Presented at "Short Course VI on Utilization of Low- and Medium-Enthalpy Geothermal Resources and Financial Aspects of Utilization", organized by UNU-GTP and LaGeo, in Santa Tecla, El Salvador, March 23-29, 2014.

UNITED NATIONS UNIVERSITY
GEOTHERMAL TRAINING PROGRAMME

LaGeo S.A. de C.V.

CURRENT STATUS OF GEOTHERMAL RESOURCES DEVELOPMENT IN CENTRAL AMERICA

Francisco E. Montalvo
LaGeo S.A. de C.V.
15 Av. Sur, Col. Utila, Santa Tecla
EL SALVADOR
fmontalvo@lageo.com.sv

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, San Jacinto Tizate in 2005, Amatitlán in 2006 and recently Las Pailas in 2011. Currently, the region has a gross installed capacity of 624.1 MWe, generating an annual average of 410.2 MWe. From the existing geothermal potential in Central America, the electricity generated provides an average of 12% of the total produced, and more significant in countries like El Salvador, Costa Rica and Nicaragua where it contributes 24%, 14% and 13% respectively of the total electricity consumption in each country for the year 2012. Geothermal generation capacity in Central America in 2012 was 3542 GWh which is equivalent to 7.9% of the total electricity generated by different sources. The potential resource in Central America has been estimated very close to the total amount currently used in electric power, that is, about 5057 MWe.

1. INTRODUCTION

Central America belongs to the so-called Pacific Ring of Fire and has been affected throughout its history by intense seismic and volcanic activity, resulting in catastrophic events that have impacted negatively on the economic, social and cultural development of the region.

The geodynamic situation of the isthmus and the occurrence of these natural phenomena can be attributed mainly to the subduction of the Cocos plate beneath the Caribbean plate (whose boundaries are known as the Middle America Trench, which are within the Pacific Ocean), and the presence of faults (fractures of the crust) that are active in the Motagua-Chamalecón Polochic fault system, thus separating the Caribbean plate from the North American plate.

In Figure 1, the Cocos and the Caribbean tectonic plates collide, about 100 km parallel to the Pacific coast of Central America. The black arrows indicate the direction of movement. Volcanoes are formed in a narrow strip parallel to the shock zone. The process of subduction occurs when the Cocos plate disappears beneath the continental crust producing a fusion of mass and extensional faulting. Along the trench, the subduction of the Cocos oceanic plate beneath the Caribbean plate is given at a rate of 73-84

mm/year (De Mets, 2001). The convergence movement of the Cocos plate is to the northeast. Some of the material of the Cocos plate melted by the high temperatures of the Earth's mantle, rises almost vertically and enters the Caribbean plate along a nearly straight line, forming the Central American volcanic chain that runs northwest -southeast.

