Costa Rica Country Update Report

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ABSTRACT

Since the last Costa Rica's country update report presented in 2015, geothermal development and exploration in the country for electrical generation purposes have grown exponentially. The past few years, geothermal exploration and development in Costa Rica for electrical generation purposes have had an important impulse. Since the country's energetic policies are mainly based on renewable energy sources in order to decrease the CO_2 emissions, and face climate change effects, geothermal energy continues to provide a base load for the electrical system in Costa Rica and to date is producing around 16.00% of the total electrical generation of the country.

The Dr. Alfredo Mainieri Protti Geothermal Field (formerly The Miravalles Geothermal Field, 154.5 MWe) continued its productivity rate in stable conditions and the first unit of Pailas Geothermal Field (42.5 MWe) completed eight years producing continuously since year 2011. The second unit in Pailas of 55 MWe saw its commissioning in July 2019. A drilling program of 20 wells for the development of Borinquen I (first of two 55 MWe units) is taking place.

Considering the important investment for geothermal development, the main challenge has been the sustainability of the reservoir, 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 through repowering of the geothermal field by extending the useful life of the reservoir.

Finally, a portfolio of geothermal projects was designed comprising areas around the country to fulfill the electricity expansion requirements until 2040.

1. INTRODUCTION

As a totally committed environmentally friendly country, electrical generation in Costa Rica relies almost completely on renewable sources of energy. By August 2019, 7.00% of the total electrical installed capacity is geothermal (

Figure 1), representing around 16.00% of the total energy delivered to the national electricity grid (Figure 2). The 97.94% of the total energy was produced from renewable sources, such as, geothermal, hydro, solar and wind power plants.

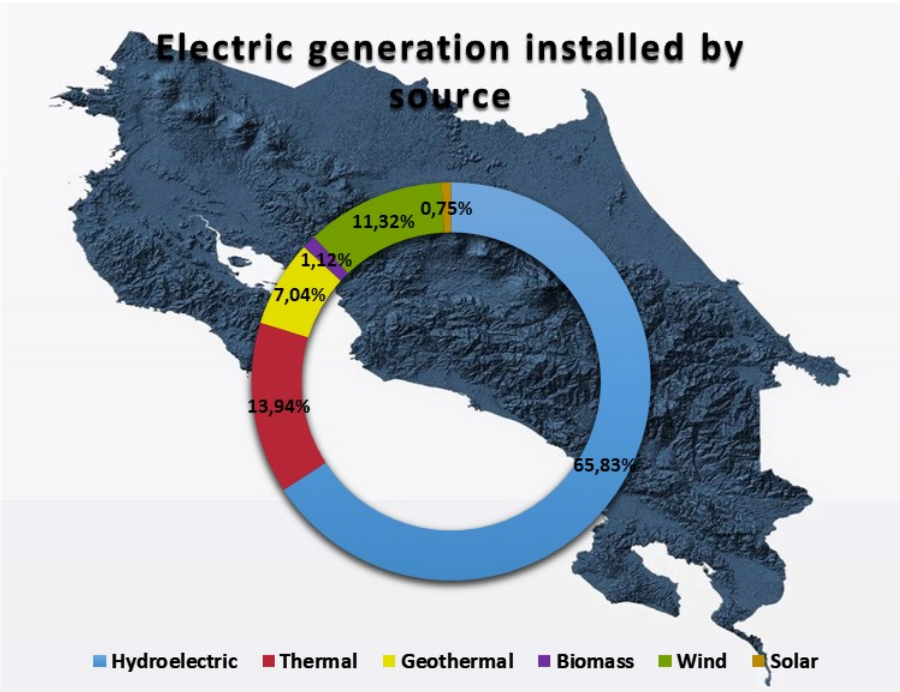

Figure 1: Installed electric generation by source in Costa Rica by august 2019. Modified after ICE (2019)

The electrical generation system in Costa Rica is organized as a regulated utility, where *Instituto Costarricense de Electricidad* (Costarican Electricity Institute) is legally mandated to fulfill the country's electricity needs. ICE is an autonomous institution of the government of Costa Rica, vertically integrated into generation, transmission and distribution divisions. Besides having the largest capacity in generation plants, its transmission network manages and distributes about 40 % of the total electrical energy generated. In the generation business, there are other companies involved. Private or independent generation through long-term contracts provides electricity to the ICE's generation system, while five of the other seven distributors in the country have their own generation plants to supply part of the demands of their customers. ICE participates for Costa Rica as the single agent in the Regional Electricity Market (Central America joined market). The *Autoridad Reguladora de los Servicios Públicos* (ARESEP The Regulatory Authority for Public Services) ensures the quality and price of public services provided by ICE and the other electric companies.

