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Costa Rica Country Update Report

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ABSTRACT

Electricity generation in Costa Rica is produced mainly from renewable sources, producing mostly over 91% in the last 12 years and over 99% in the last 7 years with clean energy sources. Geothermal plays an important role in this achievement as it continues to provide a base load for the electrical system in Costa Rica. To date it accounts for around 14% of the total electrical generation of the country.

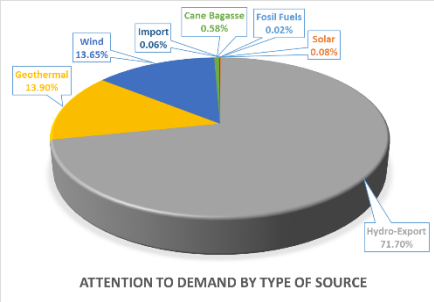
Since the commissioning of the first unit of the Miravalles Field in 1994, the installed capacity of geothermal energy in Costa Rica has reached 262 MWe or 7.3% of the total installed in the country, in 7 units spread in two geothermal fields (Miravalles and Pailas). A drilling program of 20 wells for the development of the first Unit of the Borinquen Geothermal Field (the first of two 50 MWe units) is taking place, in order to install the first of two planned units in 2027.

Considering the important investment made for geothermal development, the main challenge has been and is the sustainability of the different reservoirs, not only during the initial planned development period but also for any possible future expansion. Continuous strategies are being developed in order to secure the commercial exploitation of the Alfredo Mainieri Protti (formerly Miravalles) through repowering of the geothermal field by extending the useful life of the reservoir and the continuous monitoring of the Las Pailas Field.

Finally, a portfolio of geothermal projects, which comprises promising areas around the country to be developed in the next 40 years, continues to be revised and updated. This includes a review and update of the national assessment of geothermal resources.

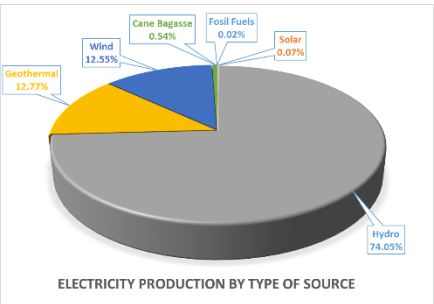
1. INTRODUCTION

Costa Rica has a good potential of renewable energies and is completely committed in the environmental friendly philosophy. During 2021, attention to the demand of electricity at the national level was met with a 99.92% of renewable resources. The five Central America countries and Panama share a regional market under the “Sistema Eléctrico Regional” (Regional Electric System) where each country sells or buy electricity when needed. In these conditions, during 2021 Costa Rica produced more energy than it consumed: 99.98% of the total energy produced came from removable sources like geothermal, hydro, solar and wind power plants. 7.3% of the installed capacity of the country is geothermal but 12.8% of the total energy generated came from geothermal. Figures 1-3 show the accumulated numbers for the year 2021 (CENCE, 2022).



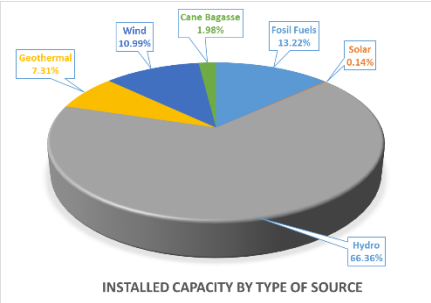
Source	Generation (%)	Generation (GWh)
Fosil Fuels	0.02	2.86
Solar	0.08	9.16
Hydro-Export	71.70	8261.61
Geothermal	13.90	1601.73
Wind	13.65	1573.30
Cane Bagasse	0.58	67.31
Import	0.06	6.55
Total		**11522.52**

Figure 1: Attention to Electricity Demand with Renewable Sources (2021).



Source	Generation (%)	Generation (GWh)
Fosil Fuels	0.02	2.86
Solar	0.07	9.16
Hydro	74.05	9285.71
Geothermal	12.77	1601.73
Wind	12.55	1573.30
Cane Bagasse	0.54	67.31
Total		**12540.07**

Figure 2: Electricity Production by Type of Source (2021).



