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LaGeo S.A. de C.V.

CURRENT STATUS OF GEOTHERMAL RESOURCES DEVELOPMENT IN CENTRAL AMERICA

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ABSTRACT

Central America is rich in geothermal resources, however only a small portion has been developed and is currently used for electricity generation. In countries like El Salvador, Nicaragua, Costa Rica and Guatemala, the geothermal exploration led to the first resource evaluation and the beginning of commercial exploitation of some areas such as Ahuachapán in 1975, Momotombo in 1983, Berlin in 1992, Miravalles in 1994, Zunil in 1998 and recently in 2005 in San Jacinto Tizate and in 2006 in Amatitlán. Currently, the region has an installed capacity of 506.6 MW, generating an annual average of 417.5 MWe. From the existing geothermal potential in Central America, the electricity generation provides an average of 13%, and seems to be significant in countries like El Salvador and Costa Rica contributing 26 and 14% respectively of total electricity consumption in each country. Geothermal generation capacity in Central America in 2009 was 2887 GWh which was equivalent to 7.6% of total electricity generated by different energy sources. The potential resources in Central America, has been estimated very close to the total amount currently used in electric power of about 4513 MWe.

1. INTRODUCTION

Central America is along of the Circum Pacific Ring of Fire and has been affected by intense seismic and volcanic activities, resulting in catastrophic events that have affected the economic, social and cultural development of the region, but at the same time, this natural phenomenon has created excellent conditions for development of geothermal resources.

The geodynamic phenomena can be attributed to the subduction of the Cocos plate beneath the Caribbean plate bounded by the Mesoamerican Trench within the Pacific Ocean.

Figure 1, shows the collision of the Cocos and the Caribbean tectonic plates about 100 km parallel to the Pacific coast of Central America. The green arrows indicate the direction of movement. Volcanoes were formed parallel to the subduction zone, which is believed to occur at a rate of 73-84 mm/year and forms the Central American volcanic chain that runs northwest -southeast.

2. GEOTHERMAL RESOURCES IN CENTRAL AMERICA

Central America is rich in geothermal resources, however only a small portion has been developed and is currently used for electricity generation. The subduction process is responsible for the creation of the volcanic chain in the region, which provides a potential source of energy because the exploited geothermal fields are located in areas with anomalous heat flow (Figure 1). These areas are usually in the vicinity of shallow magma chambers associated with volcanoes, with temperatures of 200-300 °C at depths between 500 and 3,000 m, where the heat is transported by conduction in the rocks and convection of the geothermal fluids.

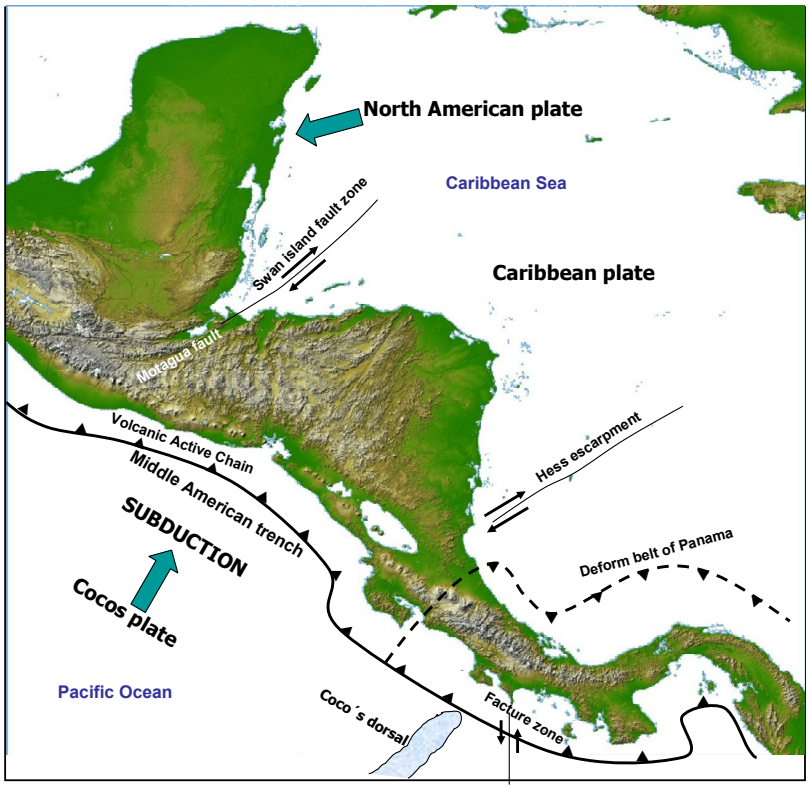

FIGURE 1: Tectonic setting of Central America and subduction of the Cocos plate under the Caribbean plate and the active volcanic chain (adapted from Chandrasekharam and Bundschuh, 2008)