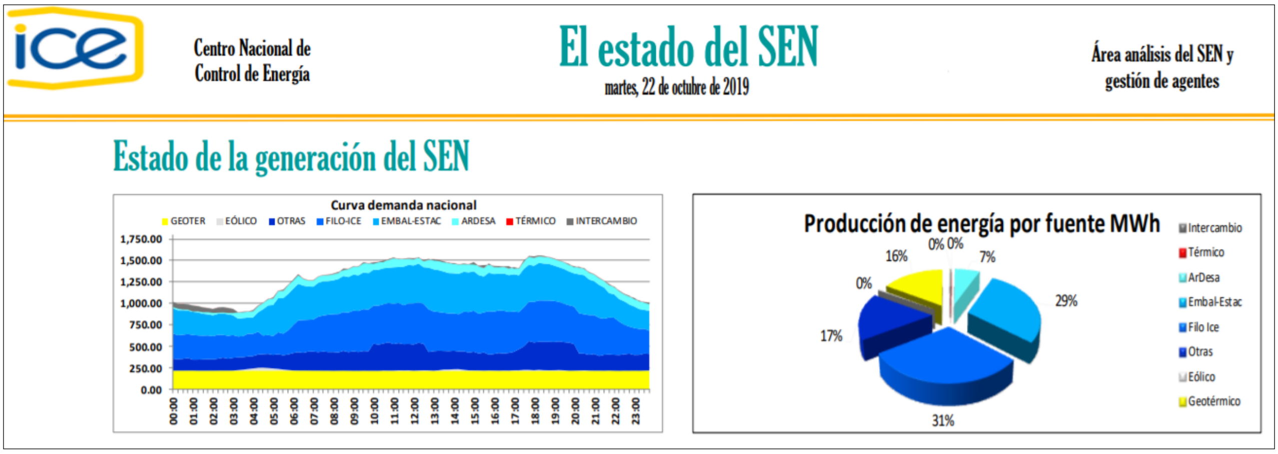

Figure 2: Energy delivered to the national electricity grid electricity production by source in Costa Rica by 22 October 2019. Modified after CENCE (2019a).

The system is organized under the *Sistema Eléctrico Nacional* (SEN, stands for "National Electricity System"). It consists of the Generation, Transmission and Distribution subsystems. All elements of the SEN are fully interconnected in a single transmission system. The generation of electricity, in Costa Rica, is made by 6 public companies and 32 private companies.

Taking into account the possible energy needs of the country in the coming years, ICE will develop an expansion plan for energy generation and distribution. This plan is reviewed every year. The latest recommended expansion plan (2018 - 2034) includes the construction, modernization and removal of several plants for a total of 546 MWe (up to a capacity of 4076 MWe at the end of 2034). This plan corresponds to the working program necessary to meet the average demand scenario. The present value of the Plan for the period 2019-2034 is USD 2184 million, of which USD 1916 million correspond to the investment costs, USD 260 million to the operating costs and USD 7 million to the energy costs not supplied (ICE, 2019).

2. GEOTHERMAL RESOURCES AND POTENTIAL IN COSTA RICA

By 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 of around 1000 MWe for Costa Rica, based on the available information and subsequent interpretations (Table 1).

Table 1: Geothermoelectric installable capacity in Costa Rica.

	Capacity that can be fed by the reserves (1)			Capacity that can be fed by the resources (2)			Priority Group
	Single Flash	Double flash	Average	Single Flash	Double flash	Average	
Miravalles	164	213	189	330	437	384	I
Rincón de la Vieja	137	177	157	284	375	330	
Irazú-Turrialba	101	130	115	223	291	257	II
Tenorio	97	123	110	215	278	247	
Platanar	97	122	109	210	272	241	
Poás	90	116	103	189	249	219	
Barva	85	109	97	186	243	214	
Fortuna	61	77	69	139	179	159	III
Orosí-Cacao	33	41	37	71	92	81	
Other Areas (3)	--	--	-	99	118	108	IV
TOTAL	865	1108	986	1946	2534	2240	

(1) Accessible resources that for a specified reference depth can be legally extracted and economically utilized according to current and "short term" energy costs (within 10 years after the assessment).
(2) Accessible resource base that for a specified reference depth. can be legally extracted and economically utilized according to energy costs assumed to be valid in a future time (between 10 and 25 years after the assessment).
(3) Caño Negro, Liberia San Jorge, Tilarán, Puerto Viejo, San José, La Tigra.

However, this is as denoted, a very old study and today estimates for the geothermal potential of the country can differ. The technology has evolved in the past 28 years and the level of knowledge in exploration and development is superior according to new techniques and approaches. There are plans to conduct a national-level study in order to update the geothermal potential of Costa Rica. The first approximation is shown in Figure 3 as an attempt to update the estimated temperature map of Costa Rica.