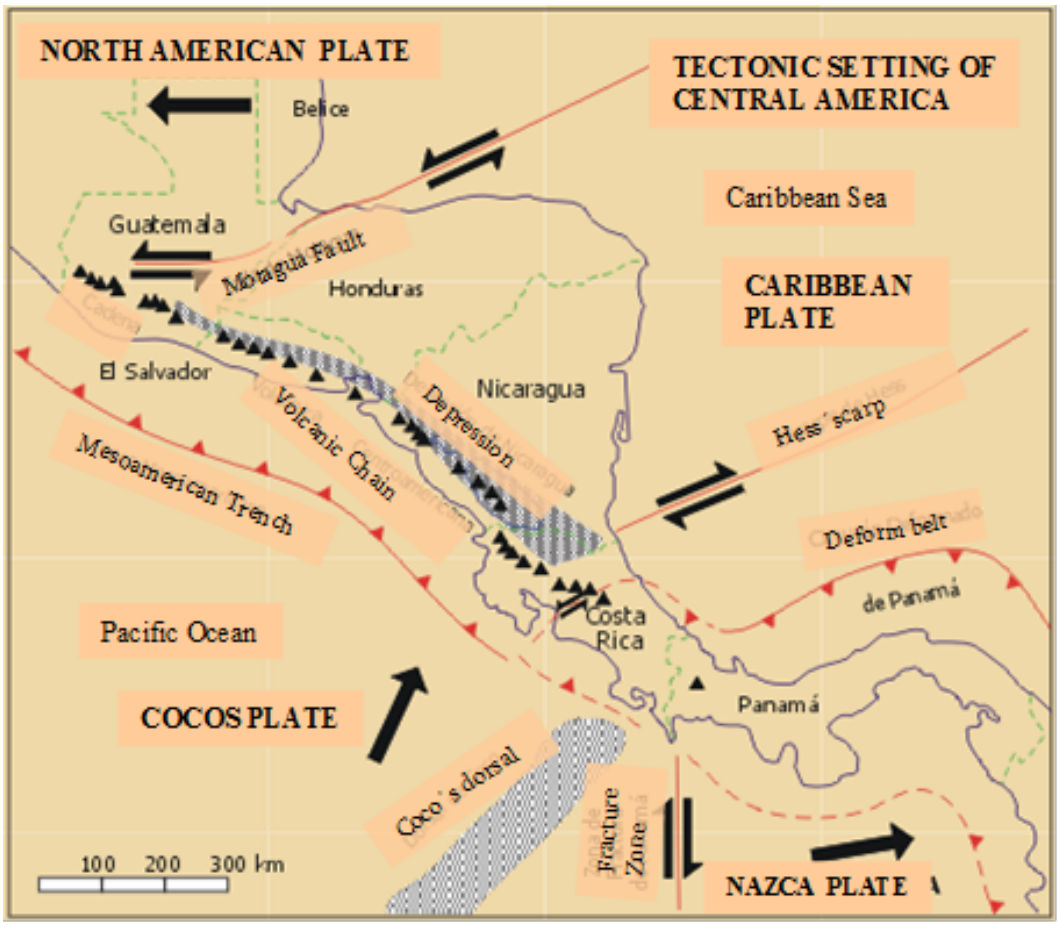

FIGURE 1: Subduction of the Cocos plate over the Caribbean plate and the volcanic chain (modified from CEPREDENAC)

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 as mentioned above 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 of anomalous heat flow in the vicinity of shallow magma chambers associated with volcanoes, producing temperatures between 200-300°C at depths between 500 and 3,000 m, where the heat is transported by conduction in the rocks and convection in the geothermal fluids.

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 for 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, San Jacinto Tizate in 2005, Amatitlán in 2006 and recently Las Pailas in July 2011 and San Jacinto Tizate in January (U3) and December 2012 (U4).

Figure 2, shows the location of the geothermal fields currently in operation and main geothermal areas that have been subject to exploration in Central America. Those with high temperature (> 200°C) have been utilized for generating electricity and very low application of low temperature resources have been done.

