

Costa Rica Country Update Report

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ABSTRACT

Since the last Costa Rica's country update report presented in 2010, geothermal development and exploration in the country for electrical generation purposes have seen a large increase. The Miravalles Geothermal Field (163.5 MWe) continued its reliable productive rate and the first unit of Las Pailas Geothermal Field (42.5 MWe) came online in 2011. Feasibility studies for a second unit in Las Pailas are underway, as well as prefeasibility studies in the Borinquen (two 55 MWe units) and Pocosol Geothermal Areas in different stages.

Management of the different geothermal fields is always an important issue, so the development of tools and actions in these areas has continued and improved. The exploration of new productive zones for sustaining the capacities of Miravalles and Las Pailas fields has been carried out; investigation in new and already in use chemical treatments of produced fluids is underway. New updated numerical models for both Las Pailas and Miravalles fields have been developed, upgrading gas extraction system of the Miravalles I and II units, and improvements in the injection strategy in Las Pailas Field are examples of this development.

As the energy policies of Costa Rica are mainly based on renewable type energy sources, geothermal energy continues to be a base load for the electrical system in Costa producing 15% of the total electrical generation of the country. The direct use of geothermal energy is very low and limited to swimming pools, and other envisioned uses reported in the past have not come to pass.

1. INTRODUCTION

As a totally committed environmental friendly country, electrical generation in Costa Rica relies almost completely in these kinds of renewal type sources. By 2013, 7.98% of the installed capacity is by geothermal but the 14.96% of the total energy generated came from geothermal. The 88.2% of the total energy produced come from removable sources like geothermal, hydro, sun and wind power plants (Figures 1 and 2 and Table 1). Electrical generation from geothermal has become very important since it has been used as replacement for the thermal power plants and as a base load for the electrical generation.

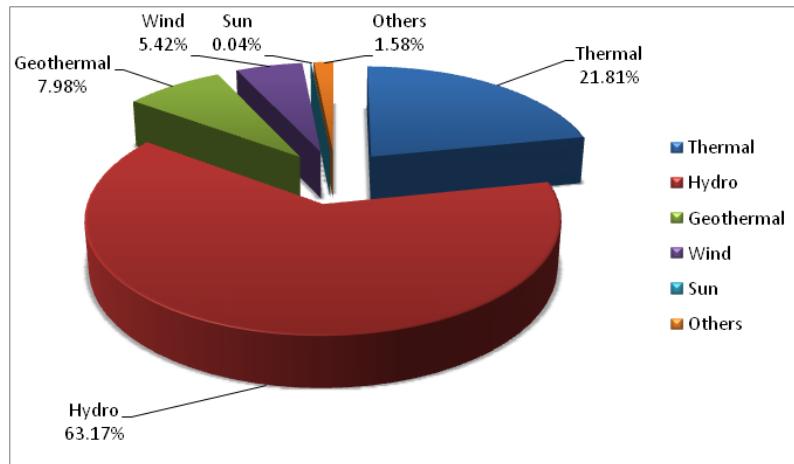


Figure 1: Total electricity installed capacity by source, in 2013.

The electrical generation system of Costa Rica is organized as a regulated utility, where *Instituto Costarricense de Electricidad* (ICE – stands for “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 in generation, transmission and distribution divisions. Besides having the largest capacity in generation plants, its transmission network manages and distributes about the 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 – stands for “The Regulatory Authority for Public Services”) ensures the quality and price of public services provided by ICE and the other electric companies.

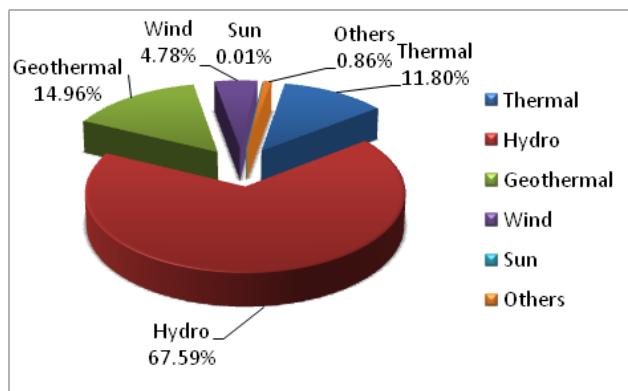


Figure 2: Total electricity production by source, in 2013.

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

Figure 3 shows the electrical generation by source during the past years (ICE, 2014), Figure 4 an illustration of the plant factor and Figure 5 shows the cost of each of these sources in 2013. It can be seen that geothermal energy has a competitive price, positioning it as an alternative to the fossil fuels production in the country.