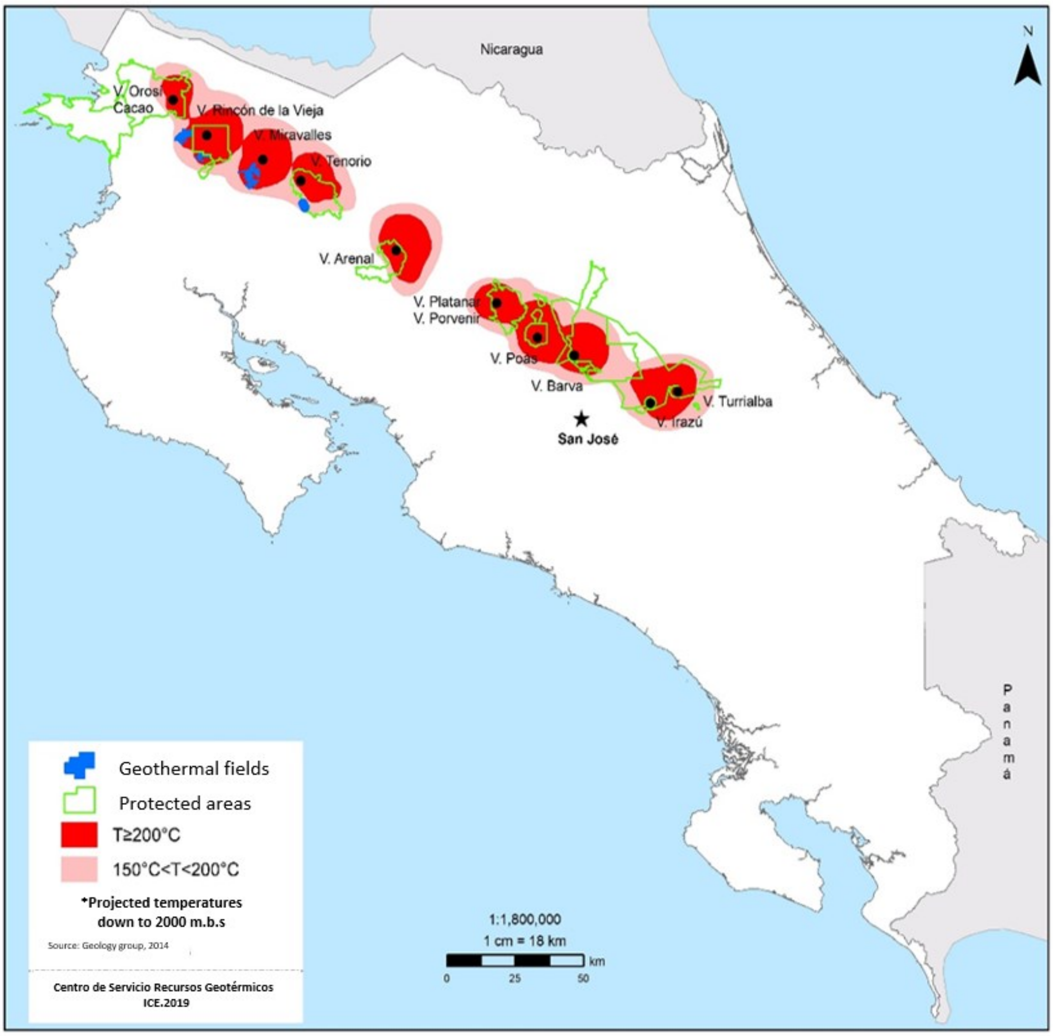

Figure 3: Estimated temperature map of Costa Rica (at 2 km depth). ICE (2019).

3. ELECTRICAL GENERATION BY GEOTHERMAL ENERGY IN COSTA RICA

Today the main geothermal potential in the country is used for electrical generation by the power plants located in the Miravalles and Pailas fields (Figure 4). Due to its strategic importance in the present and future energy supplies for the country, the sustainability of those fields is considered an issue of special relevance.

The geothermal installed capacity accounts for about 7.00 % of the country's total installed capacity; however, it represents around 16.00% of the country's current total generation. This difference is due to geothermal plants plant factor, since they produce constantly throughout the year-round, and its production is not vulnerable to the climate change effects so they are being used as a baseload for the country's electrical generation (hydro electrical plants production are sensible to seasonal variations of Costa Rica's weather). This can be seen in Figure 5. Geothermal and hydro-electrical power plants are intensively used to generate instead of using thermal power plants as a commitment to carbon-neutral policies implemented in the country. Also it is important to note that since ICE is the biggest seller of the electricity to the end-users, its final price is directly related to the averaged cost of all energy sources. For this reason, the substitution of the most expensive generation sources with geothermal (and other cheaper energy sources) is considered as an issue of high importance for the economy of the country.

