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GEOTHERMAL ACTIVITY AND DEVELOPMENT IN SOUTH AMERICA: SHORT OVERVIEW OF THE STATUS IN BOLIVIA, CHILE, ECUADOR AND PERU

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ABSTRACT

South America holds vast stores of geothermal energy that are largely unexploited. These resources are largely the product of the convergence of the South American tectonic plate and the Nazca plate that has given rise to the Andes mountain chain, with its countless volcanoes. High-temperature geothermal resources in Bolivia, Chile, Ecuador and Peru are mainly associated with the volcanically active regions, although low temperature resources are also found outside them. All of these countries have a history of geothermal exploration, which has been reinvigorated with recent changes in global energy prices and the increased emphasis on renewables to combat global warming. The paper gives an overview of their main regions of geothermal activity and the latest developments in the geothermal sector are reviewed.

1. INTRODUCTION

South America has abundant geothermal energy resources. In 1999, the Geothermal Energy Association estimated the continent's potential for electricity generation from geothermal resources to be in the range of 3,970-8,610 MW, based on available information and assuming the use of technology available at that time (Gawell et al., 1999). Subsequent studies have put the potential much higher, as a preliminary analysis of Chile alone assumes a generation potential of 16,000 MW for at least 50 years from geothermal fluids with temperatures exceeding 150°C, extracted from within a depth of 3,000 m (Lahsen et al., 2010). In spite of this enormous potential, the only geothermal power plant to have been operated on the continent is the 670 kW binary demonstration unit in the Copahue field in Argentina, which was decommissioned in 1996 (Bertani, 2010).

Global warming and the global energy market have among other factors led to a renewed world-wide interest in clean indigenous energy resources and several South American countries are currently pursuing the development of their geothermal resources. Among these are Bolivia, Chile, Ecuador and Peru. The following sections are intended to give a basic overview of geothermal activity and the state of geothermal development in these countries.

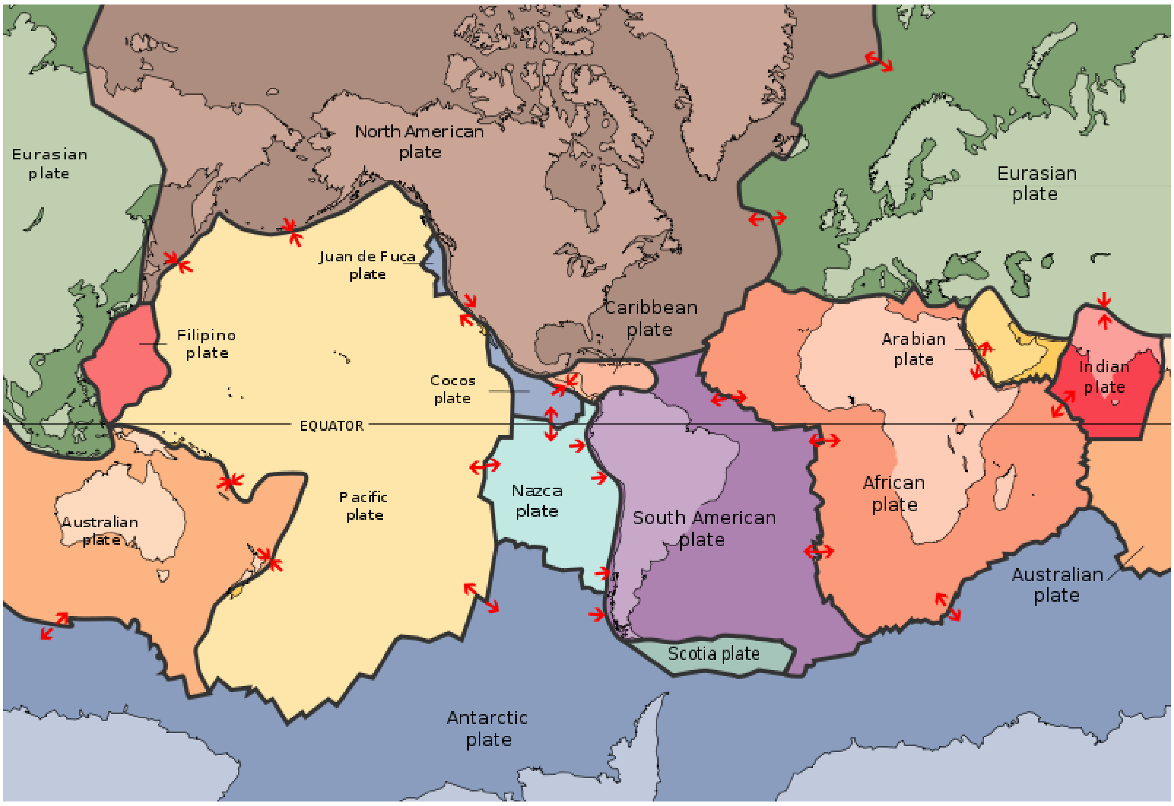

FIGURE 1: The tectonic plates of the world (Wikimedia Commons)

2. BACKGROUND

The South American tectonic plate, on which the South American continent rests, is bordered by the Nazca and Antarctic plates to the west (Figure 1). These three plates meet at the Chile triple junction. The Nazca plate subducts underneath the South American plate in a convergent boundary (Figure 2) that manifests in the Peru-Chile trench that runs along the western coast of the continent, approximately 160 km from shore and reaches a maximum depth of over 8,000 m. Part of the Antarctic plate also subducts under the South American plate. The friction and pressure created by the sliding plates and the melting of the subducting plate cause earthquakes and volcanic activity, which are both conducive to the formation of geothermal reservoirs. Earthquakes produce faults and fissures through which water can flow and volcanic activity and shallow magma chambers provide heat sources.