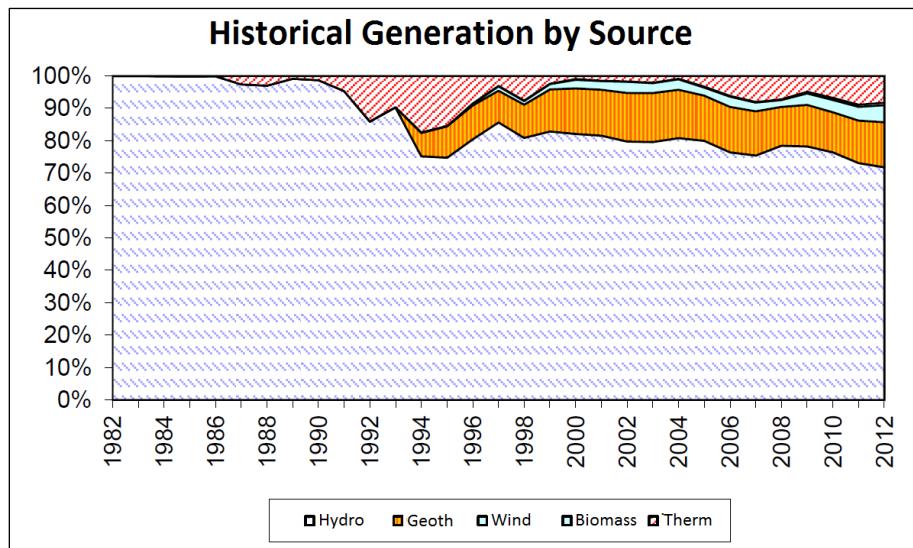


Figure 3: Historical Generation by Source in Costa Rica (1982-2012).

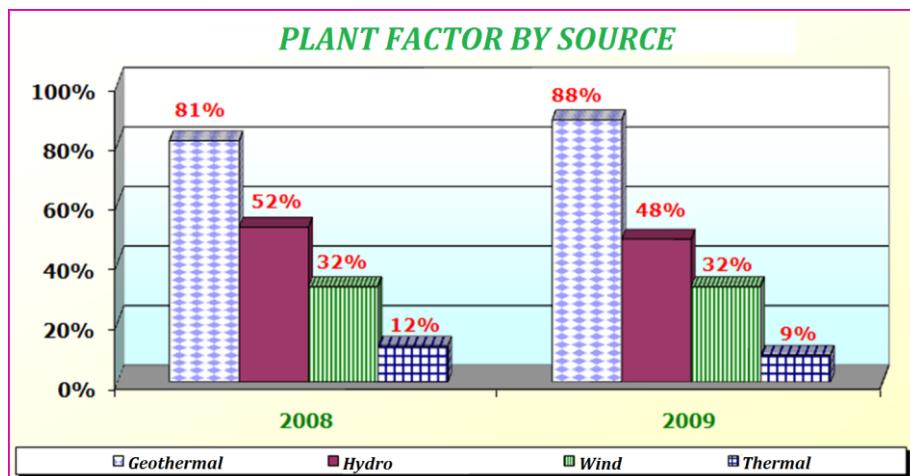


Figure 4: Plant factor by Source in Costa Rica.

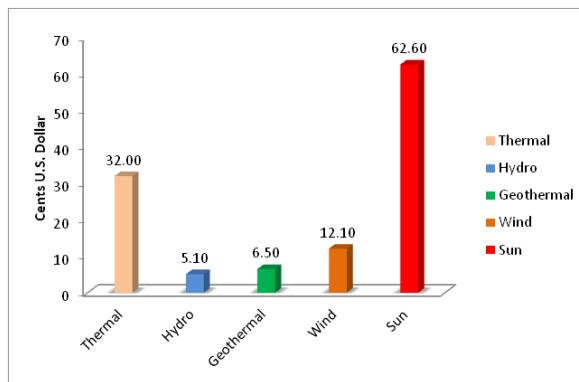


Figure 5: Total Cost per KWh by source, in 2013.

2. 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 6). 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.

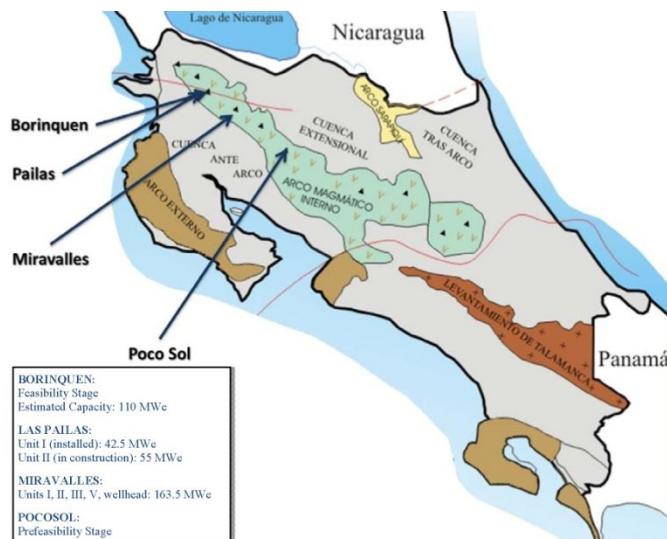


Figure 6: Geothermal development in Costa Rica.

The geothermal installed capacity accounts for about 7.98% of the country's total installed capacity; however, it represents around 14.96% of the country's total generation. Since the geothermal plants produce constantly throughout the year, they are used as a base load for the country's electrical generation, because of the variation in the hydro electrical plants production due to the seasonal variations of the Costa Rica's weather (Figure 7). Also, the geothermal and hydro electrical power plants are intensively used to generate instead of the thermal power plants. Since ICE is the only seller of the electricity to the end users, its final price is directly related with the averaged costs of the all sources. For this reason, the substitution of the most expensive generation sources with geothermal (or cheaper energy sources) is considered and is an issue of importance for the economy of the country.

