chile. At the same time, ENAP is now developing relationships with potential investment partners and marketing to promote a vibrant geothermal energy industry in Chile.

2. EXPLORATION UPDATE

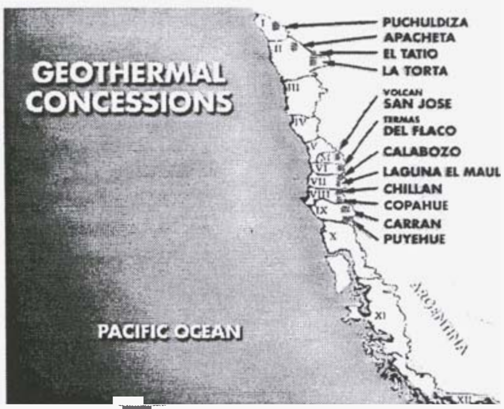

Figure 1. Map of Chile showing prospects with concession applications. Seven concessions have been granted.

Geothermal exploration began in Chile over **80** years ago. In **1921,** an Italian group began exploring at El Tatio. Since that time, exploration drilling has been conducted at El Tatio, Puchuldiza and Chillán (Raasch 2001). Over the last two decades, Chevron, Freeport, Unocal, ENAP and CFG have studied these and other prospective areas, including Copahue, Calabozos and San Jose de Maipo. ENAP has recently re-evaluated these and other prospects using state-of-the-art technology to identify the most attractive opportunities for exploration drilling in the next few years.

2.1 Apacheta

The Apacheta geothermal prospect is located in northern Chile approximately 120 km northeast of Calama and 60 km north of El Tatio. The prospect is located on an eroded volcanic complex that is within a prominent graben structure defined by two high-angle faults. While exploring for fresh water, Codelco (the national copper company) discovered a low pressure flow of dry steam in well PA-1 to a depth of 180m (Figure 2). Two vigorous superheated fumaroles with gas geochemistry compatible with an economic geothermal system were identified at Cerro Apacheta (Urzua et al., 2002). The 88°C shallow weak steam well and the 109" - 118°C fumaroles are the only geothermal surface manifestations found in the area. Gas geothermometers have shown that these fumaroles have estimated temperatures of 250°C to 325°C (Urzua et al., 2002). An geophysical survey consisting of 45 MT-TDEM stations was completed in December 2001. The results of the survey indicated a continuous zone of low-resistivity hydrothermal clay alteration underlying the volcanic complex; this clay cap coincides with the western part of Cerro Apacheta near the fumaroles and encompasses an area of at least.10 km^2 (Urzua et al., 2002). Geotermica del Norte S.A. (GDN), a joint venture between ENAP and Codelco, has signed a contract with Parker Drilling Co. to drill a deep exploration well up to 2000m in the first quarter of 2003 to prove the existence of a commercial geothermal resource.

2.2 La Torta - El Tatio

La Torta prospect is located near the Bolivian border 10 km southeast-of El Tatio, the best known geothermal field in northern Chile. The La Torta Geothermal Concession was awarded to GDN in 2002. Under the auspices of the United Nations Development Program, six slimholes (ET1 to ET6) were drilled at El Tatio to depths of 600 to 750m between 1969 and 1971. Seven

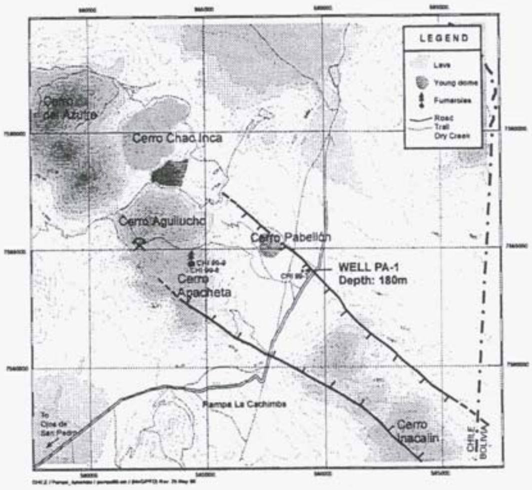

Figure 2. Apacheta Prospect location map.