The convergence has given rise to the Andes mountain range that runs from Venezuela in the north to Patagonia in the south and reaches maximum altitude of 6,962 m at Aconcagua peak in Argentina, which is entirely the result of uplift. The Andes are the longest continental mountain chain in the world, spanning 7 countries, and the highest outside of Asia. They are split into several ranges (cordilleras) that are separated by intermediate depressions. They are widest at the Altiplano plateau, the most extensive high plateau outside of Tibet, and are home to many important cities, such as Bogotá, Quito, La Paz, Sucre and Santiago de Chile.

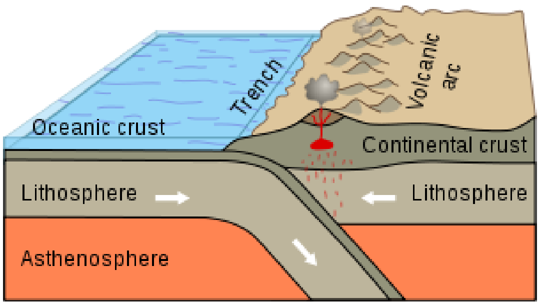

FIGURE 2: Oceanic-continental convergent boundary (Wikimedia Commons)

In a recent study, Cardoso et al. (2010) employed updated data sets on crustal seismic velocities, gravity anomalies, radiogenic heat production, terrestrial heat flow and thermal springs to outline the regional variations of the South American lithosphere. By adopting a 2°x2° grid system for data processing, they derived heat flow values from spherical harmonic expansion of the global heat flow field (Figure 3). Their results indicate that most of South America's high temperature resources occur within:

- Well known sectors of magmatic activity in Chile;
- The Altiplano region of Bolivia;
- Isolated pockets along the western Andean belt in Peru;
- Several localities along the magmatic arc covering western Ecuador, central volcanic belt of Colombia and southern Venezuela.

While many of these regions have long been known for volcanic and geothermal activity, the heat flow map is helpful for visualization on a continental scale.

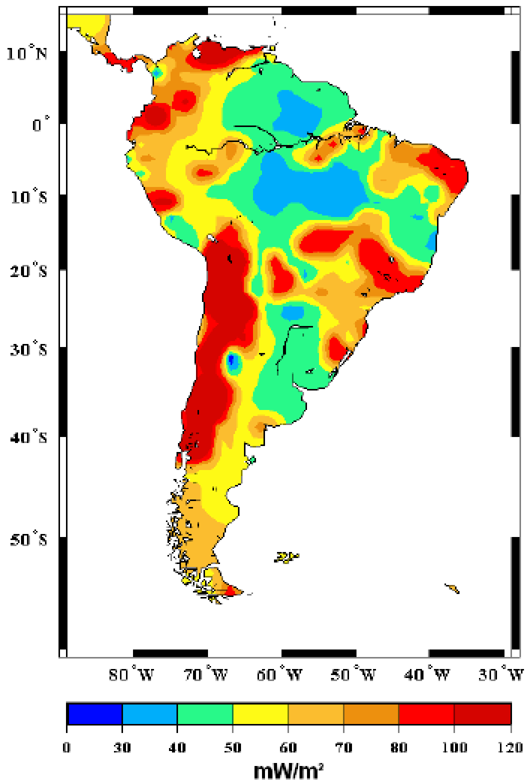

FIGURE 3: Heat flow map of South America (Cardoso et al., 2010)

3. BOLIVIA

3.1 Geographical/Geological setting

Bolivia is divided between the Andes to the west and lowlands of platforms and shields to the east. The Bolivian Andes are comprised of three main ranges (Figure 4):

- Cordillera Occidental to the west on the border with Chile, which are characterized by volcanoes and geothermal areas;
- Cordillera Central, the northern section of which is referred to as the Cordillera Real, and is rich in minerals; and
- Cordillera Oriental to the east, which is a fold and thrust belt lower than the other two.

FIGURE 4: Geographical visualization of Bolivia (www.travel-bolivia.com)

In addition to these mountain ranges, the Altiplano extends over a large area between the Cordillera Occidental and the Cordillera Central. The plateau is around 700 km long and has a maximum width of approximately 200 km. The average elevation is close to 3,750 m.

3.2 Geothermal manifestations

In 1984, Aliaga reported on more than 70 areas with geothermal manifestations in Bolivia, including hot pools, mud pools, fumaroles and steaming ground. They are found on the eastern slopes of the Cordillera Occidental, in the southern part of the Cordillera Oriental and in the eastern central part of the Altiplano. In the Cordillera Oriental, geothermal activity is associated with faults, fractures and volcanic bodies and in the Altiplano it is related to igneous bodies and probably faults. Temperatures of many surface manifestations are as high as 85°C, but most do not exceed 50°C. The largest flow measured at the time was 67 l/s at Lanza (Figure 5). The waters vary from acidic to alkaline and most of them are used for bathing.