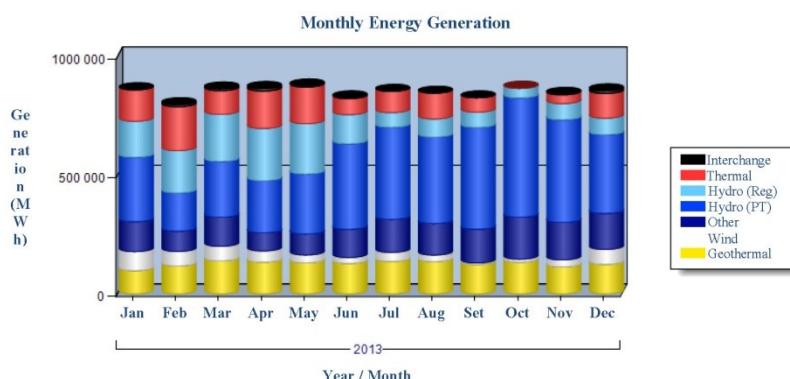


Figure 7. Monthly Generation by Source (2013).

The growth in the geothermal installed capacity had a steady pace between 1994 and 2003, when it raised from 0 to 163.5 MWe, exclusively from the development of the Miravalles Field. It comprises five units accounting for 163.5 MWe (Table 2). From 1998 to 2003 there were extensive studies in the Tenorio and Rincón de la Vieja Geothermal Areas. Those studies led to the development of Las Pailas Geothermal Field and the commissioning of a 42.5 MWe power plant in 2011, and the establishment of the Borinquen Field as a future development.

2.1. 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 (Table 2 and Figures 8 and 9).

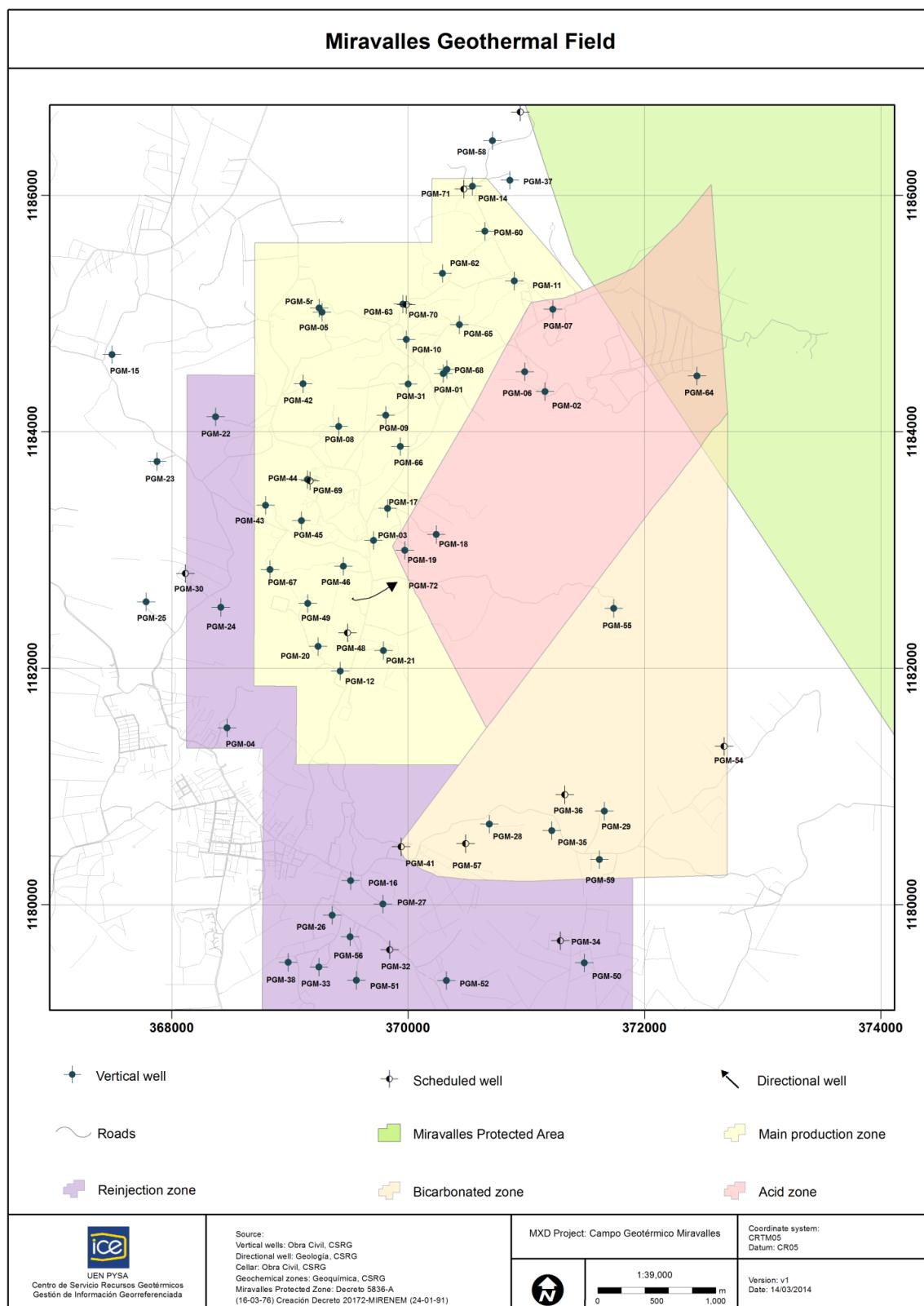


Figure 8: General View of the Miravalles Geothermal Field.



