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GEOTHERMAL ENERGY: CURRENT SITUATION IN COSTA RICA

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ABSTRACT

The Instituto Costarricense de Electricidad (ICE) leverages commercial high enthalpy geothermal resources for power generation with a total installed capacity of 204 MWe; distributed from the Miravalles Geothermal Field, consisting of three flash technology plants, a backpressure unit and a bottoming binary technology; and the Las Pailas Geothermal Field unit I, using mixed cycle binary technology. Both fields are equivalent to 7% of the total power capacity installed in Costa Rica and generate nearly 15% of the total energy produced in the national electric system.

In addition, Las Pailas Geothermal Field unit II that is in the development phase with a projected capacity of 55 MWe and the Borinquen Geothermal Field that is in the feasibility phase with a 110 MWe generation capacity.

ICE works with two plants that use binary technology which gives us the experience needed for the eventual use of medium and low enthalpy. At moment the low enthalpy is exploited for the purposes of eco-tourism.

1. INTRODUCTION

Costa Rica has significant unexploited resources for power generation, however, the national electrical sector has a matrix where more than 90% of production comes from alternative energy: hydroelectric, geothermal and wind.

The renewable source support the thermal generation when it suffers due to climate variations and changes. The strategy aims to intensify the use of alternative energies diversifying the matrix and reducing the use of fossil fuels, which involve higher costs and increase the environmental impact (Mainieri, 2010).

In Figure 1, it is observed that geothermal energy represents 7% of the total installed capacity and 15% generated; staying as the second most important source of electricity generation.

2. HIGH, MEDIUM AND LOW ENTHALPY GEOTHERMAL RESOURCES IN COSTA RICA

The important conditions for high enthalpy resources in the country allow the geothermal exploitation to focus on these types of deposits, using plants with flash technologies and binary systems. The

Miravalles Geothermal Fields and Las Pailas I are in the production stage, Las Pailas II is in the development stage and Borinquen is in the feasibility phase. Figure 2 shows the general geothermal zoning determined from superficial explorations and projections.

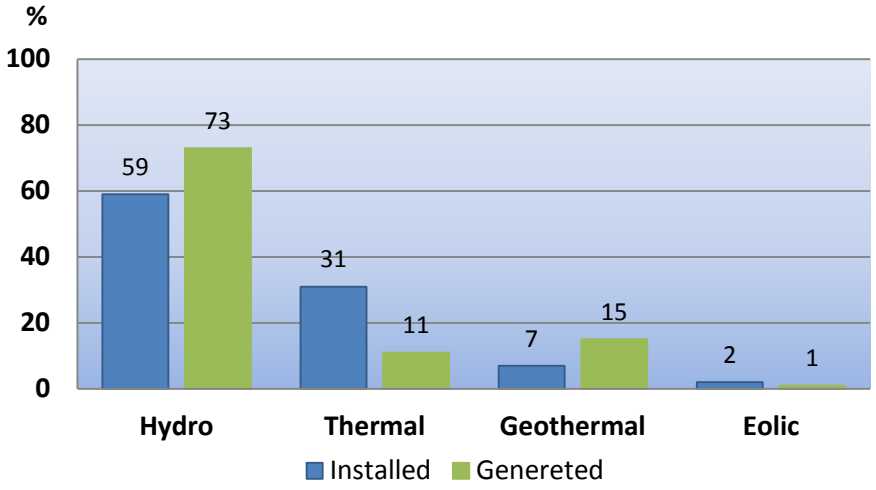

FIGURE 1: Average installed electrical capacity vs. generated in Costa Rica, data collected from Instituto Costarricense de Electricidad, 2013.