In countries like El Salvador, Nicaragua, Costa Rica and Guatemala, the geothermal exploration began in the late fifties and early sixties, resulting in the identification of several promising areas and the start of drilling that led to the first resource evaluation and the beginning of commercial exploitation of some areas such as Ahuachapán in 1975, Momotombo in 1983, Berlin in 1992, Miravalles in 1994, Zunil in 1998 and recently in 2005 at San Jacinto Tizate and in 2006 in Amatitlán.

Since the mid 90's to early 2003, the energy development in the region was focused mainly on production sustainability of existing power plants, with significant reduction of the exploration studies of new geothermal areas.

The main reasons for this were:

- Priority of government investment to other sectors;
- Low oil prices (in the range of 10-20 dollars per barrel);
- Private companies preferred power generation investment in "traditional" electricity generation schemes (such as hydro and thermal plants);

- The geothermal projects had difficulty obtaining long-term loans as Banks and private investors had become less willing to take the risks associated with this industry; and
- Support for geothermal exploration and development by local and international governments had decreased.
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Today, the different governments in the region show more interest in developing renewable energy resources in their countries, especially in geothermal energy. This change is probably the result of high oil prices, instability in oil market, uncertainties in future climate conditions (which could affect the output of hydroelectric projects), the need of reducing CO_2 emissions by overriding the environmental impacts associated with burning wood and fossil fuels to generate electricity.

Figure 2, shows the location of the geothermal fields currently in operation and main geothermal areas that have undergone exploration in Central America.

FIGURE 2. Location of the geothermal fields in operation, and main geothermal areas in Central America (modified from Google)

Most of the geothermal areas and geothermal fields are located within the volcanic chain, and only the geothermal prospects studied in Honduras derivates from different source of energy like the deep-circulation system related to extensional faulting structure (Chandrasekharam and Bundschuh, 2008).

Areas with high temperature (>200 °C) have been utilized for generating electricity, while areas with low temperature resources have less application. Lund et al. 2010 reported data on direct use of geothermal resources in Guatemala, El Salvador, Costa Rica and Honduras, mainly for agricultural drying and thermal pools.

3. GEOTHERMAL RESOURCES AND CURRENT ESTIMATED POTENTIAL

Geothermal resource development in Central America should contribute significantly to achieve the Millennium Development Goals, generating electricity based on geothermal fluids that are clean, renewable, sustainable and indigenous source of energy.
Their use can provide several advantages:

- Offset the price of electricity;
- Protecting the Central American countries against future rises in the oil market;
- Contributing to reduced environmental pollution; and
- Creating more job opportunities especially in rural areas where the developing of the geothermal projects are carried out.

Lippmann (2002) reports the total electricity generation capacity that can be achieved in Central America from geothermal resources, which could be in the range of 2000 to 16000 MW, giving a most likely value between 3000-4000 MW.

Currently, the region has a total installed capacity of 506.6 MW, generating an annual average of 417.5 MWe.

Table 1 shows the estimated geothermal potential of different sources and the geothermal potential to be developed given the current installed capacity. The total estimated potential for the region by various sources is about 3500 MWe (average of the estimated potential for various publications in Table 1).

Currently, from the existing geothermal potential in Central America only a relatively small percentage has been used to generate electricity providing an average of 13%, but provides significant savings of fossil fuels, especially in countries like El Salvador and Costa Rica contributing 26% and 13% respectively of total electricity contribution in each country (Table 2 from IILA 2010).

Table 3 shows the companies and institutions operating commercially with 8 power stations actually in generation, operating a total of 25 units, and distributed as follows: Costa Rica (5), El Salvador (7), Guatemala (8) and Nicaragua (5). It should be noted that a 5-MWe unit in Amatitlán has closed in 2007. Also included are the installed power in kW and the net generation in MWh. Among the companies, only the ICE (Instituto Costarricense de Electricidad) is the only government institution and LaGeo a semi-private, while the rest are private companies.