Figure 9: Generation Units Installed at the Miravalle Geothermal Field.

The Miravalle Complex comprises five power units in four different power houses (Figure 9), seven separations stations, the pipeline networking, 53 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 Miravalle. The actual knowledge of the reservoir and the evolutions trend observed has headed to conclude that the Miravalle field has actually reached its maximum extraction rates. There are still more zones under exploration (east zone, acid aquifer seen in Figure 8) which can help (and actually does) to solve the production decline observed in the main aquifer, and in the 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 of the main aquifer.

Some actions taken for 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. Between them it can be mentioned the following: drilling of wells and deepening of existing ones in order to equally distribute the extraction around the field and pursue the extraction of the existing but yet largely unknown deeper production zone; exploration of the unknown east-southeast area and if steam is successfully proven in this area, the produced steam could be sent to Units I and II. The non-condensable extraction system at the main power plants (Unit I and II) is actually being upgraded and this will allow the use of a fraction of steam that cannot actually be used due to high levels of non-condensable gas content; improvement of the injection program around the field which has shown to improve the condition of the reservoir.

2.2. THE LAS PAILAS GEOTHERMAL FIELD

Exploratory deep drilling carried out during 2000-2003 and the corresponding feasibility studies led to the installation and commissioning of a 41.5 MWe gross and 35 MWe net power plant. Mass extraction from the Las Pailas reservoir began in May 2011, and the Las Pailas Unit was officially commissioned on July 24, 2011 (Figure 10). To date the reservoir is exploited by seven production wells and four injection wells.



Figure 10: Generation Unit Installed at the Las Pailas Geothermal Field.

The project was developed under the “leasing with option to buy” scheme, where the Banco Centroamericano de Integración Económica (BCIE, stands for 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.

A considerable area of the geothermal reservoir is within the limits of Rincón de la Vieja National Park (Figure 11), which was created as a result of the application of a national policy that protects and preserves the natural resources and the environment. For that reason, a large part of the area of geothermal interest is excluded from any possible future commercial development. The zone that is available in the Las Pailas geothermal area is considered as the limit of the reservoir. In order to get access to the main reservoir, some bills have been proposed over the recent years, trying to authorize ICE to enter the national parks. These bills have faced the opposition of environmental protection groups and political parties that usually are very supportive to these environmental groups. However, the idea of exploiting this renewable resource has gained an increased support on the public opinion and the politician parties and the debate still continues in the Costarican Congress.