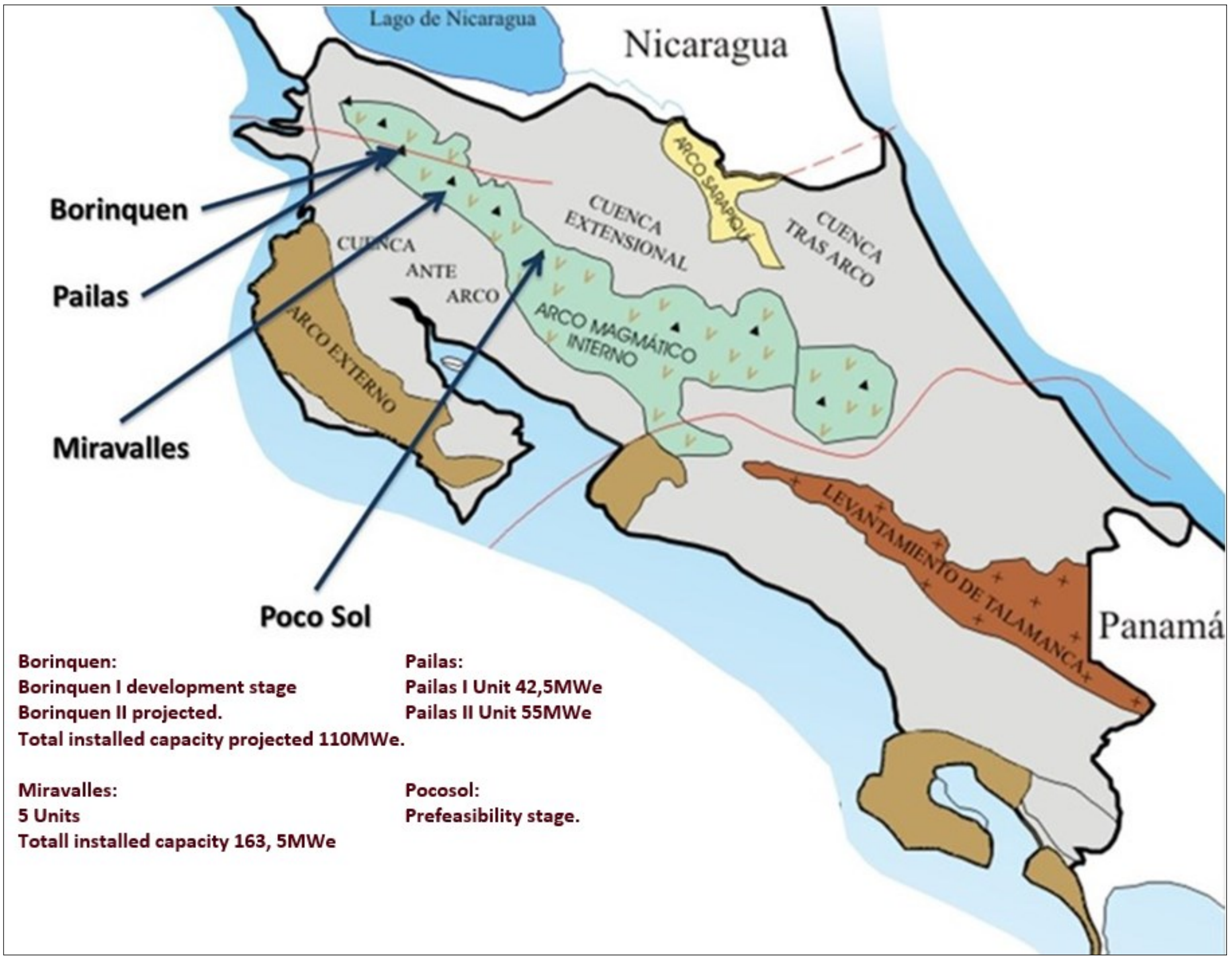

Figure 4: Geothermal developments in Costa Rica.

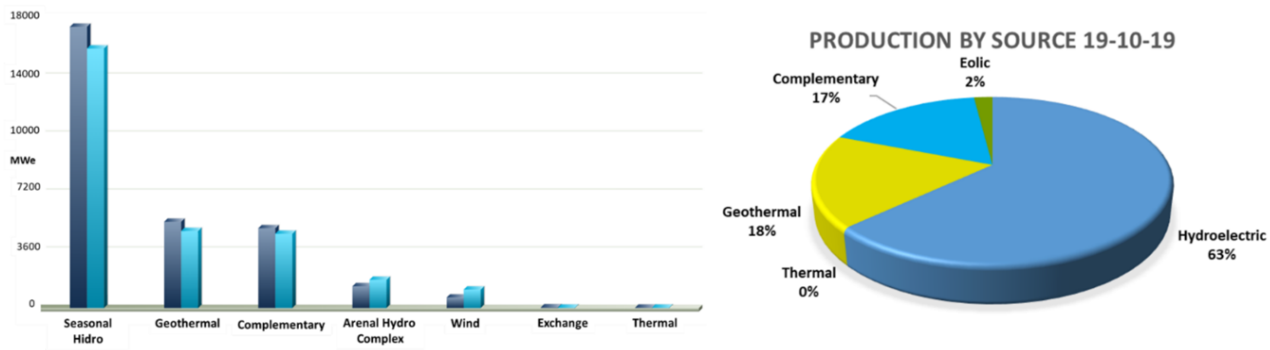

Figure 5: Left: Production by source in MWe by October 19, 2019. Right: Distribution by source by October 19, 2019. CENCE (2019b).

3.1. THE MIRAVALLES GEOTHERMAL FIELD

The Miravalles Field is the highest developed and productive of the geothermal fields in Costa Rica. The total installed capacity is of 154.5MWe distributed in five power units (Figure 6).