Geothermal generation capacity in Central America in 2009 was 3159 GWh which was equivalent to 8% of total electricity generated by different sources.

TABLE 1: Estimated geothermal potential (MWe) for electricity generation

Geot. Pot. (Mwe)	Total	Develop.	Total	Develop.	Total	Develop.	Total	Develop.	Total	Develop.	Total	Develop.
Nicaragua	1750	1662.5	1200	1112.5	992	904.5	1000	912.5	345	257.5	1519	1431.5
Costa Rica	1000	834.3	235	69.5	750	584.3	235	69.3	1059	893.3	865	699.3
Guatemala	1000	950.8	1000	950.8	480	423	1000	950.8	993	943.8	400	350.8
El Salvador	500	295.6	333	128.6	362	157.6	450	245.6	595	390.6	644	439.6
Honduras	130	130	120	120	122	122	126	126	677	677	116	116
Panama	50	50	40	40	42	42	40	40	719	719	0	0
Total	4430	3923.2	2928	2421.4	2748	2233.4	2851	2344.2	4388	3881.2	3544	3037.2
Source:	Lippmann 2002		CEPAL 2004		JICA 2005		SICA 2006		EPI 2007		IILA 2009	

TABLE 2: Geothermal power generation in 2009

Country	Installed Capacity (MWe)	Available Capacity (MWe)	Annual Energy produced (GWh/y)	National participation rate (%)
El Salvador	204.4	183.3	1421.0	26
Costa Rica	165.5	156.0	1186.0	13
Nicaragua	87.5	42.0	271.6	8.7
Guatemala	49.2	36.2	280.0	3.7
Total	506.6	417.5	3159.0	

TABLE 3: Utilities with geothermal power generation 2009

Country	Company	Installed power (kW)	Net Generation (MWh)	Number of power stations
Costa Rica	ICE	136,160	973,000	1
	G.G. Ltd.	29,550	213,000	1
El Salvador	LaGeo	204,400	1,420,939.7	2
Guatemala	ORZUNIL	25,200	125,844	1
	ORTITLAN	24,000	154,095	1
Nicaragua	ORMAT	77,500	199,089.1	1
	PENSA	10,000	72,555.5	1
Total		506,810	3,158,523.8	8

As shown in Figure 3, the geothermal generation is the third in importance compared to other types of energy used in Central America. Figure 4 shows the percentage of each power plant with the total generated electricity from geothermal resources in 2009 (IILA, 2010).

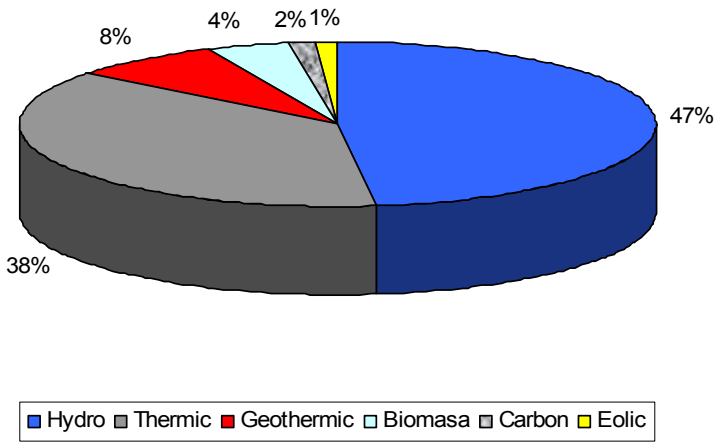

FIGURE 3: Electrical generation by energy source in Central America 2009

Table 4 shows the detailed number of units installed per country with the available capacity in MW and annual average generation in 2009. The start of operation is included (only in the case of the wellhead units in Berlin and Amatitlán where final operation date is given).