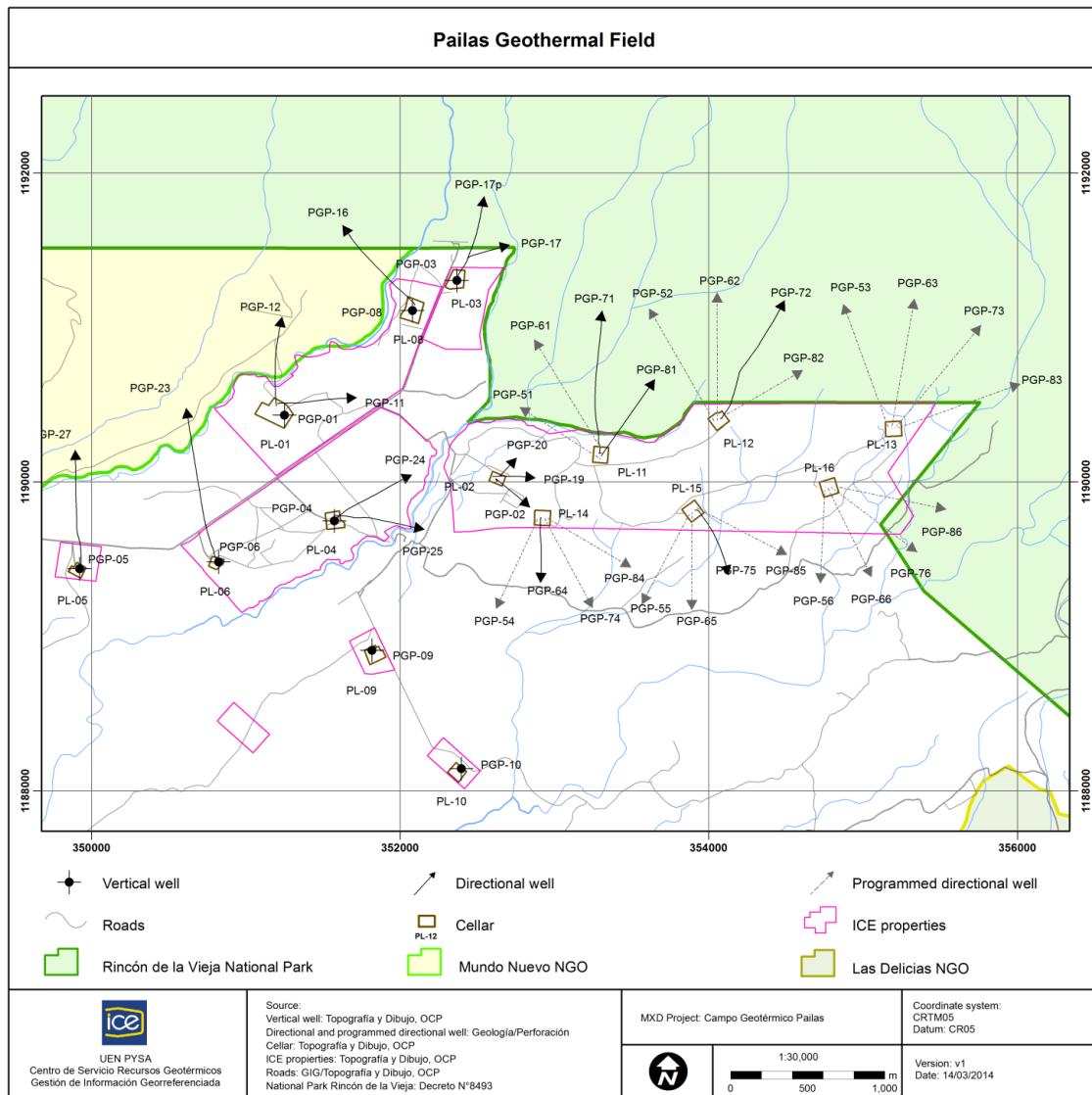


Figure 11: General View of Las Pailas Geothermal Field.

Geoscientific studies conducted in the area of Rincon de la Vieja Volcano before and during the development of studies for Borinquen and Las Pailas Units I and II, showed that the heat source is placed north of the area where Las Pailas I was developed. This makes the sector known as Las Pailas II promising for a similar development. Unit 2 will be located then to the east of Las Pailas I sector (Figure 11). This unit is set to use flash steam technology and is projected to generate between 35-55 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 is set to continue in order to have a better dimension of the future power plant. 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 240-255°C.

2.3. 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 the start of intensive development is due by 2018 (Figure 12).

The final commissioning of the two units (55 MWe each) is expected to be on 2023 and 2024 respectively. The aquifers already identified are neutral sodium-chlorinated with high salinity content, low gases content and temperatures ranging from 230-240°C. At this moment 4 wells have been drilled of which three wells are producers and one is a reinjector. These wells are currently used to monitor the thermal-hydraulic conditions and possible production conditions. Studies on the distribution of the thermal anomaly, its relationship to the structural patterns and movement of fluids are also developed.

Funds for the development of this field are already committed.