3.3. Geothermal exploration

According to Terceros (2000), geothermal exploration in Bolivia began in the 1970s. These early efforts established the existence of high enthalpy resources, mainly along the Cordillera Occidental. Pre-feasibility studies were carried out in the Salar de Empexa and Laguna Colorada fields between 1978 and 1980, after which interest was mainly concentrated on the Sol de Mañana field of Laguna Colorada. Feasibility studies were carried out between 1985 and 1990, including the drilling of new wells, which allowed the quantification and evaluation of the geothermal reservoir. The goal was to proceed with the installation of an experimental 4-10 MW power station. To that end a new well was drilled successfully and another one deepened between 1991 and 1992, although the installation of the experimental power station was not realized.

3.4 Laguna Colorada – Sur Lipez project

Terceros reports that the Laguna Colorada prospect is located in the Cordillera Occidental in the far southwest of Bolivia, near the Chilean border (Figure 5). The area consists of high plains constituted by deposits of lava and glacier material at an elevation of 4,900 m, which are dominated by the presence of volcanic structures. In 2000, 6 wells had been drilled with an average depth of 1,500 m. Reservoir studies and numerical simulation indicated a potential for at least 120 MW for 20 years and a possibility for up to 300 MW for 25 years.

FIGURE 5: Modified physical map of Bolivia showing some geothermal sites mentioned in the text (www.travel-bolivia.com)

The state power company Empresa Nacional de Electricidad (ENDE) intends to construct a 100 MW power plant at Laguna Colorada. The total project cost is 390.5 MUSD and the estimated development time is 3.5 years. The Inter-American Development Bank will support the project under the IDB project title *Sur Lipez Geothermal Project* and the project number BO-L1057. The project is comprised of three parts (IDB, 2010a):

- Resource development, including the drilling of 16 production wells and 6 reinjection wells;
- The construction of a 100 MW power plant; and
- The construction of a single circuit 230 kV transmission line with a length of 170 km to connect the plant with the national grid.

IDB financing for the project is estimated to be 71 MUSD. On Dec. 5th 2010, the bank approved a non-reimbursable fund of 150,000 USD for supporting studies for the preparation of the project (IDB, 2010b).

3.5 Electricity generation

Electricity generation capacity in Bolivia is divided between thermal (60%) and hydro (40%). The generation capacity in 2008 amounted to 1,454 MW and the gross generation was 5,982 GWh which indicates a capacity factor of 0.47 (EIA, 2010). In 1999, GEA estimated Bolivia's geothermal electricity generation potential at 510-1,260 MW, which is 35-87% of the installed capacity in 2008. Electricity availability in rural areas is among the lowest in Latin America.

4. CHILE

4.1 Geographical/Geological setting

Andean orogeny has shaped three main features in Chile parallel to the subduction zone (Figure 6):

- Cordillera de la Costa (the Chilean coastal range) to the west, which runs from the very north to the triple junction;
- The Andean cordillera to the east; and
- Valle Central (Intermediate Depression) in between the other two features, consisting of a fertile graben which has been filled with the by-products of volcanic activity and erosion of the surrounding mountains.

According to Lahsen et al. (2010), Chilean geothermal resources occur in close spatial relationship with active volcanism. There are two main volcanic zones. The northern one extends from 17°S to 28°S and is characterized by Quaternary volcanism along the high Andes and the Altiplano. Volcanic vents and hydrothermal manifestations occur within the small grabens associated with fault systems with an approximate N-S trend that have been created by differential uplift. The southern zone extends from 33°S to 46°S and is also characterized by Quaternary volcanism that is restricted to the Andean Cordillera. This activity has given rise to stratovolcanoes,

FIGURE 6: Terrain map of Chile (www.freerentacarchile.com)

pyroclastic cones and calderas that have covered extensive areas of the Valle Central with Lahar type flows. All the Chilean high temperature thermal springs are associated with the Quaternary volcanic zones.

4.2 Geothermal resources (Lahsen et al., 2010)

Lahsen et al. report that geological, geochemical and geophysical surveys have been carried out in many geothermal areas and a preliminary assessment of the geothermal potential of the country indicates an electricity generation potential in the order of 16,000 MW for 50 years from geothermal fluids with temperatures exceeding 150°C, withdrawn from a depth less than 3,000 m. At the end of 2009, 38 concessions with surface manifestations were under geological, geophysical and geochemical exploration to narrow the focus. These surveys are to be followed by exploration drilling in promising areas.

The northern geothermal/volcanic zone (Figure 7) encompasses approximately 90 geothermal areas, largely of the chloride type. In late 2009, 6 prospects were under exploration in the zone by Empresa Nacional de Geotermia (ENG), Energia Andina and other companies that are connected to copper mining. ENG is owned by Empresa Nacional de Petróleo (ENAP) and Enel (51%), while Engergia Andina is a joint venture between ENAP and Antofagasta Minerals S.A. Exploration is being carried out at Surire, Puchuldiza, Lirima, Apacheta and El Tatio. At Apacheta and El Tatio, 4 wells have been drilled up to a depth of 1,700 m. A preliminary estimate for these areas puts their electricity generation potential at 400-1000 MW, with a contribution of 5-10 MW_e per well.