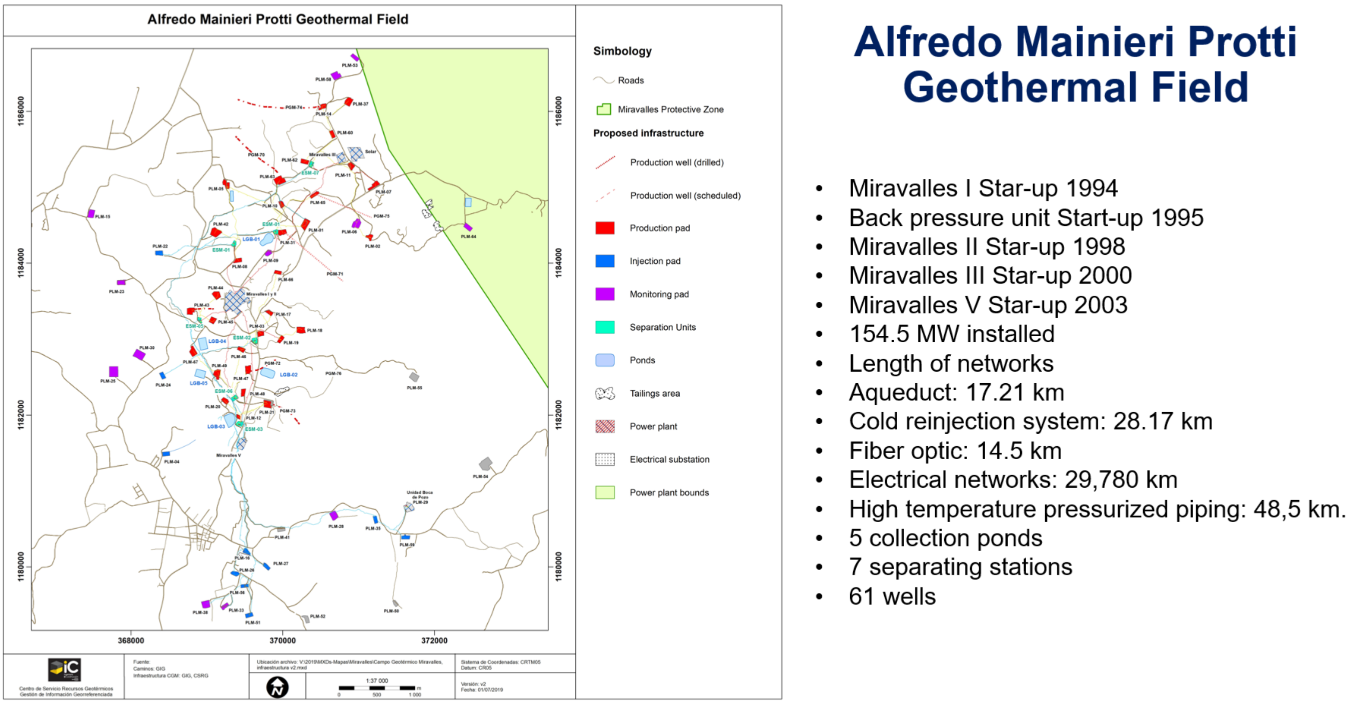

Figure 6: General View of the Dr.Alfredo Mainieri Protti Geothermal Field.

The Miravalles Complex comprises five power units in four different powerhouses, seven separations stations, 48.5km of pipelines, 61 wells (production, injection, and observation) and a series of artificial ponds aimed for cold injection, maintenance operations and containment of emergencies. Continuous monitoring of the geochemical and thermohydraulic parameters of the field and extensive reservoir simulation are important tasks done at Miravalles. The current knowledge of the reservoir and the trend of the evolution observed has headed to conclude that the Miravalles field has actually reached its maximum extraction rates at the already developed areas. Some actions taken by ICE in order to stabilize the field production and reach the maximum field productive levels are currently implemented or will be done in the near future, such as repowering the Miravalles units on 2028, 2029 and for 2030 (Units I, II and II respectively).

3.2. PAILAS GEOTHERMAL FIELD

With 42.5 MWe gross and 35 MWe net power plant, Pailas I unit was officially commissioned on July 24, 2011 (Figure 7). To date Unit I comprises seven production wells and four injection wells. Aquifers in the area have a composition of neutral sodium-chlorinated, high salinity, low gases and temperatures ranging from 240-255°C.

The project was developed under the “leasing with option to buy” scheme, where the Banco Centroamericano de Integración Económica (Central American Bank for Economic Integration) owns the plant and leases to ICE for a 12 years period. After that time, ICE will buy the power plant. The US$160 Million power plant built is a 42.5 MWe 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.