Source	Installed Capacity (%)	(MWe)
Fosil Fuels	0.13	474.00
Solar	0.00	5.00
Hydro	0.66	2379.00
Geothermal	0.07	262.00
Wind	0.11	394.00
Cane Bagasse	0.02	71.00
Total		**3585.00**

Figure 3: Installed Capacity by Type of Source (2021).

2. GEOTHERMAL RESOURCES AND POTENTIAL IN COSTA RICA

At the end of the 1980's a study of the country's geothermal capacities was completed (ICE, 1991), showing a possible distribution of high, moderate and low temperature resources. This study showed a possible potential in the country of around 986 fed by the reserves and 2240 MWe fed by the resources, based on the available information and subsequent interpretations.

However, this is a very old study and today numbers for the geothermal potential of the country can differ. The technology has evolved in the past 28 years and the level of knowledge is superior now. A national level study in order to update the true geothermal potential of Costa Rica was conducted during 2021-2022, and the results are soon to be published. Figure 4 shows an updated temperature map of Costa Rica with the most important geothermal prospects.

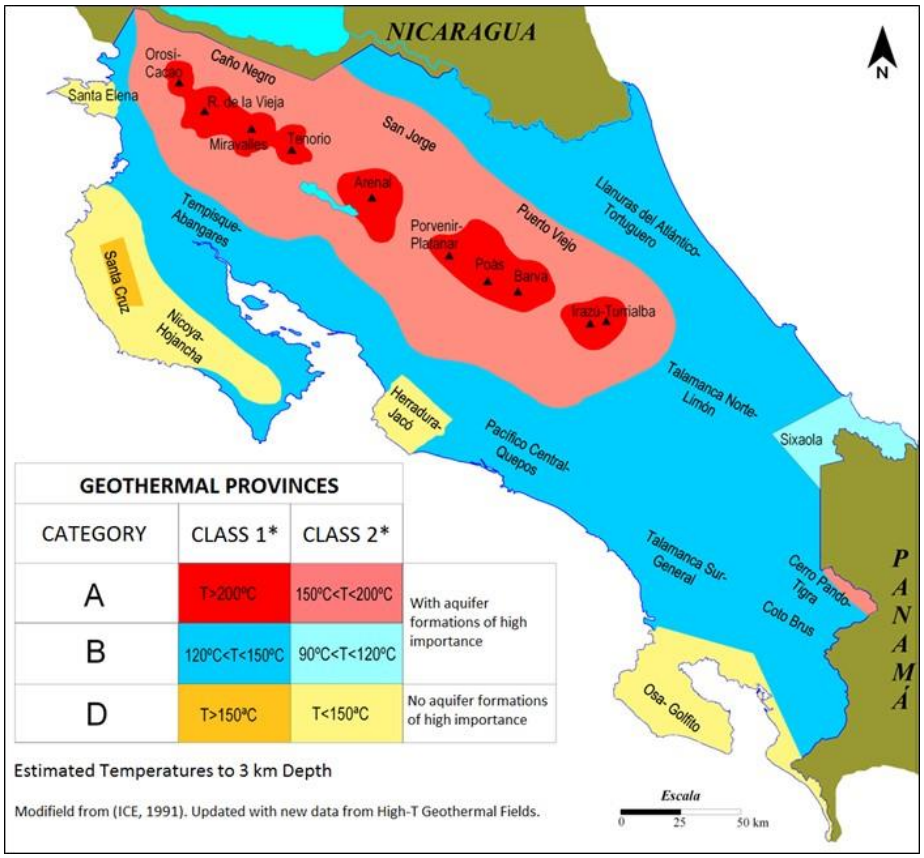


Figure 4: Estimated temperature map of Costa Rica (at 3 km depth) [Modified from ICE, 1991].

3. ELECTRICAL GENERATION BY GEOTHERMAL ENERGY IN COSTA RICA

Geothermal energy in the country is used for electrical generation by the power plants complexes at the Miravalles and Las Pailas fields (Figure 5). Due to its strategic importance in the present and future energy supplies for the country, the sustainability of those fields is considered and issue of special relevance.

The geothermal installed capacity accounts for about 7.3 % of the country's total installed capacity; however, it represents around 12.8% of the country's total generation.