The southern geothermal/volcanic zone (Figure 8) encompasses more than 200 geothermal areas of acidic-sulfate, bicarbonate and chloride type. In late 2009, the prospects of Tinguiririca, Calabozos, Laguna del Maule, Chillán, Tolhuaca, Sierra Nevada and Puyehue-Cordón Caulle were under exploration by ENG, Universidad de Chile and some private companies. Exploration slim holes have been drilled at Calabozos, Laguna del Maule, Chillán and Tolhuaca. Preliminary estimates for electricity generation from these areas vary from 600 MW to 950 MW, with a contribution of 3-10 MW_e per well.

4.3 Grid system and electricity generation (Lahsen et al., 2010)

There are two independent electricity grid systems in Chile. The Northern Interconnected Power Grid (SING) has an installed capacity of 3,600 MW with a gross generation of 14,500 GWh/yr, out which 99.6% is generated by fossil fuel based power plants. The main customers are large copper mines. The Central Interconnected Power Grid (SIC) has an installed capacity of 9,348 MW, out of which 52% is provided by hydropower and the rest from fossil fuel based power plants. The grid supplies 90% of the population.

The total installed capacity for electricity generation in Dec. 2009 was 13,086 MW, producing approximately 56,676 GWh/yr with a capacity factor of 0.49. The total projected capacity for 2015 is 19,568 MW, of which anticipated geothermal capacity is 75 MW_e. These numbers can be put in context with the estimated 16,000 MW_e geothermal potential of the country.

4.4 Legal environment

The Non-Conventional Renewable Energy Law requires energy providers in systems of an installed capacity of 200 MW or greater to demonstrate that 10% of the energy provided comes from non-conventional renewable energy resources by 2024 (OECD/IEA, 2010). A Geothermal Law was enacted in 2000, providing a framework for the exploration and development of geothermal energy (Lahsen et al., 2010).

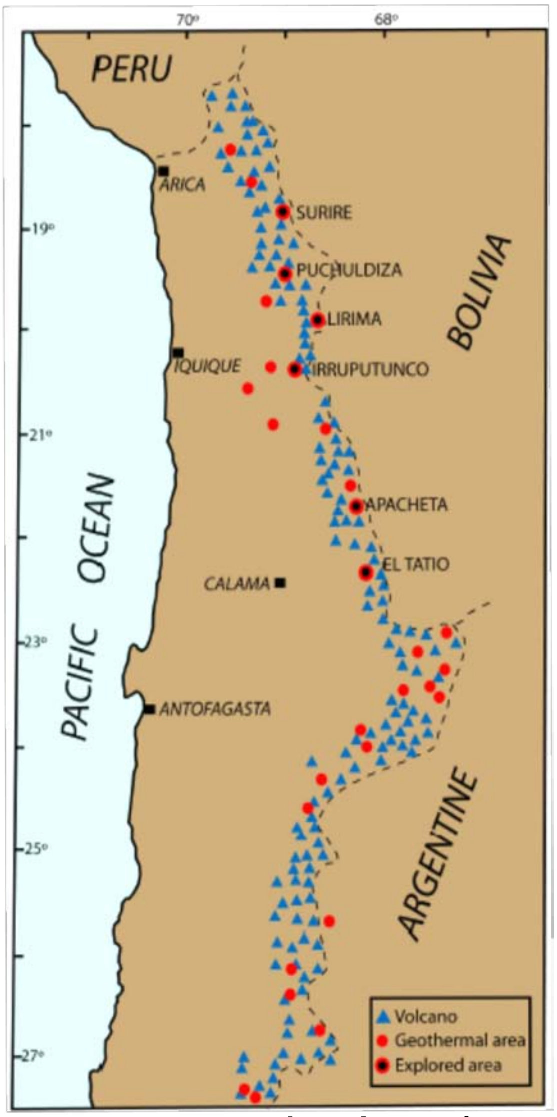

FIGURE 7: Geothermal areas of Northern Chile (Lahsen et al., 2010)

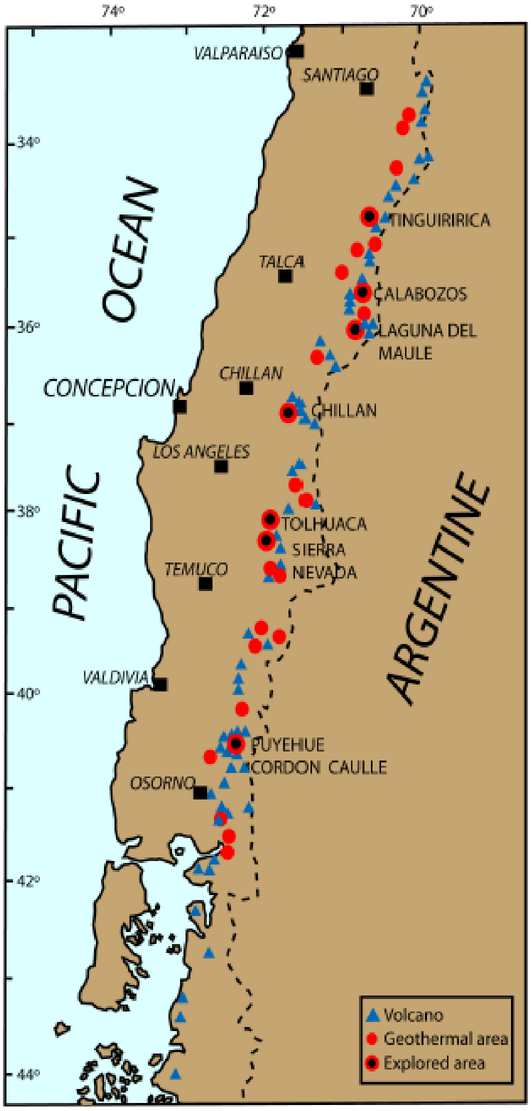

FIGURE 8: Geothermal areas of Central-Southern Chile (Lahsen et al., 2010)