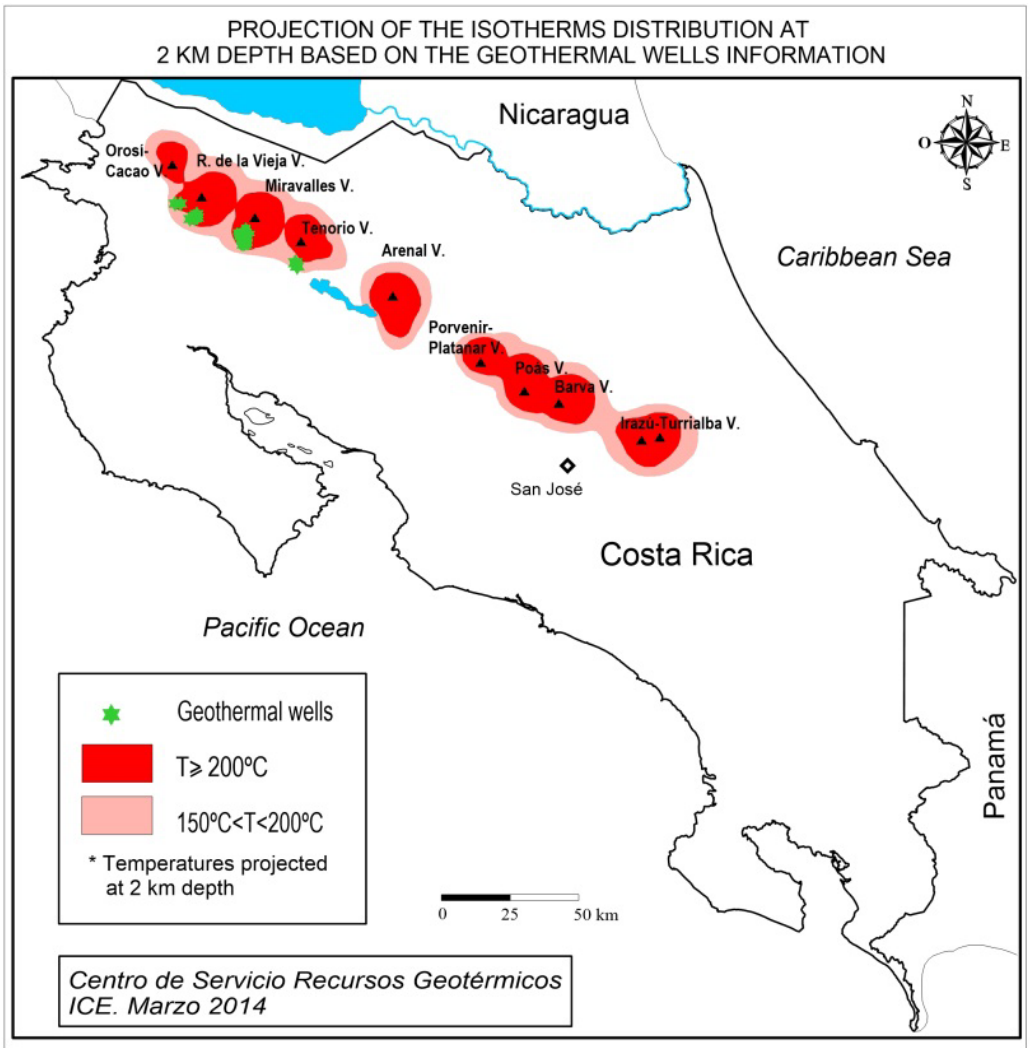

FIGURE 2: Geothermal zoning and sites of interest in Costa Rica

In the areas of exploitation aquifers have been found with temperatures between 150–180°C and even lower, however they are isolated to prevent thermal contamination toward aquifers with higher temperatures. Studies have not been done to estimate the value of the exploitation of these due to the focus on power generation from high enthalpy resources, because it needs less infrastructure and lower costs.

Although there is no exploitation of medium enthalpy there are 2 plants that work with binary technology which gives us the experience to know the characteristics of the process if it is implemented in the future. Currently, low enthalpy is used in the development of thermal pools in different areas of the country, benefiting from the growth of ecotourism.

3. MIRAVALLES GEOTERMAL FIELD (MGF)

Located in the southern flank of the Miravalles volcano, this field came into operation with the first unit in 1994 and the last in 2003. It is composed of five units with a total installed capacity that reaches 162 MWe distributed in the following form: unit I and II with 55 MWe each, unit III 29 MWe, unit V 18 MWe and the backpressure unit is 5 MWe.

The reservoir has a liquid dominance with an average temperature of 240°C, enthalpy between 980 and 1150 kJ/kg (Vargas, 2013a), and is divided according to the chemistry of fluids: pH neutral, acidic-sulfated and neutral-bicarbonated (Mainieri, 2010).

In total 56 wells have been drilled: 30 for production, 11 for injection and 15 for monitoring (Castro and Chavarría, 2014). Of the production wells, 26 generate fluids with a neutral pH and the remaining 4 with an acidic pH (Figure 3). This field is unique in the world in that it produces electricity using acidic wells, which is a great achievement for the country because of the high cost invested in its drilling.

The plan is to increase the installed capacity of MGF by 2016 with deep wells to the east and southeast sectors of the field.

3.1 Units I, II and III

Unit I came into operation in March 1994, and was the first plant installed by ICE and Unit II was started in August 1998. These use flash technology, and each have a generation capacity of 55 MWe. However, its design allows working with an overload, so the real generation is 60 MWe.