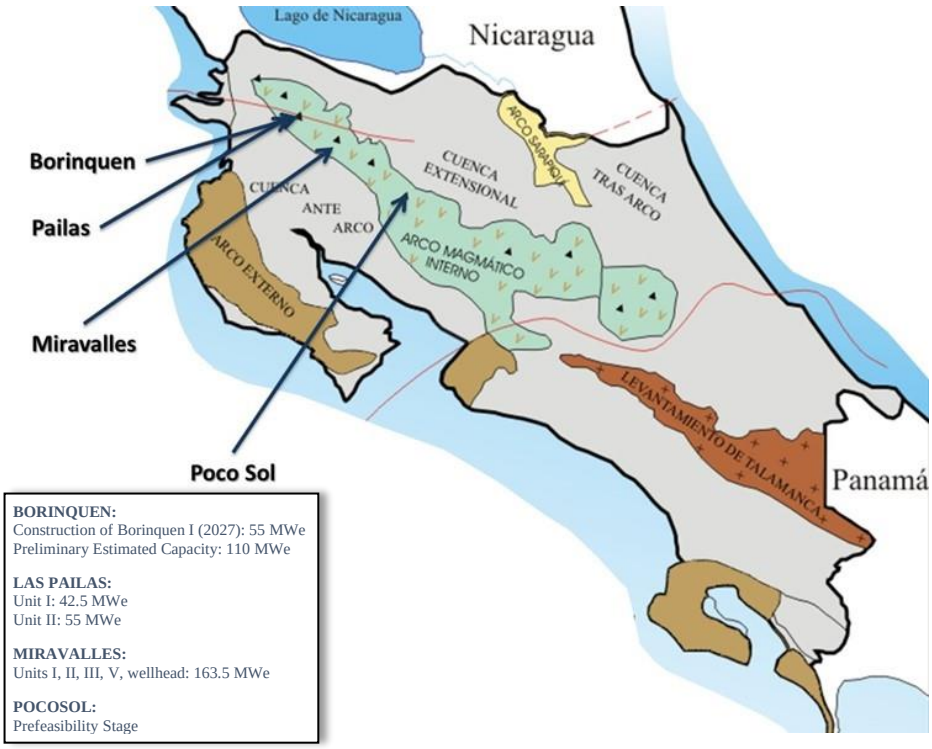


Figure 5: Geothermal development in Costa Rica

3.1. THE MIRAVALLES GEOTHERMAL FIELD

The Miravalles Field is the more developed and the higher producer of the geothermal fields in Costa Rica. The total installed capacity is of 163.5 MWe coming from five power units (Figure 6). The first unit was commissioned in 1994 and the last one in 2003.