production wells (ET7 to ET13) were then drilled in the vicinity of ET3 to depths of 870 to 1,820m. Three of these wells (ET7, ET10 and ET11) were successful producers, with a flow capacity of about 15 MWe. The maximum temperature encountered by the wells was 254°C, but geochemistry, shallow geophysics and reservoir studies suggested that the wells were on the margin of an outflow from a >270°C resource located to the east or southeast. Subsequent to the discovery of warm gas seeps and springs near the La Torta dome in 1998 and their analysis in 2001, a detailed geophysical survey including 53 MT-TDEM stations was conducted in January 2002. In conjunction with an earlier ENAP/Unocal MT-TDEM survey of El Tatio, this survey (Cumming et al, 2002) showed a continuous low-resistivity clay cap extending southeast of El Tatio, doming over an interpreted upflow feature located below Cerros del Tatio on the La Torta concession. This indicated a substantially larger geothermal resource than the relatively small area explored by the deep wells at El Tatio. Earlier studies estimated the potential of the drilled field at 50-100 MW; however, based on recent results at La Torta, the total electric power potential is likely to be larger. GDN will drill two exploration wells up to 2000-2500m at La Torta (Fig. 3) starting in December 2002 to demonstrate a commercial resource capable of supporting an initial 100 MWe development.

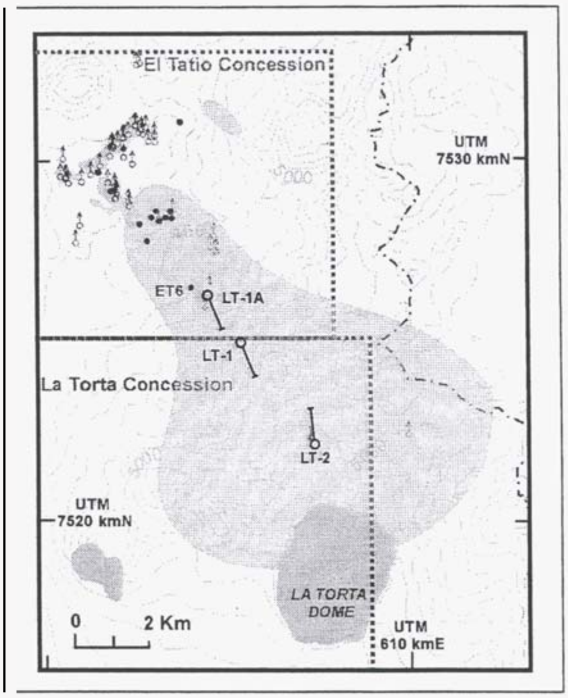

Figure 3. La Torta-El Tatio concession area, showing potential field size and location of first two exploration wells, with optional site LT-1A.

2.3 Calabozos

Located about **250 km SE** of the capital, Santiago, Calabozos was identified as one of the most promising geothermal prospects in Chile. The most obvious indications of a potential resource were the high-flow-rate (up to **3000** liters/minute) hot springs aligned along the Rio Colorado, which follows the northern and northeast ring fracture of the Calabozos caldera. The hot springs include dilute chloride, mixed chloride-sulfate, and sulfate-bicarbonate waters. ENAP's field work in **2002** confirmed that the Llolli Sur chloride spring indicated the existence of a benign **>270°C** geothermal reservoir near the northern caldera boundary. **A** fumarole discovered in **2002** about **5** km to the northeast of Llolli is consistent with a steam cap overlying a >260°C outflow. In May **2002,** an **88** station MT-TDEM resistivity survey was conducted. The results indicated that the caldera is filled with high-resistivity welded tuffs that may be hot at depth but are likely to represent a higher risk of low permeability. The caldera is surrounded by low to moderate-resistivity Mesozoic sediments, mainly sandstones and scattered gypsum domes. These sandstones are expected to host the geothermal reservoir in the Calabozos prospect. **A** model incorporating the geophysical, geologic and geochemical results indicates the presence of a benign, low gas, liquid-dominated hydrothermal system centered on or near the northern caldera rim. ENAP prepared an Information Memorandum for potential partners interested in co-developing this resource area, and plans to make a partner selection in late **2002.**

2.4 Chillin

Chillh is located in south-central Chile about **80 km SE** of Chillán city. This prospect is associated with Nevados de Chilliin, an active volcano contained within the 5.5km x 11km Aguas Calientes caldera. Most of the thermal features are located in two main zones, Aguas Calientes caldera and the Termas de Chillán. In 1995, CFG (France) and **ENAP** drilled a shallow exploratory well to a depth of **274** m and encountered 198°C fluid at **240m** depth. The fluid chemistry indicated that the source was a <1000 ppm mixed chloride-bicarbonate water. The well had an estimated vapor production of 15 t/h with a single flash capacity of **2.4 MW** (Correira et al. 1996). Geothermometry suggests a temperature range of around 200°C for the shallow mixed $Cl\text{-}HCO_3$ reservoir and up to 265°C for a deeper resource. The well was abandoned for safety reasons in 1996. Future exploration efforts will focus on identifying the higher temperature upflow area.