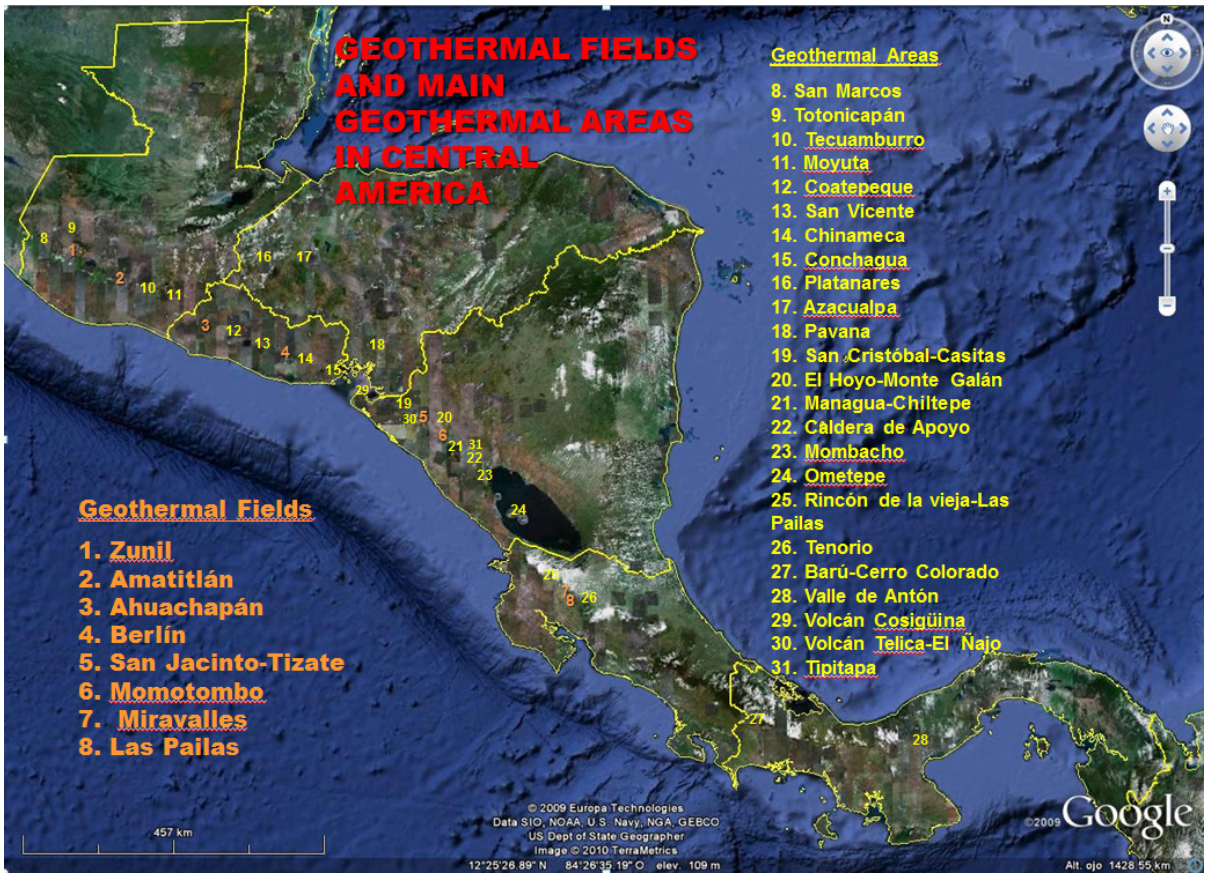

FIGURE 2: Location of the geothermal fields in operation and main geothermal areas in Central America (modified from Google)

Currently, 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 this market, uncertainties in future climate conditions (which could affect the output of hydroelectric projects), and the need of reducing CO_2 emissions by overriding the environmental impacts associated with burning wood and fossil fuels to generate electricity.

3. GEOTHERMAL RESOURCES AND CURRENT ESTIMATED POTENTIAL

Geothermal resource development in Central America should contribute significantly to achieving the Millennium Development Goals, generating electricity based on geothermal fluids that are clean, renewable, sustainable and an indigenous source of energy.

Their use can provide several advantages:

- offset the price of electricity;
- protect the Central American countries against future rises in the oil market;
- contribute to reduced environmental pollution; and
- create more job opportunities especially in rural areas where the development 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, could be in the range of 2000 to 16000 MW, giving a most likely value around 4000 MW. Table 1 shows the estimated geothermal potential of different sources including the geothermal potential to be developed given the current installed capacity. It can be seen that the total estimated potential for the region by the various energy sources is up to 4594 MWe and an average of 3510 MWe (various sources for TE in Table 1).

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

Geot. Pot. (MWe)	**TE**	**FD**	**TE**	**FD**	**TE**	**FD**	**TE**	**FD**	**TE**	**FD**
Nicaragua	1750	1586	1200	1036	992	828	1000	836	1519	1355
Costa Rica	1000	796	235	31	750	546	235	31	865	659
Guatemala	1000	951	1000	951	480	431	1000	951	1000	951
El Salvador	500	296	333	129	362	158	450	246	644	440
Honduras	130	130	120	120	122	122	126	126	116	116
Panama	50	50	40	40	42	42	40	40	450	450
Total	4430	3808	2928	2306	2748	2126	2851	2230	4594	3971
Source:	**Lippman 2002**		**CEPAL 2004**		**JICA 2005**		**SICA 2006**		**Essen 2013, mod. IILA 2009**	

Note: Geot. Pot. = Geothermal potential; TE = Total Estimated; FD = Future Development

4. GEOTHERMAL RESOURCES AND CURRENT ELECTRICAL GENERATION

Currently, from the existing geothermal potential in Central America, only a relatively small amount has been used to generate electricity providing an average of 13%, but seems to have significant savings in fossil fuels, especially in countries like El Salvador, Costa Rica, Nicaragua and Guatemala contributing 23.97, 13.92, 12.7 and 2.82% respectively of total electricity consumption in each country (Table 2).