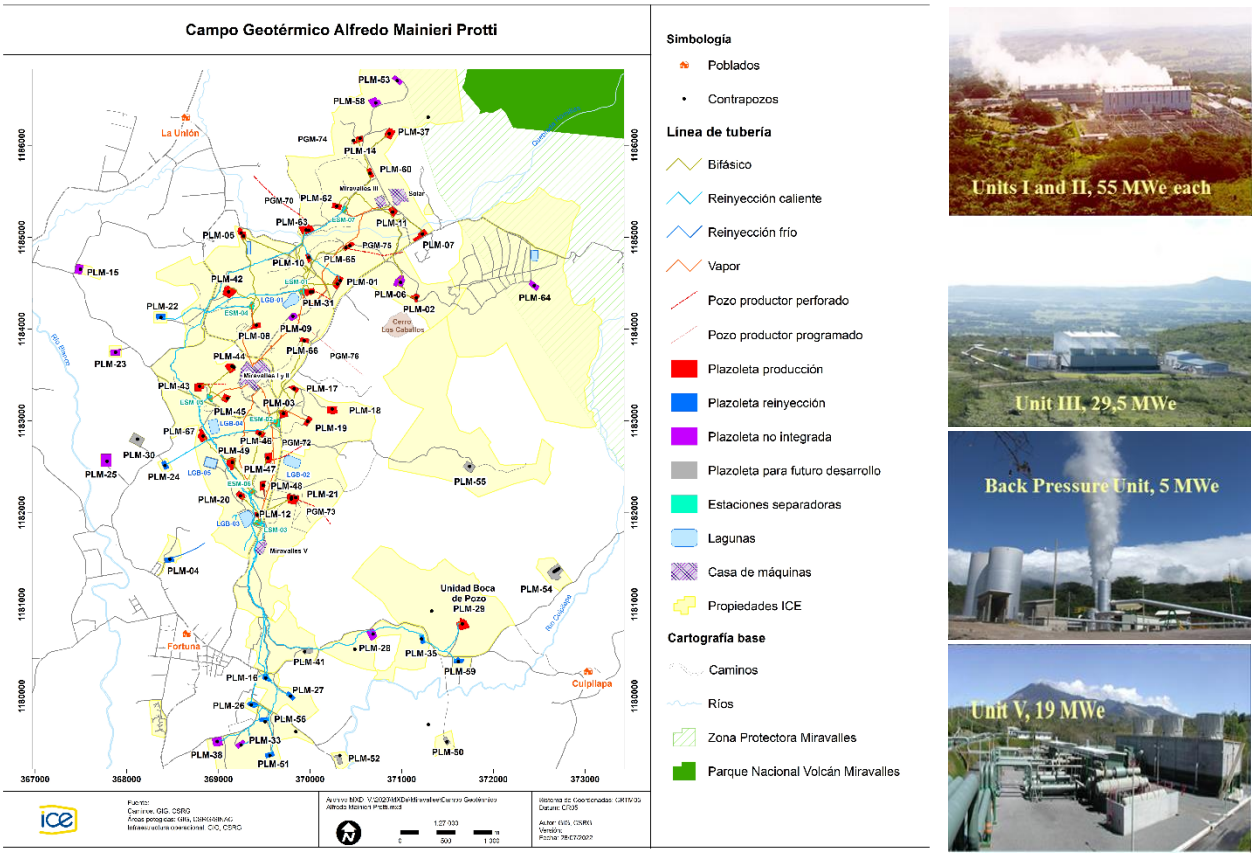


Figure 6: General View of the Miravalles Geothermal Field (Installations).

The Miravalles Complex comprises five power units in four different power houses (4 flash units and one binary), seven separations stations, a 48 km pipeline network, 61 wells (production, injection and observation) and a series of artificial ponds aimed for cold injection, maintenance operations and emergencies. Continuous monitoring of the geochemical and thermo hydraulic parameters of the field and extensive reservoir simulation are important tasks done at Miravalles. The actual knowledge of the reservoir and the evolutions trend observed has headed to conclude that the Miravalles field has actually reached its maximum extraction rates at the already developed areas. There are still some zones under exploration which can help to solve the production decline observed in the main aquifer, and in a future to evaluate an expansion of the field if it is proven that these other zones are independent and not following the same declining rates as the main aquifer. Some actions taken in order to stabilize the field production and reach the maximum field productive levels were and are currently implemented or will be done in the near future such as repowering the Miravalles units on 2030, and 2031 (Units I, II and III).

3.2. THE PAILAS GEOTHERMAL FIELD

The Pailas Field supplies 97.5 MWe with two power plants (Figure 7). Pailas I unit was officially commissioned on 2011with 42.5 MWe gross and 35 MWe net power plant, Ormat two-module combined cycle binary plant where the steam is sent to the vaporizers and the brine is sent to the preheaters. The power cycle working fluid is N-pentane. To date Unit I comprises 20 production and injection wells and 13.9 km of pipeline network. Pailas II unit, a 55 MWe flash plant was officially commissioned on 2019 and works with 12 production wells and 9 injection wells located in 6 pads and 13.9 km of pipeline network.

Las Pailas II unit was designed with the newest concept for operational flexibility (each production pad connects directly to a separation unit and its own reinjection pad). The optimization of infrastructure was done to minimize the footprint, in order to preserve the majority of biodiversity of the area (a single road connects the vast majority of the pads, and is utilized as well to place the hot and cold pipelines). This project accounted for the highest and newest standard in ecological monitoring due to its closeness to the Rincon de la Vieja National Park.