3. GEOTHERMAL LAW IN CHILE

In 2000, the Chilean government created a law to establish the framework to develop geothermal energy projects, establishing a clear distinction between this activity and that of mining or groundwater production (Salgado & Raasch **2002).** This law provides for the development of geothermal resources through a concession granted by the Ministry of Mines and gives the owner of the concession the exclusive rights over the geothermal energy. There are two kinds of geothermal concessions: the first is an exploration concession valid for two years and extendable for an additional two years; the other is an exploitation concession that can be held indefinitely. The exploitation concession gives the exclusive right to own all the geothermal power and brine production that exists within the limits of the concession, to use the land for exploration or exploitation, and to transfer or sell the concession without limitation.

4. CHILE ELECTRICAL SYSTEM

In the early 1980s, Chile was the first country to reform its electricity sector. The introduction of a power pool as the place where competing private generators coordinated their supply activities was a revolutionary change. Private enterprises are responsible for electric power generation, transmission and distribution in an open market where any party can build and operate a generation or transmission company. In keeping with the country's free-market economic policy, the State plays a subsidiary role as regulator and supervisor. At the same time the legislation establishes an operator formed by the generation companies that commands the pool of power plants, selects the dispatch order to minimize the cost of generation, and dispatches those with lower variable cost first (a short-term marginal cost system to determine dispatch).

Electrical energy can be sold through three different mechanisms (Salgado & Raasch **2002).** The first is by contract, with the price established between the generator and any client that consumes more than **2 MW.** The second avenue is by the node price established by the government every six months, which corresponds to the projected marginal cost estimated over the next **24** to **48** months. This sets the price under which the generator may sell energy to a distribution company. The node price is established with a price band, which is determined by the average price of contracts negotiated between generators and large customers. The width of this band can not be more than 10% of the total price. The third method of power sales is the spot market. Those generators without contracts can sell their power into the spot market if their generation costs are lower than the marginal cost. Those generators that are not able to produce power at or below the marginal cost are not allowed to run, even though they may have a contract to provide power to a client. They are required to purchase their power needs fiom lower cost producers on the spot market. The spot price **is** determined hourly, depending on the variable cost of the most expensive generator that is running at that hour.

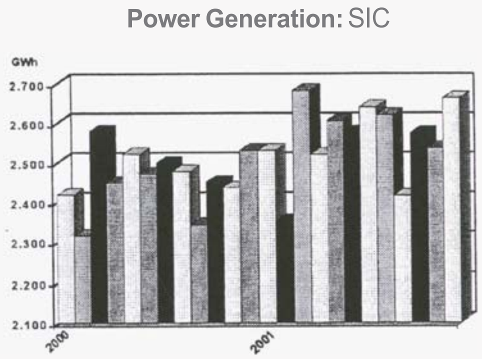

Figure **4.** Monthly power generation in the SIC during **2000 - 2001**

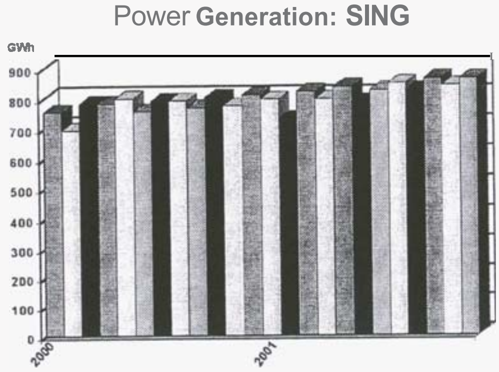

Figure **5.** Monthly power generation in the SIC and the **SING.**

The current installed electric capacity of Chile is about **9,000MW,** of which **6000MW** are connected to the southern Chile grid (SIC) and 3000MW are connected to the northern Chile grid **(SING).** Monthly power generation in **2000-2001** to the SIC and **SING** grids is shown in Figures **4** and **5**. Chile, like most South American countries, is heavily dependent on hydroelectric power. This dependence leads to high supply uncertainty caused by variations in annual rainfall. Most hydro-electric plants are run-of-river and do not have sufficient storage capacity to generate power during the dry season. In the Andean-Pacific countries, river flow levels vary substantially over the year and between years, which means that the power generation from these plants is subject to significant uncertainty. The efficient operation of these plants therefore depends on the option price of stored water, which is based on the expectation of future rainfall and the expected future marginal costs of thermal plants. All this is reflected in the spot price for power. Geothermal, with its very low marginal cost, can therefore enter the grid ahead of any fuel burning power plant and would be able to sell all its power at the spot price or higher.