The units require about 420 tons of steam per hour for normal operation. The production wells feed the satellites with biphasic fluid that have the function to separate the steam from the liquid, supplying steam to the plant and sending liquid to the injection wells.

The construction of Unit II was designed to be interconnected with Unit I, while the steam to be used by both units arrives at independent collectors, which in turn are interconnected to each other. The operation of the Unit III began in 2000, a new separation unit was built for it and is independent of the other two units. By 2014 these units will be implemented in a non-condensable gas extraction system to make better use of wells with significant gas content.

3.2 Unit V

This unit is the first binary cycle plant installed. The system of production in this type of plant consists of a cycle of heat exchange. Using residual geothermal fluid that comes out of units I, II and III with a temperature of about 160°C, this is known as a bottoming binary process. Before being reinjected, it is passed through heat exchangers, which in turn evaporate pentane that drives the

turbine. The outgoing fluid heat exchangers is at a temperature of approximately 130°C, and continues its path to the wells for reinjection. The use of pentane has as the benefit of cleaning the turbine, moving impurities which can be stored.

The design of the plant is environmentally friendly in that it does not have atmospheric emissions except water vapor and CO_2 coming from the cooling towers, and only a small loss of pentane (about 0.0001% of the circulation flow rate), (Moya and DiPippo, 2006).