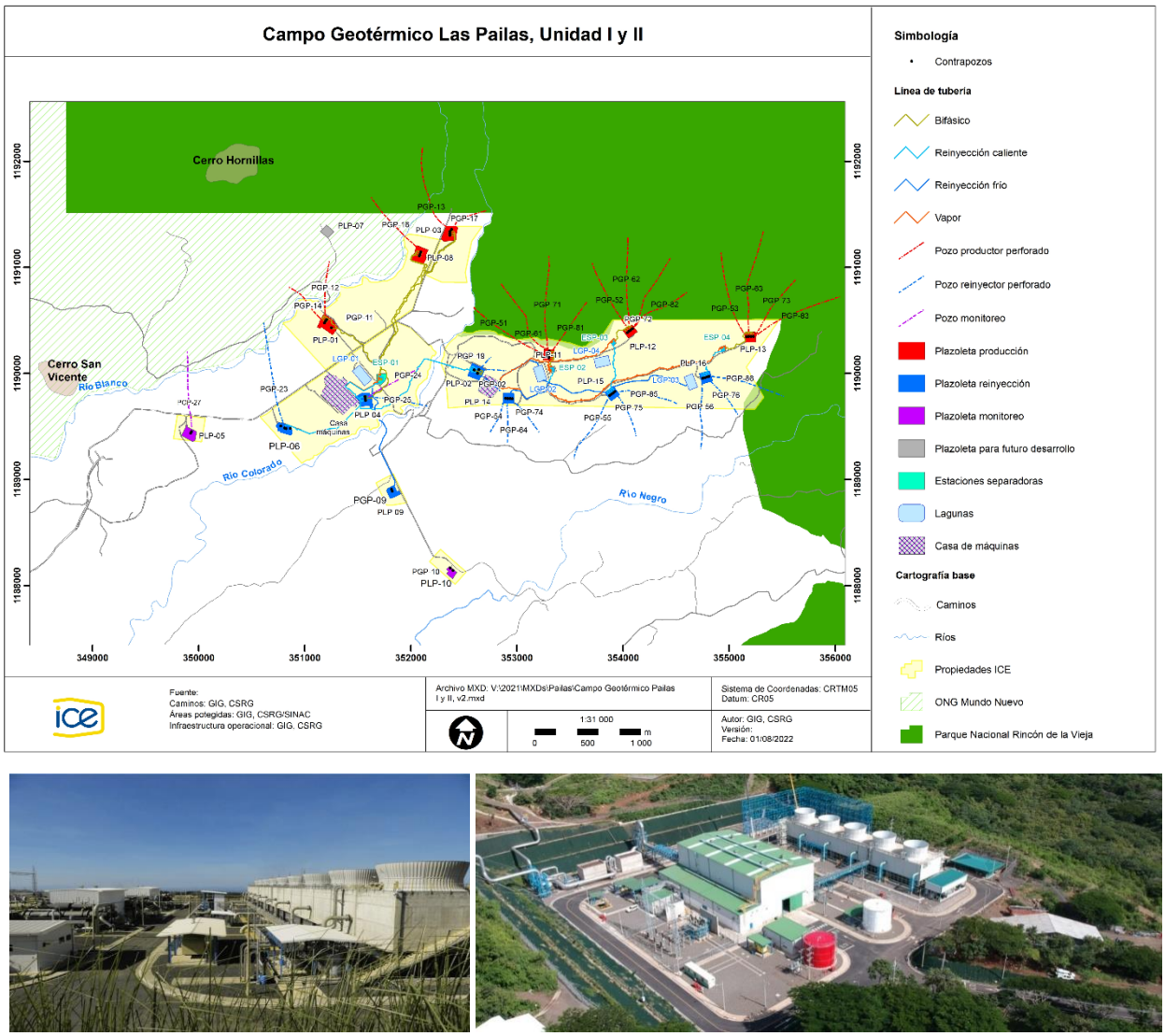


Figure 7: Unit I and II Installed at the Las Pailas Geothermal Field.

3.3. THE BORINQUEN GEOTHERMAL FIELD

Located on the southwest flank of the volcano Rincon de la Vieja, this field is projected to have a generation of 110 MWe gross power (by Volumetric Assessment and Monte Carlo simulations) and is currently on intensive development (Figure 8). The commissioning of the first unit (55 MWe each) is expected to be on 2027 and the second unit in a future date to be set. The aquifers already identified are neutral sodium-chlorinated with high salinity content (higher than Miravalles and Las Pailas Fields), low gases content and temperatures ranging from 230-273 °C. At this moment, 10 wells have been drilled. These wells are currently used to monitor the thermal-hydraulic conditions and possible production conditions.