5. ENVIRONMENTAL LEGISLATION

The framework of environmental management in Chile was established by Law **N° 19.300,** the General Basis for the Environment in **1994.** This Environmental Law guaranties the right to live in an environment free of pollution and it establishes the guidelines and policies for the environmental protection in the country. Its purpose is to assure environmental sustainability and incorporate environmental concerns into the assessment of projects and activities. It is applied to projects and/or activities performed by the public and private sectors. There are a number of other laws regulating different environmental permits and constraints including air pollution, wastewater, and land use that have to be considered. The Environmental Law stipulates that the environmental aspects of all these permits and approvals are requirements for one major process, the Environmental Impact Assessment (EIA), so all these special permits are granted with the approval of the EIA.

The Environmental Law establishes that any new project or activity that is explicitly classified for mandatory inclusion in the system can only be executed following the approval of an EIA. The way to initiate the EIA process is to submit either an Environmental Impact Report (EIR) or an Environmental Impact Study (EIS) depending on the specific effects, characteristics or circumstances of the project. Projects or activities identified in the law that are considered to produce environmental impacts are explicitly identified in the Environmental Law. For any other project or activity not expressly included in the law, the developer is not compelled to submit to the Environmental Impact Assessment process, but may elect to do so voluntarily (Fig. *6)*. The following activities related to geothermal projects are examples of those requiring an EIS submittal under the environmental system:

- High voltage power transmission lines and their substations;
- Power stations generating in excess of **3** MW;
- Oil and gas pipelines, mining ducts and other comparable facilities;
- Construction activity in national parks, national reserves, natural monuments, virgin wildlife reserves, nature sanctuaries, ocean parks, marine reserves or any area under official protection.

The Chilean Environmental Impact Assessment system requires that electrical utilities submit every new power project to the Environmental System to receive approval for the development phase. The environmental approval process is related to the geothermal development phase, and not exploration through exploration drilling.

The EIR or EIS must be submitted before development work begins to the regional environmental authority (COREMA) where the work proposed for the project or activity is to be performed. The regional environmental authority shall have a 120-day period to respond to the EIS and a 60-day period to respond to an EIR. If the authorities fail to respond within these respective periods, the project shall be deemed to have received a favorable rating.

The EIS ends with a resolution issued by the respective authorities, which certify whether the project or activity complies with all applicable environmental requirements.

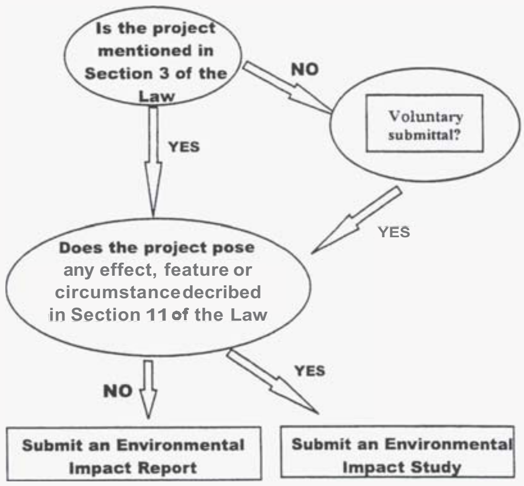

Figure 6. Flowchart to determine whether a project or activity must be entered into EIA System and if an EIS or EIR is required.

6. GREENHOUSE GASES UNDER THE KYOTO PROTOCOL

The 12* article of the Kyoto Protocol (PK) establishes the so-called Clean Development Mechanisms (CDM), in which developing countries (including Chile) can receive financial assistance for power projects that result in the reduction of gas emissions that cause the greenhouse effect. Chile has approved the Climate Change Convention and has begun to implement several projects to take advantage of the benefits of selling CO_2 Carbon Tradable Offsets, under a CDM. One example of the use of CDM in the Chilean energy market is the run-of-river hydroelectric power plant, Chacabuquito, that utilizes the waters of the Aconcagua river located about 100 km northeast of Santiago. This plant will dispatch energy based on the principle that it will replace the most expensive units on line. The environmental analysis shows that the incremental hydropower generation displaces coal-based generation at all times. Assuming that the CO_2 emissions from coal-fired steam plants are at 860t/GWh based on IPCC default values, emissions avoided by Chacabuquito would be 137,600t of CO_2 per year.

Geothermal electric plants in Chile are expected to replace greenhouse gas emissions from both coal and gas-fired power plants. Utilizing the CDM as established under the Kyoto Protocol will create additional financial incentives for geothermal projects.

7. ACKNOWLEDGEMENTS

Gonzalo Salgado wishes to thank the GDN Geothermal Team for their contributions and commitment to the project, and David Sussman for editing this paper.

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