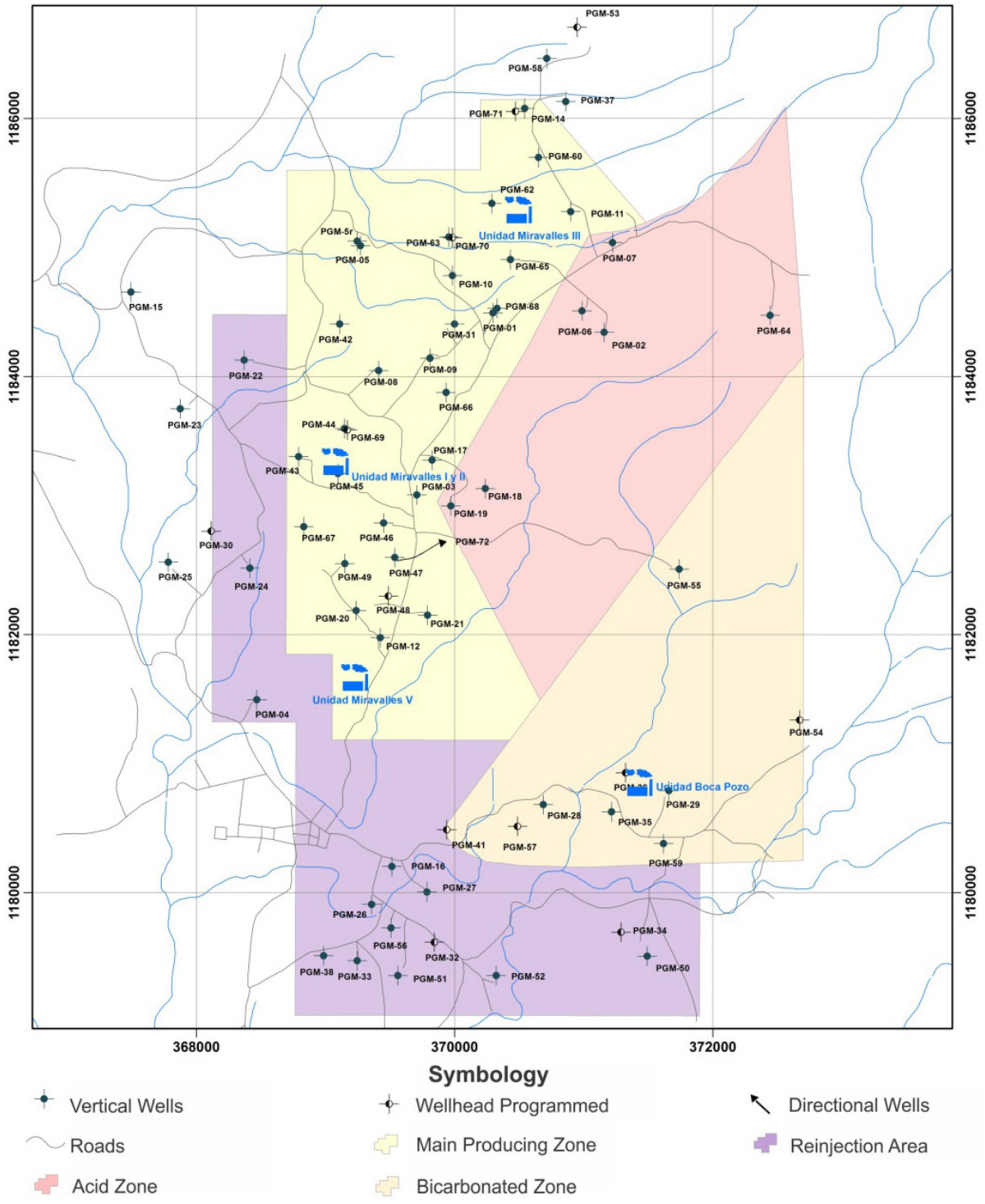

FIGURE 3: Location of wells and chemical zoning within Miravalles Geothermal Field

The bottoming cycle involves some limitations in the operations and logistics of reinjection in the entire Miravalles field, because if the temperature of the output fluid is less than 130°C it would result in greater cooling in the reservoir, which should be compensated for with reinjection in far away places, resulting in a decrease in the pressure of the system.

3.3 Backpressure unit

In November 1994, a backpressure unit was also installed which is fed by a single well (PGM-29) and provided with a single separator with automated control. The PGM-29 presents different conditions from the rest of the geothermal reservoir; the non-condensable gases are higher than the average value in the rest of the field.

4. LAS PAILAS GEOTHERMAL FIELD (LPGF)

4.1 Unit 1

LPGF is located on the southern flank of the volcano Rincon de la Vieja. It is a binary power plant that came into operation in July 2011. It generates 42 MWe and provides 36 MWe to the system. The production system, like Miravalles Unit V, operates with a cycle of heat exchange with pentane as the working gas, however this plant has a higher generation capacity. It directly uses two-phase fluid with a total mass flow of 460 kg/s from the production wells (Moya and DiPippo, 2012). Before entering into the plant, the fluid is separated into brine and steam with a flow of 350 kg/s and 88 kg/s respectively to a temperature of 159°C and 6 bar absolute. The brine passes to the pentane preheater and the steam is directed to the heat exchanger to evaporate the pentane. After the process, the liquid is reinjected at a temperature of 140°C and the outgoing vapor is condensed at 45°C.

LPGF is not visually invasive because of its proximity to the Rincon de la Vieja National Park, its design is environmentally friendly, with no emissions except water vapor and CO_2, outgoing from the cooling towers and only a small loss of pentane.

The binary-type power cycle for high temperatures implies some limitations, since it requires use of the energy generated in its consumption. For Las Pailas this corresponds to approximately 6 MWe (14%), which is used in: the transfer of pentane, cooling towers and injection pumps. Additionally, the brine reinjection creates complications causing more wear on the mechanical pump seals.

Currently there are a total of 16 wells in this field: nine to production, five of injection and seven of monitoring. The aquifers in the area have a composition sodium-chlorinated of neutral pH, high salinity and low gases; average temperatures of 250°C and enthalpies between 979-1295 kJ/ kg (Vargas, 2013b).

4.2 Unit 2

Unit 2 is located on the south-southeast of Rincon de la Vieja volcano flanks, east of Las Pailas I. This unit will use flash steam technology and is projected to generate 55 MWe. The production stage for this unit is planned for 2018.

At the moment, there are four production wells and one injection well, this year the drilling of production and injection wells continues. Aquifers in the area have a composition of neutral sodium-chlorinated, high salinity and low gases similar at Las Pailas I and temperatures ranging from 215-255°C (Figure 4).