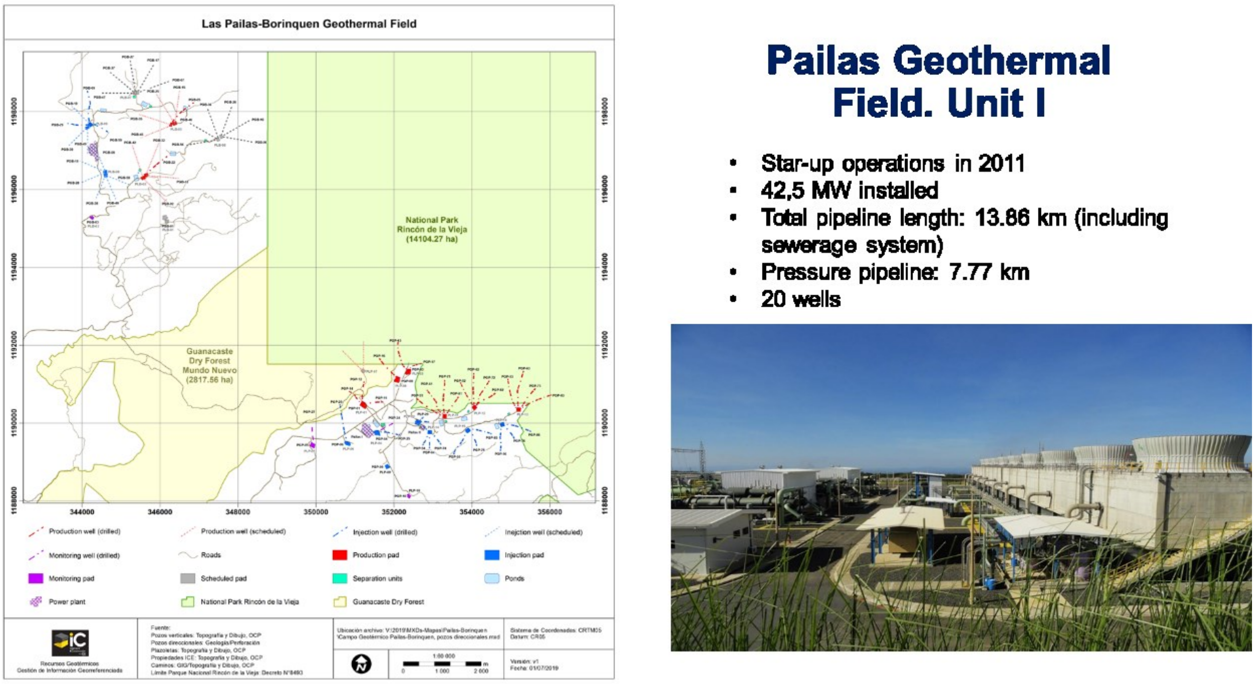

Figure 7: Pailas I Unit, a 42.5 MWe binary plant installed by 2011 at the Pailas Geothermal Field.

Located to the east of the first power plant of the area, is Pailas II unit, a 55 MWe flash plant (Figure 8). It was officially commissioned on July 23, 2019 and works with 12 production wells and 9 injection wells, located in 6 pads. Aquifers in the area have a composition of neutral sodium-chlorinated, high salinity, and temperatures up to near 270°C.

Las Pailas II unit was design with the newest concept for operational flexibility (each production pad connects directly to a separation unit and its own reinjection pad), optimization of infrastructure to minimize the footprint, in order to preserve the majorority 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 with a unique technique denoted as "Biomonitoring through DNA" from insects collected from several places in the project.

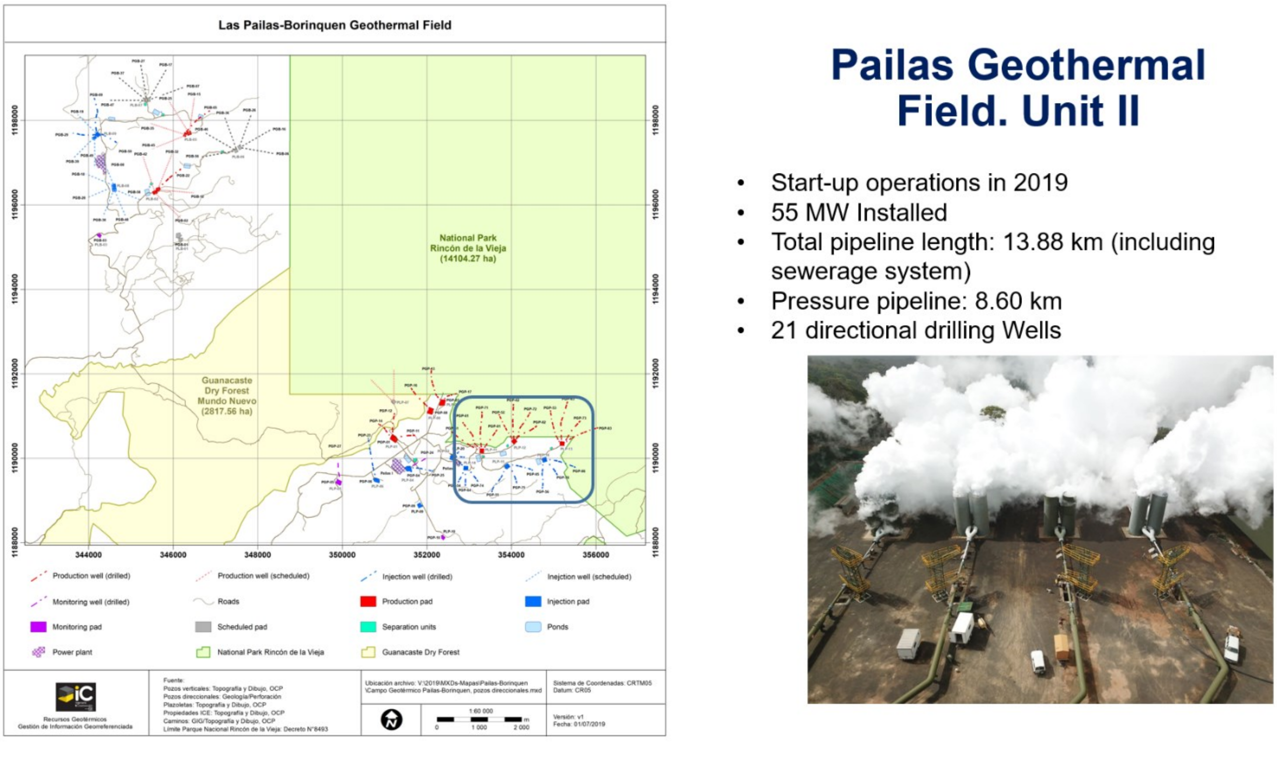

Figure 8: Pailas II Unit, a 55 MWe flash plant installed by 2019 at the Las Pailas Geothermal Field.