4.5 Current concessions and developers

In early September 2010, the Chilean Ministry of Energy announced a tender for 21 new geothermal exploration concessions (ThinkGeoEnergy, 2010a). These are an addition to 24 exploration concessions and 6 operating force. Further licensing of concessions is planned in the next few years. Most current concessions and developers are listed in Appendix I.

5. ECUADOR (Beate and Salgado, 2010)

5.1 Geographical/Geological setting

Geographically and geomorphologically, mainland Ecuador consists of three regions (Figure 9):

- Costa (the coastal range);
- Sierra (the Andes mountain chain); and
- Oriente (the Amazon basin).

The Galapagos islands are the fourth region about 1,000 km west of the mainland. They are thought to be the product of a hot spot and consist of about 15 basaltic shield volcanoes, increasing in age towards the east.

The Ecuadorian Andes consist of two parallel NNE striking mountain chains:

- Cordillera Real to the east; and
- Cordillera Occidental to the west.

Both cordilleras have been uplifted and are capped by late Tertiary volcanics. Volcanic activity is extinct in the southern part, but a well developed Quaternary volcanic arc that extends into Colombia covers both in their northern half. It consists of more than 50 volcanoes, out which 30 are still active. Between the cordilleras is the Inter-Andean Valley.

FIGURE 9: Geographical visualization of Ecuador

5.2 Geothermal exploration and resources

A reconnaissance study carried out in 1979-1980 divided hydrothermal systems in areas of recent volcanism into two main groups based on temperature (Figure 10):

- Group A: Tufiño, Chachimbiro and Chalupas high temperature areas; and
- Group B: Ilaló, Chimborazo and Cuenca low-temperature areas.

Further studies by the government's Instituto Ecuatoriano de Electrificación (INECEL) indicated an electricity generation potential of 534 MW for the three high-temperature areas. Following the shut-down of INECEL in 1993, a period of exploratory stagnation lasted until 2008. In that year, the Ministry of Electricity and Renewable Energy (MEER) restarted exploration with the aim of developing one or more of the former INECEL geothermal prospects. Exploration drilling was undertaken at the Tufiños-Chiles prospect, where the first geothermal exploration well in Ecuador was completed in May 2009. The Chachimbiro prospect received 1 MUSD of funding for geophysical exploration and siting of deep exploration wells. The National Council for Electricity (CONELEC) commissioned a desk-top study on a 50 MW_e plant at the Chalupas prospect and an overall assessment of Ecuador's geothermal prospects. Also, Electroguayas, a part of the National Utility Corporation, funded a geological and geochemical reconnaissance study of the Chacana Caldera and an upgrade report on the Tufiños, Chachimbiro and Chalupas prospects.

5.3 The Tufiño-Chiles prospect

The development area of the Tufiño-Chiles prospect lies across the Ecuador-Colombia border, in Carchi province on the Ecuadorian side and Nariño department on the Colombian side. Gas thermometers indicate temperatures as high as 230°C and resistivity data confirm a reservoir under the Volcán Chiles massif. Assessment based on surface data indicates an electricity generation potential of 138 MW. The governments of Ecuador and Colombia are currently working together on the development of this resource and have signed a bilateral agreement on *Proyecto Geotérmico Binacional Tufiño-Chiles-Cerro Negro*. Likely drilling elevation is between 3,800 and 4,200 m a.s.l.

5.4 Current utilization and electricity generation

Current utilization of geothermal resources in Ecuador is restricted to direct use for bathing, balneology and swimming pools. Several aquaculture projects (fish hatcheries) await funding.

The installed electricity generation capacity of Ecuador was 4,557 MW in 2008 with a gross generation of 18,609 GWh/yr, of which 51.7% came from hydro power and 44.0% from fossil fuel based power plants. These numbers indicate a capacity factor of 0.47. Ecuador has imported approximately 500 GWh of electricity from Colombia and Peru per year, but that is expected to reverse when new hydro power plants come on line. In 1999, GEA estimated Ecuador's geothermal electricity generation potential at 420-850 MW, which is 9-19% of the installed capacity in 2008.