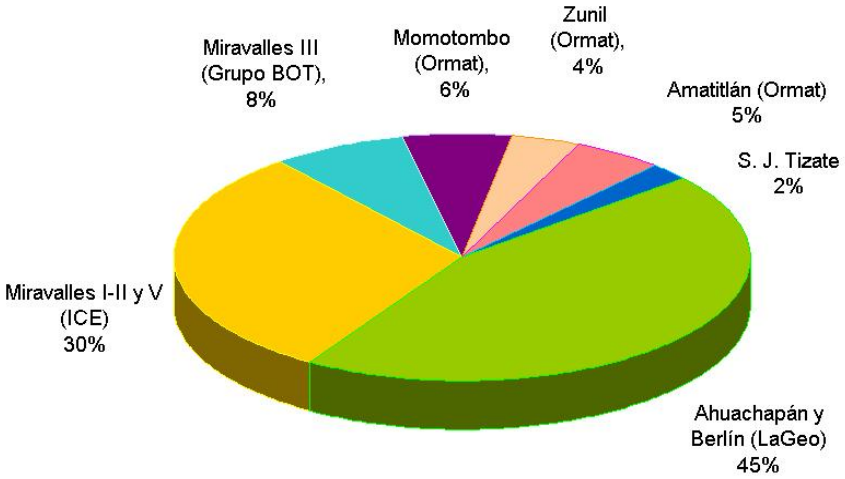

FIGURE 4: Percentage of each geothermal power plant in Central America by 2009

TABLE 4: Details of the 2009 Central American geothermal power plants

Country	Geothermal power plant	Initial operation	End of operation	Installed capacity (MWe)	Available capacity (MWe)	Annual generation (GWh)
El Salvador				**204.4**	**183.3**	**1421**
	Ahuachapán I-II-III	1975	***	95.0	79.0	665.3
	Berlin Boca Pozo	1992	1999	-10.0	0.0	0.0
	Berlin I-II	1999	***	56.2	54.4	441.0
	Berlin III	2007	***	44.0	41.4	264.0
	Berlin CB	2009	***	9.2	8.5	50.0
Guatemala				**49.2**	**36.2**	**280.0**
	Zunil (8)	1998	***	24.0	16.1	125.8
	Amatitlán	2006	***	25.2	20.1	154.1
	Amatitlán	2006	2007	-5.0	0.0	0.0
Costa Rica				**165.5**	**156.0**	**1185.7**
	Miravalles I	1994	***	55.0	55.0	420.3
	Miravalles II	1998	***	55.0	55.0	403.3
	Miravalles Boca Pozo	1998	***	5.0	5.0	16.0
	Miravalles III (BOT)	2000	***	29.5	26.0	237.15
	Miravalles V	2003	***	21.0	15.0	109.0
Nicaragua				**87.0**	**42.0**	**271.6**
	Momotombo (3)	1983	***	77.0	35	199.1
	San Jacinto Tizate (2)	2005	***	10.0	8.0	72.5

It should be noted that El Salvador, Costa Rica, Nicaragua and Guatemala are considered among the first 10 countries in the world providing a high percentage of total electricity contribution in the energy. Figure 5 shows the percentage data since 2007, however the current data remains consistent in all Central American countries.

The contribution of geothermal power to the national grid of the four countries with the highest percentage of geothermal energy production in Central America is given in Figure 6 with the updated data for 2009, both in percentage and geothermal generation (GWh).

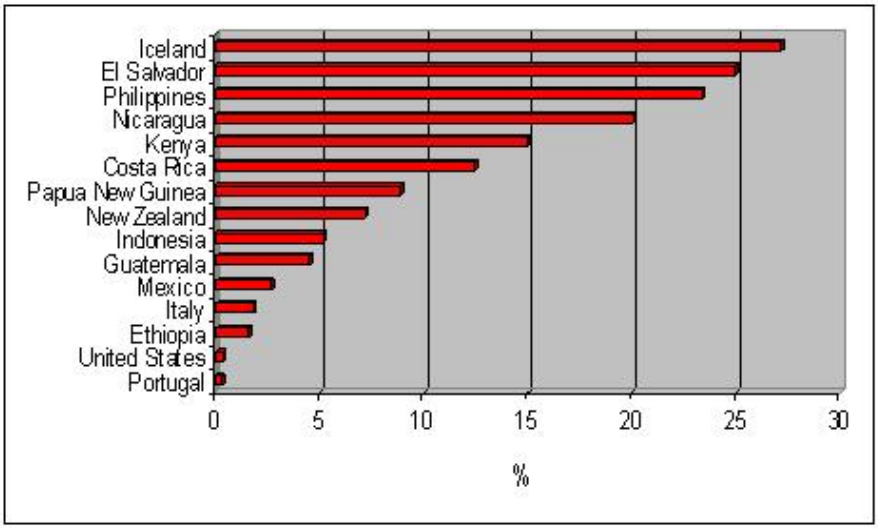

FIGURE 5: The 15 countries with the highest percentage contribution of geothermal power to the national grid of each country (Source: Bertani, GEA, EIA, Fridleifsson, 2007)