The data in Table 2, includes information regarding the installed capacity for the new power plants in Costa Rica and Nicaragua (Las Pailas and San Jacinto Tizate, respectively).

TABLE 2: Geothermal Power Generation in 2012 (CEPAL)

Country	Installed Capacity (MWe)	Available Capacity (MWe)	Annual Energy produced (GWh/y)	National participation rate (%)
El Salvador	204.4	168.0	1420.4	24.29
Costa Rica	206.0	160.1	1402.6	13.92
Nicaragua	164.5	54.1	473.8	12.70
Guatemala	49.2	28.0	245.6	2.82
Total	624.1	410.2	3542.4	

Note: CEPAL 2012 reports a geothermal installed capacity for Costa Rica of 217.5 MW.

By the year 2009, the region has an installed capacity of 506.6 MW, generating an annual average of 417.5 MWe. In 2010, the installed capacity remained the same and the annual generation was a little bit lower at 357.4 MWe. Currently, the installed capacity has increased in 2012 up to 624 MW, generating annually 410 MWe and 3542 GWh which is equivalent to 7.9% of the total electricity generated by different sources. Figure 3 shows the evolution of installed capacity and annual average generation in the last 5 years in C.A.. Even though the installed capacity has increased, the generation does not show the same trend. This is an important point of discussion, as there may be several influencing factors such as technical, economic and regulatory aspects.

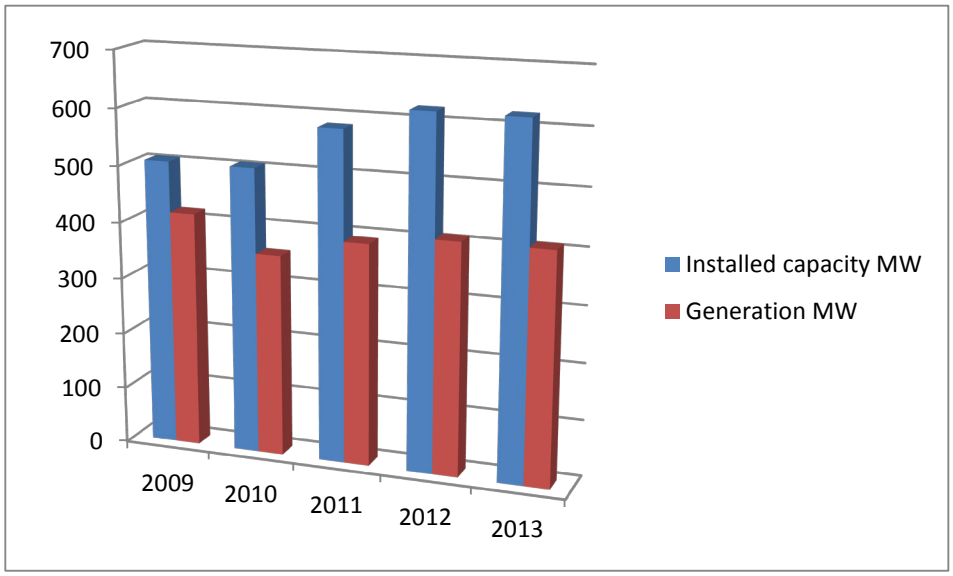

FIGURE 3: Evolution of installed capacity and annual average generation since 2009

On the other hand, as shown in Figure 4, the geothermal generation is the third in importance as a percentage compared to other types of energy used in Central America.

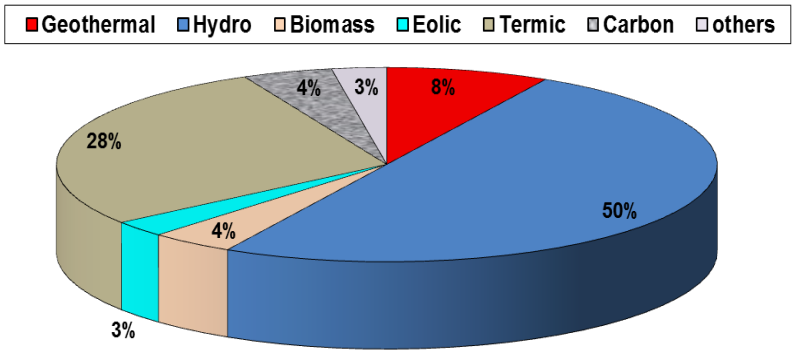

FIGURE 4: Electrical generation by energy source in Central America 2012

Figure 5 shows the percentage for each country of the total generated electricity from geothermal resources in 2012.