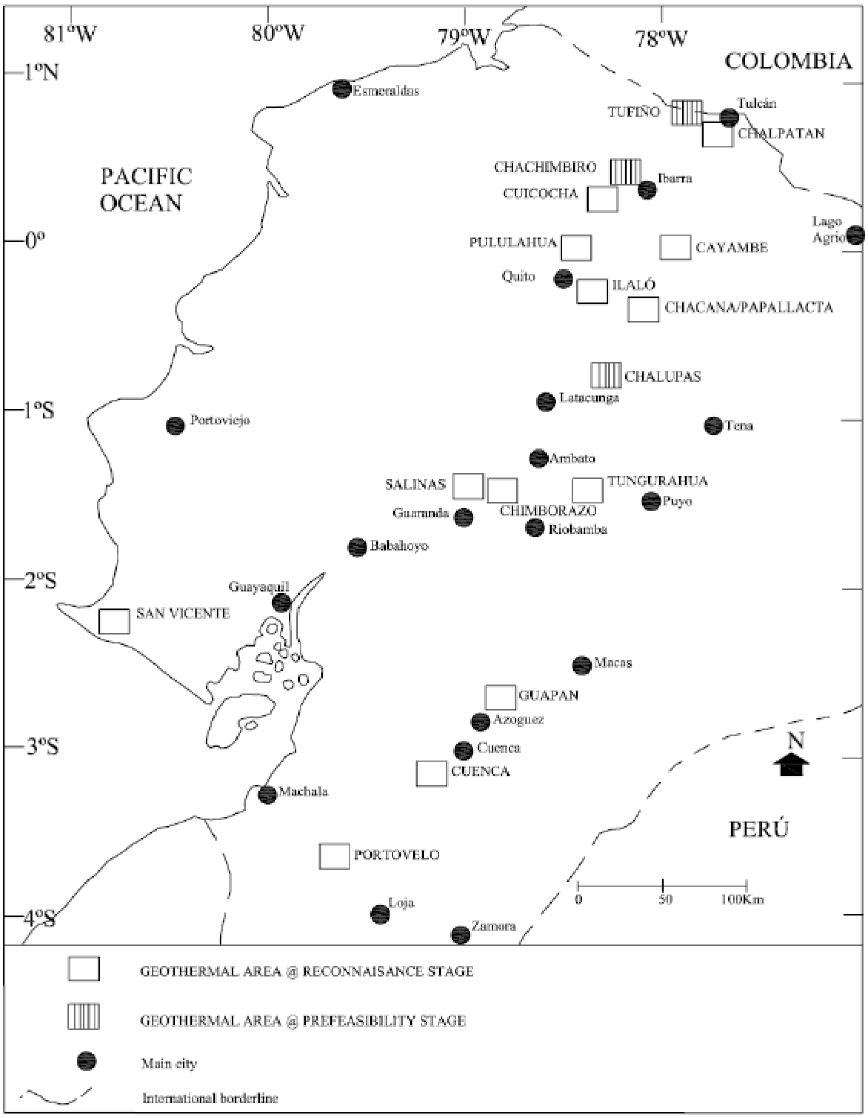

FIGURE 10: Geothermal areas in mainland Ecuador (Beate and Salgado, 2010)

5.5 Outlook

Geothermal resources can help Ecuador achieve self-sufficiency in electricity production as they offer reliable base load power. The government has decided to fund, explore and develop clean, indigenous, renewable energy resources, including geothermal. The first geothermal power plant is expected to be on line in the next 5 to 10 years. The government also intends to further explore and develop direct use for the tourist industry, agribusiness and fish hatching. In reaching these goals, public investment plays a key role.

6. PERU

4.1 Geographical/Geological setting

Geographically, Peru is divided into three regions (Figure 11; Figure 12):

- The Coast;
- The Andean mountain chain; and
- The Amazon basin, which accounts for approximately 60% of the land area.

FIGURE 11: The three geographic regions of Peru

FIGURE 12: Geographical map of Peru (www.nowpublic.com)

4.2 Geothermal resources (Vargas and Cruz, 2010)

Peru has a vast geothermal potential that is evident in numerous surface manifestations such as hot springs, geysers and fumaroles. In northern and central Peru, high temperature manifestations are the result of the geothermal gradient and infiltrated meteoric water flowing in deep faults, while in the southern part the manifestations are related to active volcanism, and hot spring water is of both meteoric and volcanic origin.

In the Geothermal Map of Peru, recently updated by Vargas and Cruz, the country is divided into six geothermal regions with different temperatures of surface manifestations (Figure 13):

- Cajamarca – La Libertad (28-74°C);
- Callejón de Huaylas (24-60°C);
- Churín (20-73°C);
- Central (20-55°C);
- Eje Volcánico Sur (20-90°C); and
- Cuzco – Puno (24-88°C).

In this context it is worth noting that the boiling point of water at 3,000 m is approximately 90°C. Most of the studies to date have been focused on Eje Volcánico Sur, which has more than 300 volcanic centers. Recent activity has been noted in Misti, Ubinas, Ticnasi, Sabancaya, Huaynaputina, Tutupaca and Yucamante. The region has more than 300 surface manifestations from hot springs to fumaroles. It is subdivided into three zones based on the quality of resources recognized from preliminary studies:

- Zone A (high importance): Tutupaca, Calacoa, Maure, Laguna Salinas, Chachani and Chivay;
- Zone B (medium importance): Puquiao, Parinacochas and Orcopampa; and
- Zone C (low importance): Catahuasi, Coropuna, Caylloma and Mazo Cruz.

Some companies have started geothermal exploration projects in Eje Volcánico Sur.