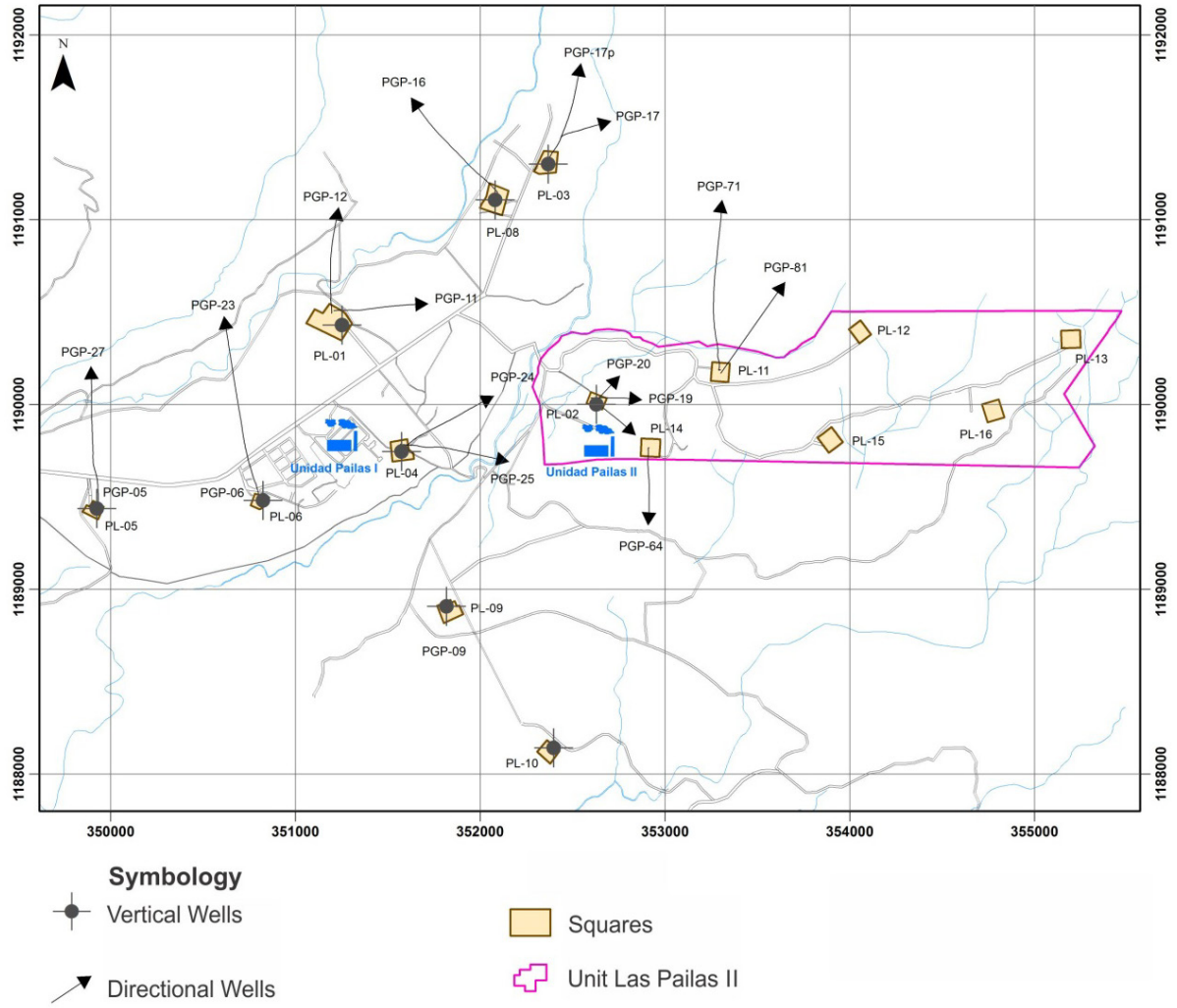

FIGURE 4: Location of wells for units I and II, Las Pailas Geothermal Field

5. BORINQUEN GEOTHERMAL FIELD (BGF)

BGF is located on the southwestern flank of the Rincon de la Vieja volcano. This field has a projection of 110 MWe total power generation and its development stage is planned for 2018.

4 wells have been perforated: three for production and one for injection. These wells are currently used for monitoring the thermohydraulic conditions and possible production. There are also studies on the distribution of the thermal anomaly, its relation to the structural patterns and fluid motion. The aquifers present high salinity, composition sodium-chlorinated, neutral pH, with a low gases and temperatures ranging between 230–240°C (Arias, 2014).

6. OTHER EXPLORATIONS

At present the C.S.R.G is developing the following geothermal exploration work:

Arenal-Poco Sol: The sector of interest is located 12 km south of the Arenal volcano, and is called the Poco Sol sector and is located in the margins of the Peñas Blancas river. For this area, reconnaissance was carried out in the beginning of 2011 covering an area of 690 km^2, with much of the area studied by means of remote sensing. Due to the favorable geological characteristics present in

the sector it is now in an advanced pre-feasibility phase, for which a geochemical study was performed, geological-structural mapping, recommendation of sites for perforating geothermal gradient wells and geophysical surveys (Rodríguez, 2002).

North of the Rincón de la Vieja volcano: In the beginning of 2009 the study of geothermal recognition (covering an area of 130 $km^{2)}$ was concluded, including surface geological features and geochemical surveys of thermal and cold creeks.

North of the Tenorio volcano: This area has been in the recognition stage since 2008 by geochemical sampling of emerging springs.

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