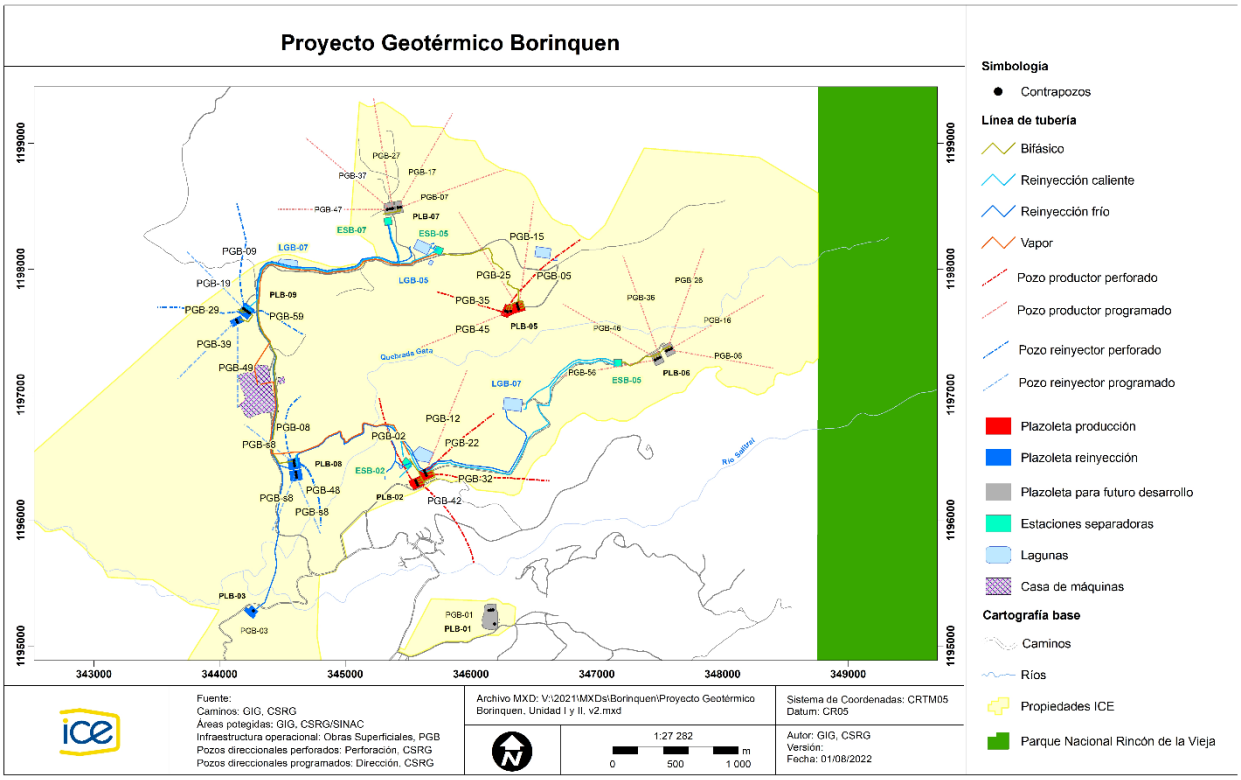


Figure 8: General View of the Borinquen Geothermal Field.

Studies on the distribution of the thermal anomaly, its relationship to the structural patterns and movement of fluids are also developed. There is a conceptual model developed and a numerical model is currently in development (Figure 9) (DEYG, 2021; Arias & Garrido, 2022; Garrido, 2021; Modified from West JEC, 2022). Funds for the development of this field are already committed.