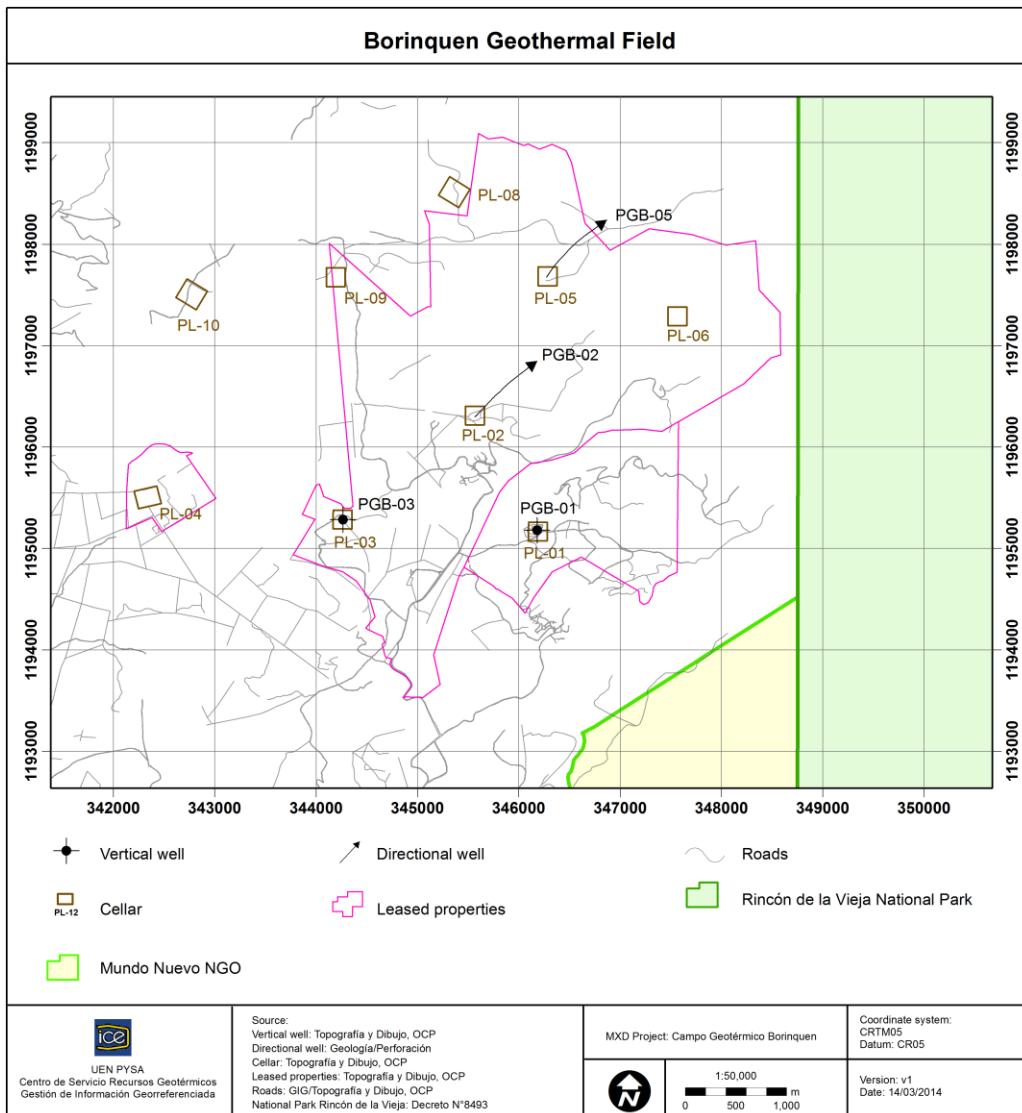


Figure 12: General View of Borinquen Geothermal Field.

2.4. OTHER GEOTHERMAL SITES OF INTEREST

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

Arenal - Poco Sol: the sector under investigation is located 12 km south of the Arenal volcano, focused in the Poco Sol sector, on the banks of the Peñas Blancas River. Recognition for this area in early 2011 concluded covering an area of 690 km², being much of the area studied by means of remote sensing (Figure 13). Due to favorable geological features in this area there is an advanced feasibility stage for which were conducted a structural geological mapping, geochemical detail, recommendation of sites for conducting geothermal gradient wells and geophysical surveys (Chavarría et al, 2011).

With the information gathered so far is not possible to define the geothermal reservoir; however based on the preliminary conceptual model three possible areas are proposed, a minimum of 4.5 km² a more likely 11.2 km² and 31.6 km² maximum. According to the volumetric method used to calculate the energy potential of each area a more likely value 46.4 MWe was obtained during a period of 25 years, assuming a "single flash" power plant and a reinjection temperature of 165°C. This value should be taken as a first approximation because in this study the uncertainty of the reservoir parameters is still large.

The ability to fully exploit any of these energy reserves are considerably difficult at this moment because much of the area of interest is located within protected forest areas, and under the current laws of the country it would not be possible the resource exploitation.