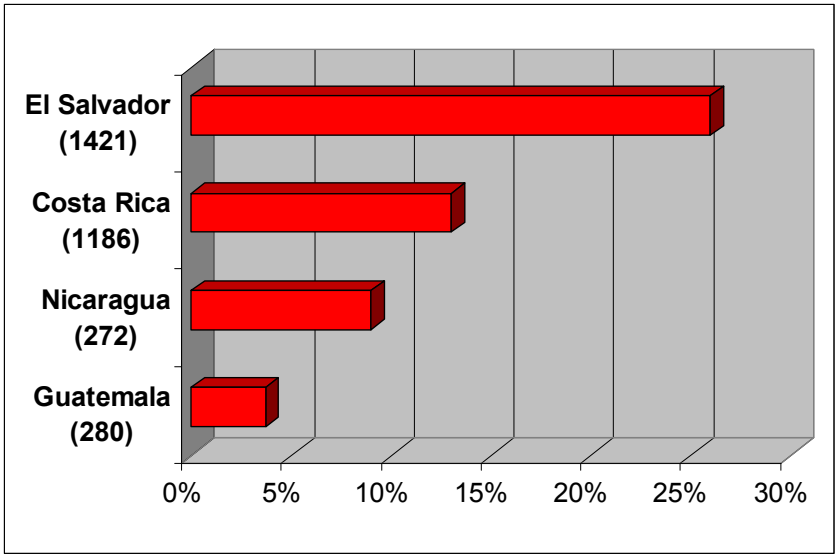

FIGURE 6: Percentage of contribution and electrical generation for 2009

4. DEVELOPMENT HISTORY

The geothermal development in Central America since 1975 is shown in Figure 7. The increasing in installed capacity was faster in the first twenty five years, with an increment of around 400 MWe, after that, developing projects seemed to be of minor importance. Similar behavior was reported for the geothermal generation increasing from 72 to 3159 GWh in 35 years.

5. FUTURE DEVELOPMENT

According to Earth Policy Institute Estimates 2007 (www.earthpolicy.org), the MW required to meet the total demand of electricity for each country in Central America for 2010 are shown in Figure 8. It should be emphasized the importance for the governments and private companies to accelerate research and development of geothermal resources in the region.

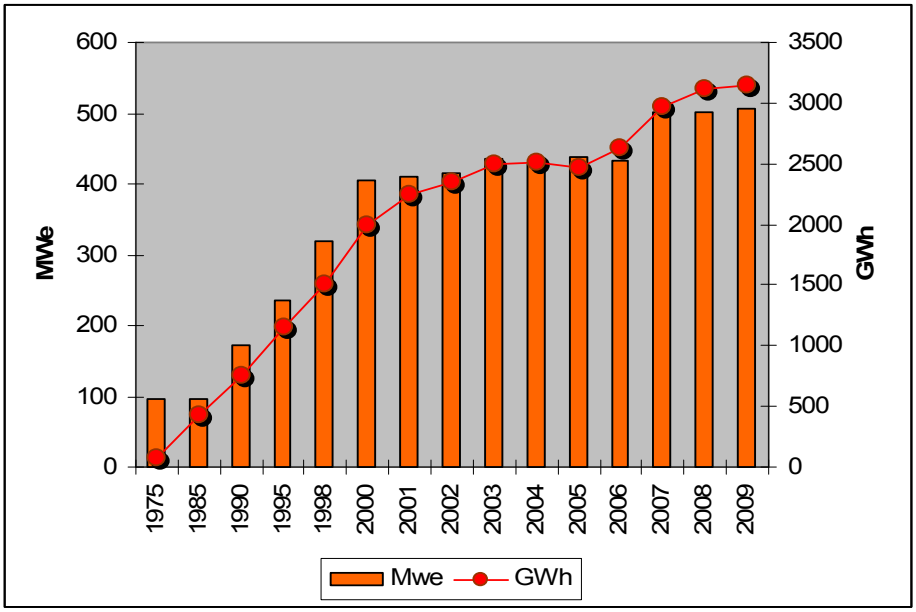

FIGURE 7: Geothermal development history and generation in Central America

As has been mentioned the potential resources in Central America has been estimated very close to the total amount currently used in electric power generation of about 4513 MWe (CEPAL, 2009). Figure 8 shows the MWe required from geothermal resources in the Central American countries to achieve the annual current total demand of electricity by 2010 (see also Table 1).