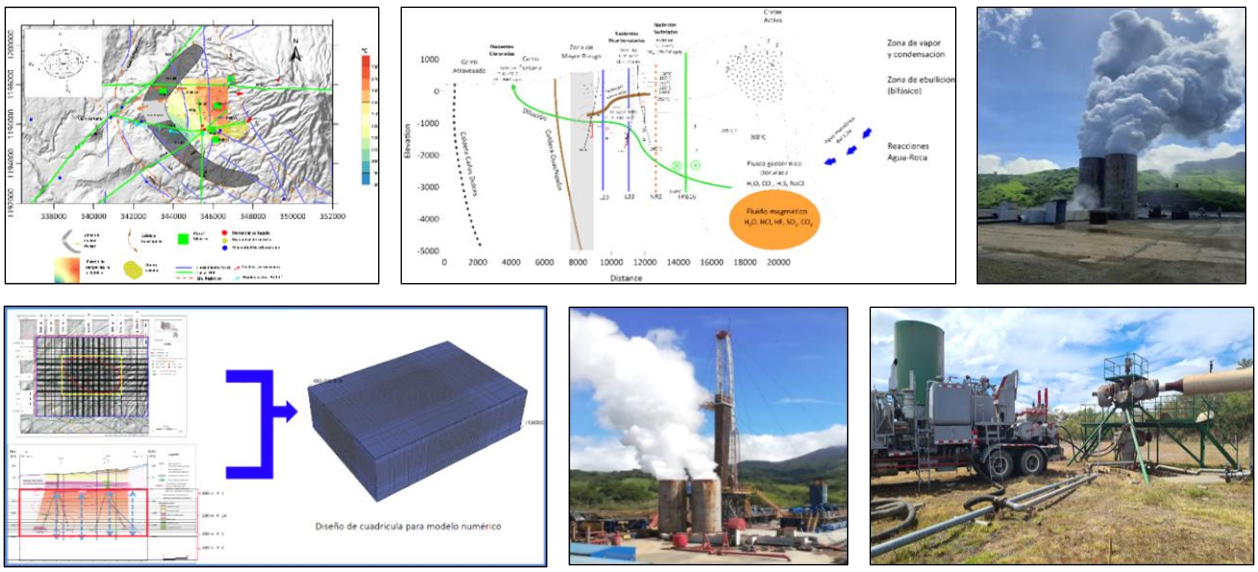


Figure 9: Different Aspects of the Borinquen Geothermal Field.

3.4. OTHER GEOTHERMAL SITES OF INTEREST

Currently there are some developing works in geothermal exploration in other promising geothermal areas around the country:

Arenal - Pocosol: the sector under investigation is located 12 km south of the Arenal volcano, focused in the Pocosol sector, on the Peñas Blancas riverbanks. Exploration in this area occurred in early 2011, resulting in an area of 690 km2, much of this area studied using remote sensing. Due to favorable geological features in this area, an advanced feasibility was conducted including structural geological mapping, geochemical data, recommendation of sites for conducting geothermal gradient wells and geophysical surveys (Chavarría et al, 2011).

Northern part of the Rincón de La Vieja Volcano: in early 2009 the geothermal reconnaissance study (covering an area of 130 km2, Figure 17) including surface geological and geochemical survey of thermal springs and some cool was concluded (Chavarría et al, 2009[2]).

Northern part of Tenorio volcano: is in the stage of recognition from 2008 through geochemical sampling of hot springs. The area of interest includes the northern section of Tenorio Volcano National Park and a large area located east of Bijagua, specifically the towns of San Miguel, Las Flores, Los Chorros, Chimurria Arriba and Olla de Carne Hill (Figure 18). This is an area of 198 km2 (Chavarría and Fajardo, 2009).

3.5. GEOTHERMAL DEVELOPMENT PLANS

Continued use of geothermal fields has produced a long-time wear on mechanical equipment, and an impact on the geothermal reservoirs that is difficult to avoid. With the intention of extending the life of the different geothermal fields and repowering both these and the geothermal power plants, plans have been drawn up to ensure their life at least by 2060.

In that sense, the evolution of the reservoirs have been studied and production scenarios have been drawn up. The useful life of the power plants and the possible financing schemes for the replacement or refurbishments of the plants have been considered. The possible scenarios of growth of the country's energy demand, the existing power generation plants and future expansion plans of other energy sources were also considered. Finally, a master plan for geothermal resources was drawn (Table 1).