3.3. BORINQUEN GEOTHERMAL FIELD

Located on the west flank of the volcano Rincon de la Vieja, this field is projected to have a generation of 110 MWe gross. Intensive development started by 2018 (Figure 9) with funds from JICA (Japan International Cooperation Agency). The final commissioning of Borinquen I unit (55 MWe flash plant) is expected by 2026, and by 2030 Borinquen II unit. The aquifers already identified are neutral sodium-chlorinated with high salinity content, and temperatures ranging from 240-273 °C. At this moment 8 wells have been drilled, of which, three wells are producers and four re-injectors (one is destined for the second unit and one is an observation well). These wells are currently used to monitor the thermal-hydraulic conditions and possible production conditions.

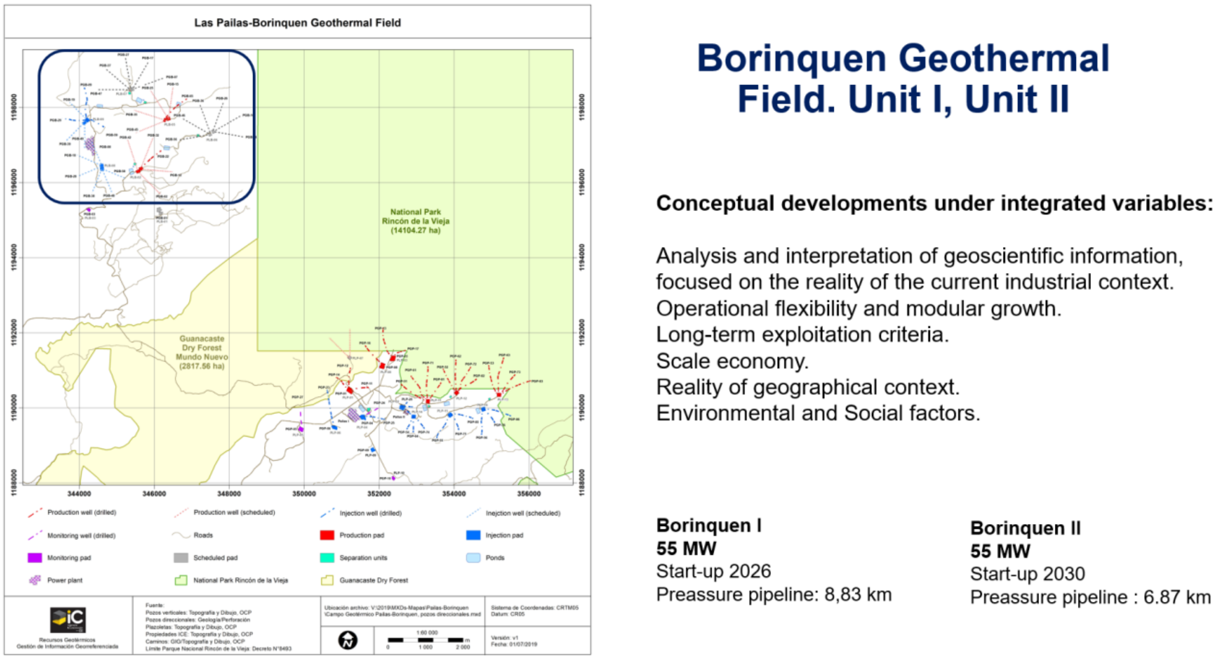

Figure 9: General View of the projected Borinquen Geothermal Field.

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 km^2, 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 km^2, 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 km^2 (Chavarría and Fajardo, 2009).

3.5. Geothermal development plans

With the intention of extending the life of the different geothermal fields and repowering both these and the geothermal power plants, a plan has been drawn up to ensure their use until 2060.

Also, the evolution of the reservoirs has 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 was drawn (Table 2).

Table 2 Portfolio of geothermal projects for the Electricity Expansion Plan (Until 2060)