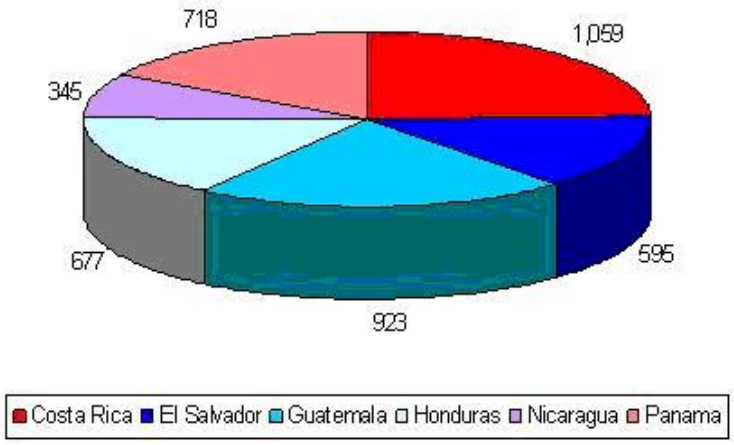

FIGURE 8: MWe required from geothermal resources in the Central American countries to achieve the annual current total demand of electricity by 2010

Bertani (2010) presents a forecasting for the geothermal installed capacity in Central American countries by the year 2015 as shown in Table 5. These estimations gave an increase in installed capacity of 378.9 MWe. Some new projects that are underway and will be developed in the near future are described in Table 6, which would imply an increase in geothermal capacity in the region of about 224-254 MWe for the next few years.

TABLE 5: Geothermal installed capacity forecasting by the year 2015 (Bertani, 2010)

Country	MWe
Costa Rica	200
El Salvador	290
Guatemala	120
Nicaragua	240
Honduras	35
Total	885

Currently, in Costa Rica there is only one operating geothermal field (Miravalles) with five power plants units in operation with a total installed capacity of 165.5 MWe. For the second half of 2011, it is scheduled to start the first unit of 41.5 MWe Las Pailas power plant, currently under construction.

El Salvador has increased its total geothermal power production since 2007 from 134 MWe to 183 MWe, with the construction of two new units in the area of Berlin and the project of optimization in Ahuachapán, reaching up to 85% of the total installed capacity. The country is in the process of developing geothermal energy projects in the areas of San Vicente and Chinameca, where drilling is being undertaken to confirm the resource. Exploitation is scheduled to continue in 2011 in San Vicente and currently taking place in Chinameca where temperatures of about 250 °C and 230 °C respectively have been measured in the recently drilled wells.

Nicaragua, in addition of Momotombo, has begun the exploitation of the geothermal field in San Jacinto-Tizate, developed by Polaris Energy Nicaragua (PENSA), with the installation of two wellhead units, giving a total installed capacity of 10 MWe. The field is expected to expand to 35 MWe. Recently, the Mombacho volcano and Caldera de Apoyo concessions have been awarded to PENSA. On the other hand, Enel from Italy and its partner LaGeo of El Salvador has started exploratory drilling in two geothermal areas: El Hoyo Monte-Galán and Managua-Chiltepe. Exploration activities in Nicaragua are expected to confirm the generation potential currently estimated for the new fields between 100 MWe and 200 MWe.

For Guatemala, the potential of geothermal energy has been estimated at 400 MWe, which has been successful in the fields of Zunil and Amatitlan. Feasibility studies are conducted in geothermal fields in Tecuamburro, San Marcos and Moyuta. In addition, expansions of 30 MWe are planned in Amatitlán.

TABLE 6: Future development projects in Central America

Country	New geothermal development
Costa Rica	Las Pailas 41.5 MWe
El Salvador	Chinameca 50 MWe and San Vicente 10 MWe; Third Unit Berlin 28 MWe; Optimization Ahuachapán Phase III 5 MWe
Guatemala	Amatitlán from 20 to 50 MWe
Nicaragua	San Jacinto Tizate 35 MWe El Hoyo-Monte Galán & Managua-Chiltepe Mombacho Volcano & Caldera de Apoyo
Honduras	GeoPlatanares 35 MWe

Honduras will develop its first geothermal power plant in Platanares geothermal field, located in different geological structures of the typical features of high-temperatures fields, and associated with volcanic structures. Geoplatanares, the company that holds the concession will start to drill exploration wells to confirm the feasibility and eventually proceed to commercial development.

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