TABLE 1. MASTER PLAN FOR GEOTHERMAL DEVELOPMENT (UNTIL 2060)

	Projet	Locatión	Capacity MW	Stages	Until	Comments
Exploitation	Miravalles Unit I	Miravalles Volcano, Guanacaste	55	Commercial operation since 1994	2030	Repowering by 2032-2060 with power adjustment to 35 MW
	Wellhead Unit	Miravalles Volcano, Guanacaste	5	Commercial operation since 1995	2030	Continuing operation 5 MW
	Miravalles Unit II	Miravalles Volcano, Guanacaste	55	Commercial operation since 1998	2030	Repowering by 2033-2060 with power adjustment to 35 MW
	Miravalles Unit III	Miravalles Volcano, Guanacaste	29.5	Commercial operation since 2000	2030	Repowering by 2033-2060 with power adjustment to 26 MW
	Miravalles Unit V	Miravalles Volcano, Guanacaste	6	Commercial operation since 2003	2031	Binary system, bottoming cycle, operating until 2031
	Pailas Unit I	Rincón de la Vieja Volcano, Guanacaste	42.5	Commercial operation since 2011	2036	Optimization of reservoir exploitation strategies in development
	Pailas UnitII	Rincón de la Vieja Volcano, Guanacaste	55	Commercial operation since June 2019	2054	Optimization of reservoir exploitation strategies in development (related with Pailas Unit I)
Development	Borinquen Unit I	Rincón de la Vieja Volcano, Guanacaste	55	To be commissioned by 2027	2061	Project has environmental impact study, technical study and financing (Project is under development)
	Borinquen Unit II	Rincón de la Vieja Volcano, Guanacaste	55	Date pending	2065	Project has environmental impact study, technical study and financing (Commissioning in a future date to be decided)
Feasibility	PLB-01	Rincón de la Vieja Volcano, Guanacaste	12	Advanced Feasibility	30 years	Available for the Electrical Expansion Development Plan, period 2030 - 2060
	PLM-55	Miravalles Volcano, Guanacaste	12	Advanced Feasibility	30 years	Available for the Electrical Expansion Development Plan, period 2030 - 2060
	PLM-54	Miravalles Volcano, Guanacaste	12	Feasibility	30 years	Available for the Electrical Expansion Development Plan, period 2030 - 2060
Reconnaissance	Rincón de la Vieja Norte	Rincón de la Vieja Volcano, Guanacaste	35	Recconaissance	35 years	Available for the Electrical Expansion Development Plan, period 2030 - 2060
	Orosí	Orosí – Cacao Sector, Guanacaste	35	Recconaissance	35 years	Available for the Electrical Expansion Development Plan, period 2030 - 2060
	Poco Sol	Arenal – Poco Sol Sector, Alajuela	35	Recconaissance	35 years	Available for the Electrical Expansion Development Plan, period 2030 - 2060
	Irazú	Irazú-Turrialba Sector, Cartago	35	Recconaissance	35 years	Available for the Electrical Expansion Development Plan, period 2030 - 2060

3.6. DIRECT USE

The use of this type of resource is limited to low temperature forms in hotel pools dedicated to ecological tourism (Figure 10). Local factors have discouraged the use of these resources, like the favorable climatic conditions and the incipient industrial development of geothermal resources in the country. In summary, with the exception of small domestic applications, currently there are no other uses known of direct use outside ICE.

Figure 10: Pools and Spas around Costa Rica (not a detailed map).

It is unknown how many pools and spas are around the country at this moment, neither the individual consumption of every one of them, so an estimation of the corresponding production of energy is not possible.

Power posts Factory: Power poles of ICE for use in the whole country were made at Miravalles, taking a fraction of the steam produced by the well PGM-45 (Figure 11). The steam entered at a temperature of 80-90 ° C, reducing the setting time of cement in three hours. The plant had a production rate of 8 poles/day (Arias et al, 2013). It was retired from production around 2016-2017.

Figure 11: power posts factory at the Miravalles Field.

Since the utilization of this factory is on demand, its utilization is variable every year.

Other Projects: The Deutsche Gesellschaft für Internationale Zusammenarbeit (German Society for International Cooperation - GIZ) has been developing some projects in Central America, in order to promote the use of the geothermal energy for direct uses. One of them is the Geothermal Heat Utilization Project in Industrial Processes in the Member Countries of the Central American Integration System (SICA). There are at least two different projects identified and/or in develop: a Geothermal Direct Use for a Crop Drying Center in Costa Rica (GIZ, 2020) and a project to take advantage of the geothermal resource available at a hotel direct uses to increase energy efficiency (Alfaro, 2021 and UCR, 2021). None of these projects has been completed.

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