	Projet	Location	Capacity MW	Stages	Until	Comments
Exploitation	Miravalles Unit I	Volcán Miravalles, Guanacaste	55	Commercial exploitation since 1994	2030	Repowering by 2028-2060 with a potency adjustment to 35 MW
	Wellhead Unit	Volcán Miravalles, Guanacaste	5	Commercial exploitation since 1995	2030	Repowering by 2028-2060 with a potency of 5 MW
	Miravalles Unit II	Volcán Miravalles, Guanacaste	55	Commercial exploitation since 1998	2030	Repowering by 2028-2060 with a potency adjustment to 35 MW
	Miravalles Unit III	Volcán Miravalles, Guanacaste	29,5	Commercial exploitation since 2000	2030	Repowering by 2028-2060 with a potency of 29,5 MW
	Miravalles Unit V	Volcán Miravalles, Guanacaste	10	Commercial exploitation since 2003	2030	Binary system, secundary system
	Pailas Unit I	Volcán Rincón de la Vieja, Guanacaste	42,5	Commercial exploitation since 2011	2036	Repowering analysis pending
	Pailas Unit II	Volcán Rincón de la Vieja, Guanacaste	55	Commercial exploitation since 2019	2054	Optmization of the reservoir development strategies for operational flexibility. 100% directional drilling.
Development	Borinquen Unit I	Volcán Rincón de la Vieja, Guanacaste	55	To be commisioned by 2026	2061	On development.
	Borinquen Unit II	Volcán Rincón de la Vieja, Guanacaste	55	To be commisioned by 2030	2065	The project has an environmental impact assessment, technical and financial analysis.
Feasibility	PLB-01	Volcán Rincón de la Vieja, Guanacaste	12	Advanced feasibility	30 años	Available for the Electrical Expansion Development Plan by 2030-2060.
	PLM-55	Volcán Miravalles, Guanacaste	12	Advanced feasibility	30 años	Available for the Electrical Expansion Development Plan by 2030-2060.
	PLM-54	Volcán Miravalles, Guanacaste	12	Feasibility	30 años	Available for the Electrical Expansion Development Plan by 2030-2060.
Reconnaissance	RV Norte	Volcán Rincón de la Vieja, Guanacaste	35	Pre feasibility	35 años	Available for the Electrical Expansion Development Plan by 2030-2060.
	Orosí	Sector Orosí – Cacao, Guanacaste	35	Pre feasibility	35 años	Available for the Electrical Expansion Development Plan by 2030-2060.
	Pocosol	Sector Arenal – Poco Sol, Alajuela	35	Pre feasibility	35 años	Available for the Electrical Expansion Development Plan by 2030-2060.
	Irazú	Sector Irazú-Turrialba, Cartago	35	Pre feasibility	35 años	Available for the Electrical Expansion Development Plan by 2030-2060.

4. DIRECT USE

The use of this type of resource is limited to low temperature developments in hotel pools dedicated to ecological tourism (Figure 100). Local factors have discouraged the use of these resources, like the favorable climatic conditions and the initial direct use applications of geothermal resources in the country. In summary, with the exception of small domestic applications, currently there are no other uses known for direct use outside ICE.

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

Figure 10: Main thermal pools and spas locations around Costa Rica (not a detailed map).

REFERENCES

Centro Nacional de Control de Energía (CENCE a): El Estado del SEN 22-10-2019, 2 pp. 1-2. https://apps.grupoice.com/CenceWeb/CenceDescargaArchivos.jsf?init=true&categoria=3&codigoTipoArchivo=3010

Centro Nacional de Control de Energía (CENCE b): Gráficos de Energías del Resumen de Operación del SEN sábado 19 de octubre de 2019. https://apps.grupoice.com/CenceWeb/CencePosdespachosDiarios.jsf?init=true

https://apps.grupoice.com/CenceWeb/CenceDescargaArchivos.jsf?init=true&categoria=3&codigoTipoArchivo=3010

Chavarría R., Leyner; & Fajardo T., Hugo: *Informe de gira de reconocimiento preliminar al Sector Norte del Volcán Tenorio*; Internal Report; Centro de Servicio Recursos Geotérmicos, Área de Geociencias, Grupo de Exploración, Instituto Costarricense de Electricidad; San José, Costa Rica (2009).

Chavarría R., Leyner; Rodríguez B., Alejandro; & Vallejos R., Osvaldo: *Reconocimiento geotérmico Sector Norte del Volcán Rincón de la Vieja*; Internal Report; Centro de Servicio Recursos Geotérmicos, Área de Geociencias, Grupo de Exploración, Instituto Costarricense de Electricidad, San José; Costa Rica (2009[2]).

Chavarría R., Leyner; Fajardo T., Hugo; & Vallejos R., Osvaldo: *Reconocimiento geotérmico del Área Arenal-Pocosol, cantones de San Carlos y San Ramón*; Internal Report; Centro de Servicio Recursos Geotérmicos, Área de Geociencias, Grupo de Exploración, Instituto Costarricense de Electricidad; San José, Costa Rica (2011).

Instituto Costarricense de Electricidad (ICE): *Evaluación del Potencial Geotérmico de Costa Rica*, Internal Report; Instituto Costarricense de Electricidad; San José, Costa Rica (1991).

Instituto Costarricense de Electricidad (ICE): *Plan de expansión de la generación eléctrica, 2018-2034.* Report; Proceso Expansión del Sistema de la Dirección de Planificación y Desarrollo Eléctrico, Dirección Corporativa de Electricidad; Instituto Costarricense de Electricidad; San José, Costa Rica (2019).

Instituto Costarricense de Electricidad (ICE): *Informe anual 2018 – Generación y demanda*. Report; Centro Nacional de Planificación Eléctrica, Instituto Costarricense de Electricidad; San José, Costa Rica (2018).

Instituto Costarricense de Electricidad, ELC Electroconsult. Proyecto Geotérmico Miravalles: Informe de factibilidad 1a. Unidad. Instituto Costarricense de Electricidad, ELC Electroconsult. Informe GMV-2-ELC-R-12400(R01). San José, Costa Rica. 1986. (In Spanish).