FIGURA 1. UBICACIÓN DEL ÁREA DE ESTUDIO, ZONAS PROTEGIDAS Y MUESTRAS GEOQUÍMICAS

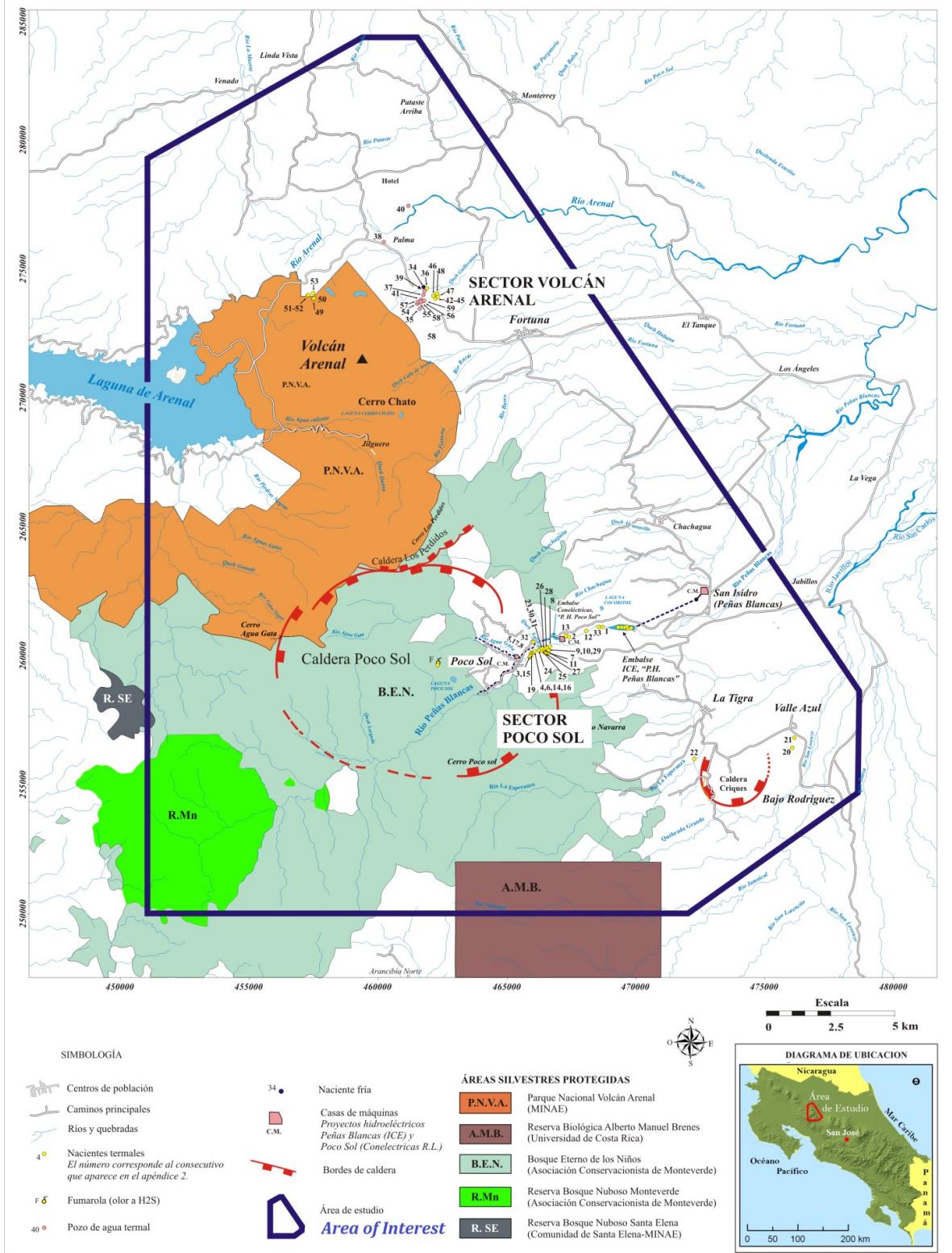


Figure13: General View of Arenal-Pocosol Geothermal Area.

Northern part of the Rincón de La Vieja Volcano: in early 2009 the geothermal reconnaissance study (covering an area of 130 km², Figure 14) including surface geological and geochemical survey of thermal springs and some cool was concluded (Chavarria et al, 2009[2]). In order to calculate the energy potential of the study area the "volumetric method" was used by applying the Monte Carlo simulation. This calculation is made based on the "minimum", "maximum" and "most likely" identified areas into the one considered in these preliminary studies, and estimating other values of which there was no information available. This estimation was based on similar values obtained from values found in other geothermal fields in Costa Rica and other similar geothermal fields in the world.

With the information obtained and estimated, it is considered that the field could produce between 0.65 and 260.71 MWe, the most probable value being 15.09 MWe over a period of 25 years. This corresponds to the maximum capacity of a power plant. This value should be taken as a first approximation; in this study the uncertainty of reservoir parameters is still large.

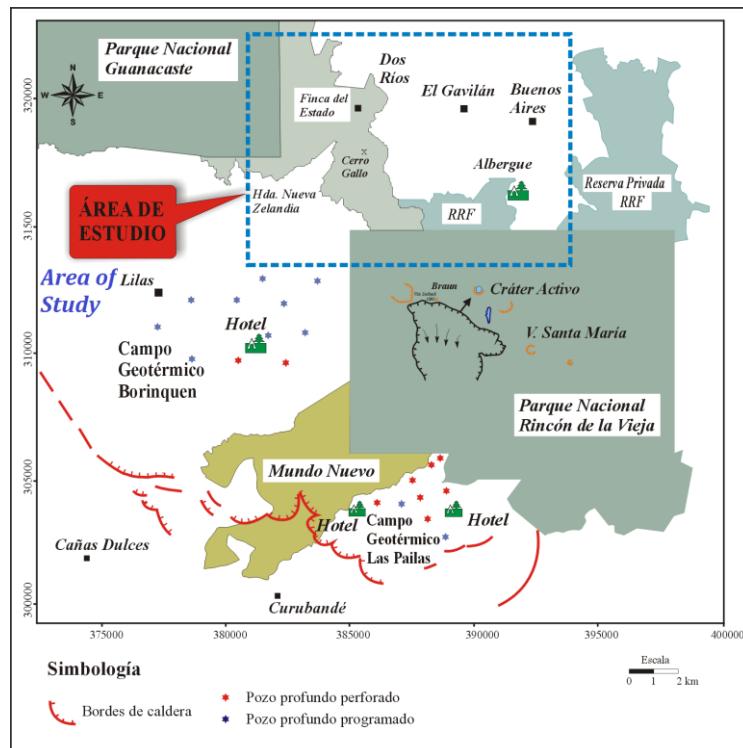


Figure 14: General View of the Rincón de La Vieja Volcano Geothermal Area, including the Northern Part.

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 Tenorio Volcano National Park section 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 15). This is an area of 198 km² (Chavarría and Fajardo, 2009).