4.3 Past and current utilization

The use of geothermal manifestations for entertainment and balneology in Peru goes back to pre-Inca and Inca periods (Cernik et al., 2010). The pre-Incan Caxamarca culture built an important city by the hot springs that later became known as the Baños del Inca (Inca baths). The place at that time consisted of some buildings that were one of the principal residences of the Caxamarca chiefs, who used the hot springs for healing and the worship of water (Figueroa Alburuqueque). As the Incas gained influence in the region, the baths by Cajamarca became one of the principal residences of Inca chiefs prior to the arrival of the Spanish conquistadors. This is where Inca emperor Atahualpa first heard of the Spanish invasion and some sources say that he was aroused from the baths to receive the news. Atahualpa was subsequently captured at Cajamarca.

Kepinska (2003) notes that a great number of Inca palaces and temples were built near natural geothermal ponds and hot springs that were equipped with bathing facilities supplied with hot and cold water through a system of pipelines. Both aristocracy and common people had opportunities to bathe in warm springs.

The utilization of geothermal resources in Peru is still mostly limited to entertainment and balneology at places such as Baños del Inca, Callejón de Huaylas, Churín hot spring and the Aguas Calientes baths, which are located at the closest access point to Machu Picchu. As such, they play an important role for the tourist industry.

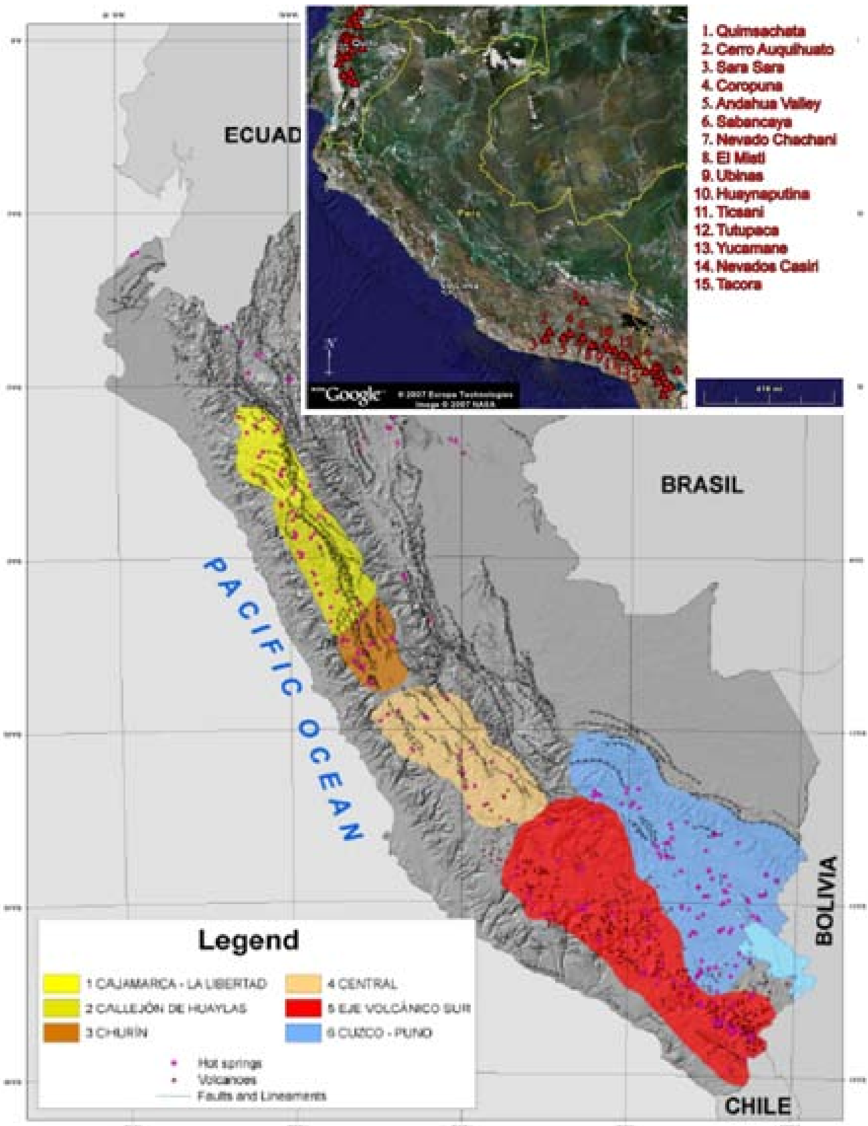

FIGURE 13: Updated geothermal map of Peru (Vargas and Cruz, 2010) and the volcanoes of Eje Volcánico Sur (Europa Technologies; NASA)

4.4 Electricity generation

Electricity generation capacity in Peru is evenly divided between thermal and hydro, although the latter accounts for around 70% of the actual generation. The generation capacity in 2008 amounted to 7,158 MW and the gross generation was 31,921 GWh which reveals a capacity factor of 0.51 (EIA, 2010). In 1999, GEA estimated Peru's geothermal electricity generation potential at 600-1,410 MW, which is 8-20% of the installed capacity in 2008.

4.5 Recent developments

According to Vargas and Cruz (2010), the Peruvian Geological Survey (INGEMMET) conducted the first geothermal studies in the 1970s. Due to world market trends, a renewed emphasis has been placed on geothermal development and to that end all existing information has been collected in the Geothermal Map, which is intended to help with management decisions to be taken on possible investment in exploration and exploitation.