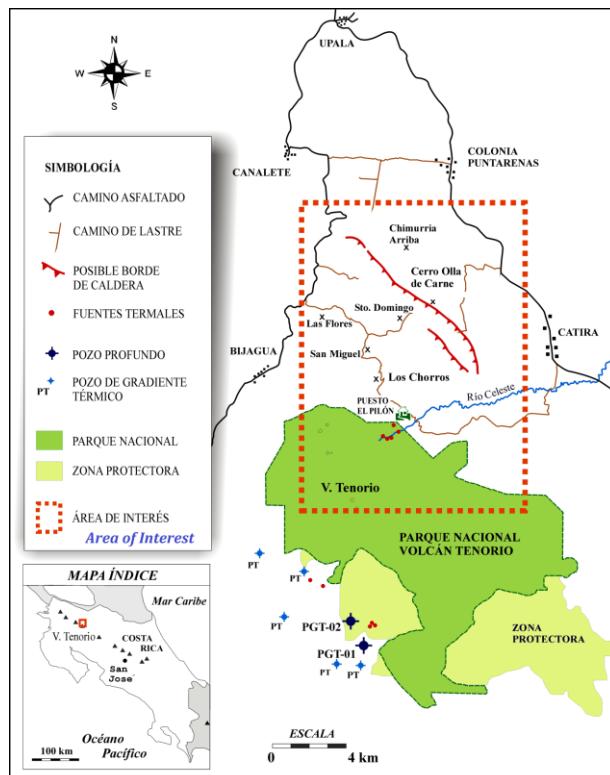


Figure 15: General View of Tenorio Geothermal Area.

2.5. DIRECT USE

At the end of the 1980's a study of the country's geothermal capacities was completed (ICE, 1991), showing various possible zones of moderate and low temperature resources (Figure 16). However, the use of this type of resource is limited to low temperature forms in hotel pools dedicated to ecological tourism (Figure 17). 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.

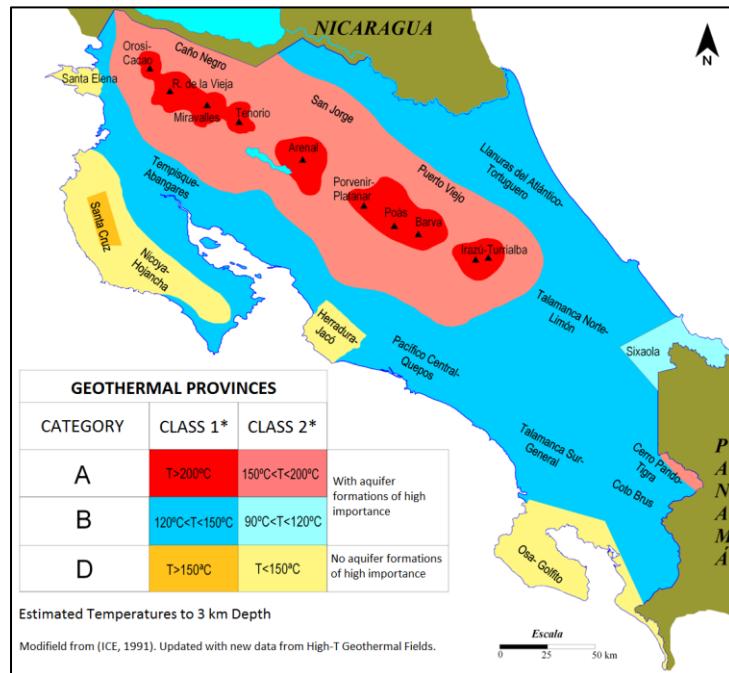


Figure 16: Estimated temperature map of Costa Rica (at 3 km depth).



Figure 17: 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 are made at Miravalles, taking a fraction of the steam produced by the well PGM-45 (Figure 18). The steam enters at a temperature of 80-90°C, reducing the setting time of cement in three hours. The plant has a production rate of 8 poles/day (Arias et al, 2013).

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



Figure 18: power posts factory at the Miravalles Field.

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STANDARD TBALES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Wind		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr								
In operation in December 2014	217.5	1516.7	595.7	1196.00	1725.3	6847.0	0.0	0.0	148.1	484.6	2731.2 ⁽¹⁾	10136.1 ⁽²⁾
Under construction in December 2014	0.0	0.0					0.0	0.0				

Funds committed, but not yet under construction in December 2014	55	379.1 ⁽⁴⁾				0.0	0.0				
Estimated total projected use by 2020	272.5		575.7		2358.3		0.0	0.0	368.1		3769.2 ⁽³⁾

(1) Includes 40 MWe on Bagasse, 3.7 MWe on Biogas, and 1.0 MWe on Solar.

(2) Includes 86.3 GWh on Bagasse and 1.44 GWh on Solar.

(3) Includes 50 MWe on renewable yet to be determined.

(4) Estimated average 2019-2035 (365-417 GWh/yr).

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2014

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status	Type of Unit ⁽¹⁾	Total Installed Capacity MWe	Total Running Capacity MWe	Annual Energy Produced 2014 GWh/yr	Total under Constr. Or planned MWe
Miravalles	I	1994	1	Operative	1F	55	Up to 60		
Miravalles	Boca de pozo	1995	1	Operative	1F	5	5		
Miravalles	II	1998	1	Operative	1F	55	55		
Miravalles	III	2000	1	Operative	1F	29	29.5		
Miravalles	V	2003	1	Operative	B	17	17		
Las Pailas	I	2011	1	Operative	H	42.5	42.5		

(1) 1F= Single Flash

B= Binary

H= Hybrid (Combined Cycle Binary and Single Flash)

TABLE 3. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other	
Exploration	(all)	4	NA	NA	NA	9.488
Production	> 150 °C	10	NA	NA	NA	17.050
	150-100 °C	NA	NA	NA	NA	NA
	< 100 °C	NA	NA	NA	NA	NA
Injection	(all)	6	NA	NA	NA	9.467
Total		20	NA	NA	NA	36.006