On March 25th 2010, the Peruvian Ministry of Energy and Mines presented a draft regulation on Law No. 26,848 for public commenting (MINEM, 2010). The regulation is considered necessary to reorganize and develop the various aspects regulating the rational development of geothermal resources to ensure energy supply necessary for economic growth, the welfare of the population and the efficient diversification of the country's energy sources, cautious development of those activities, access and issues related to competition (ThinkGeoEnergy, 2010b). The regulation addresses planning, the acquisition of land, the application of concessions, exploration, exploitation, rights, permits, performance guarantees, taxation, general procedures and obligations. It is indicative of the intent of the Peruvian government to develop the country's geothermal resources beyond the traditional direct use of natural hot-springs.

5. FINAL REMARKS

Based on the World Energy Council 2007 Survey of Energy Resources, Fridleifsson and Haraldsson (2011) report a 0.73 capacity factor for geothermal power plants, which is far higher than that of any other renewable power plants. Assuming this average factor in the four countries reviewed in this paper and a geothermal generation potential that is midway between the GEA low and high estimates from 1999, except for Chile where the generation capacity is assumed to be that reported by Lahsen et al. (2010), leads to the numbers presented in Table 1. US Energy Information Administration data are used for capacity and generation in 2008 and those numbers may vary slightly from other sources. It is clear that geothermal can in all cases contribute significantly to the energy mix of the countries.

In 1999, the Geothermal Resources Council estimated average carbon dioxide emissions from geothermal power plants to be 0.08 kg/kWh, while the emissions from fossil fuel plants were: coal 0.97, petroleum 0.71, and natural gas 0.47 kg/kWh of carbon dioxide respectively (Bloomfield and Moore, 1999). This compares with 0.12 kg/kWh for geothermal power plants reported by Bertani and Thain (2002). From these numbers it is clear that using geothermal resources to generate electricity in place of fossil fuel based thermal power plants can avoid substantial CO_2 emissions.

The unharnessed geothermal resources of Bolivia, Chile, Ecuador, Peru and South America in general can be used to provide reliable base load, reduce greenhouse gas emissions, lessen reliance on imported energy, bring electricity to the rural poor and possibly lower electricity prices. The exploitation of geothermal resources can thus help raise the standard of living in these countries, while also contributing to a better worldwide environment.

TABLE 1: Comparison of installed capacity and generation in 2008 to estimated geothermal potential

	Cap. factor		**Gen. capacity**		**Generation**		**Geoth. vs. 2008**	
	Total 2008 -	**Geoth. -**	**Installed 2008 MWe**	**Geoth. potential MWe**	**Total 2008 GWh**	**Geoth. potential GWh**	**Generation capacity %**	**Generation %**
Bolivia	0.47	0.73	1,454	885	5,982	5.659	61	95
Chile	0.52	0.73	13,145	16,000	60,281	102.317	122	170
Ecuador	0.49	0.73	4,189	635	18,061	4.061	15	22
Peru	0.51	0.73	7,158	1,005	31,921	6.427	14	20

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APPENDIX: Chilean geothermal concessions and developers

DEVELOPER	CONCESSION/PROJECT	AREA	SOURCE
Energia Andina	Juncalito 1-2	North	latinpetroleum.com
Energia Andina	Pampa Lirima 1-4	North	thinkgeoenergy.com
Energia Andina	Polloquere	North	thinkgeoenergy.com
Energia Andina	Tinguiririca	South-Central	thinkgeoenergy.com
Energia Andina	Tuyajito 1-3	North	latinpetroleum.com
ENG	Calabozo	South-Central	latinpetroleum.com
ENG	Licancura 1		latinpetroleum.com
ENG	Necul		latinpetroleum.com
GeoGlobal Energy	Alitar	North	mightyriverpower.co.nz
GeoGlobal Energy	Colimapu	South-Central	mightyriverpower.co.nz
GeoGlobal Energy	Puchuldiza	North	mightyriverpower.co.nz
GeoGlobal Energy	Ranquil	South-Central	geogloballlc.com
GeoGlobal Energy	Tolhuaca	South-Central	geogloballlc.com
Geotermica del Norte	Apacheta	North	thinkgeoenergy.com
Hot Rock Chile S.A.	Calerias	South-Central	businessspectator.com.au
Hot Rock Chile S.A.	Galo	South-Central	businessspectator.com.au
Hot Rock Chile S.A.	Santa Antonia	South-Central	thinkgeoenergy.com
Hot Rock Chile S.A.	Santa Sonia	South-Central	thinkgeoenergy.com
Hot Rock Chile S.A.	Tuyajito 4	North	latinpetroleum.com
Magma Energy	Laguna del Maule	South-Central	magmaenergycorp.com
Magma Energy	Pellado	South-Central	magmaenergycorp.com
Ormat Andina S.A.	San Pablo II	North	ormat.com
Ram Power	Aucan I	North	ram-power.com
Ram Power	Laguna Verde	North	ram-power.com
Serviland Minergy S.A.	Licancura 3		latinpetroleum.com
Serviland Minergy S.A.	Volcan Tacora	North	latinpetroleum.com