Figure 6 shows the percentage of the different geothermal fields on the total generated electricity from geothermal resources in 2012.

The contribution of geothermal power to the national grid of each country in Central America contains the updated data for 2012 both in geothermal generation (GWh) and percentage (Figure 7 and Figure 8).

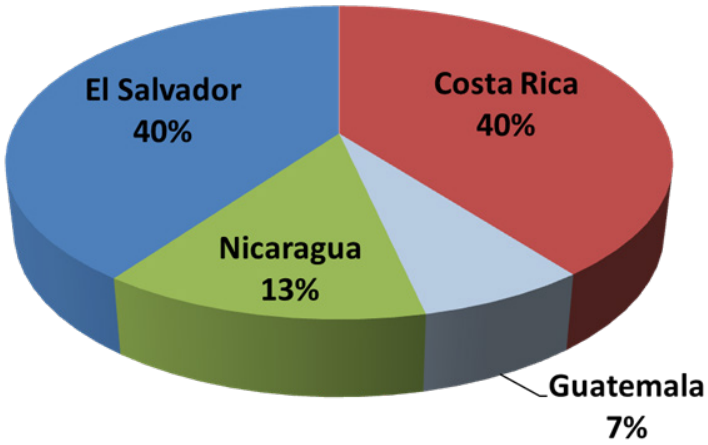

FIGURE 5: Electrical generation by geothermal resources in Central America 2012

It should be noted that El Salvador, Costa Rica, Nicaragua and Guatemala are considered among the top 10 countries in the world producing a good percentage of the total electricity consumption in each country (Figure 9).

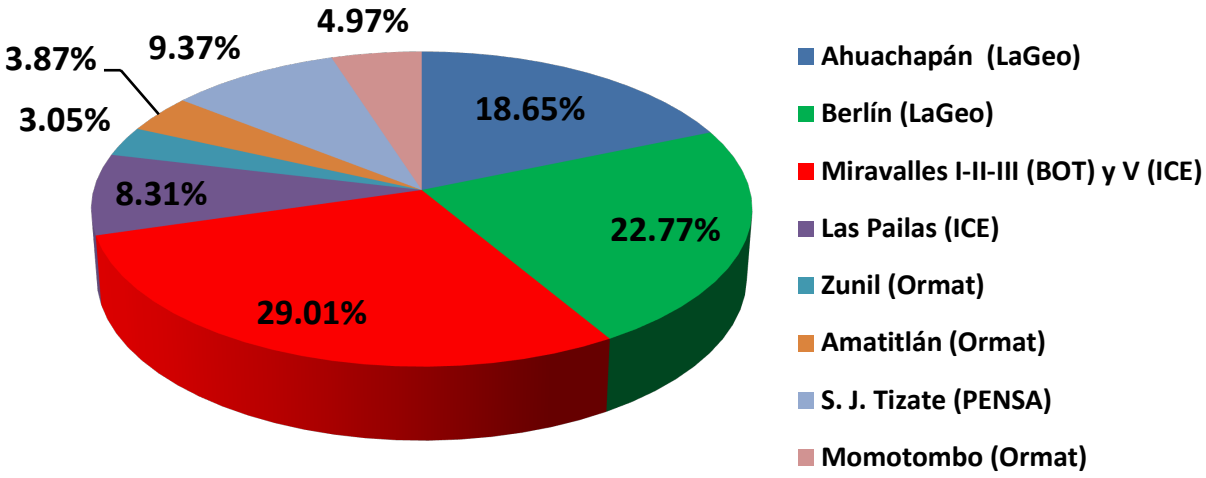

FIGURE 6: Percentage of geothermal production for each field in Central America by 2012

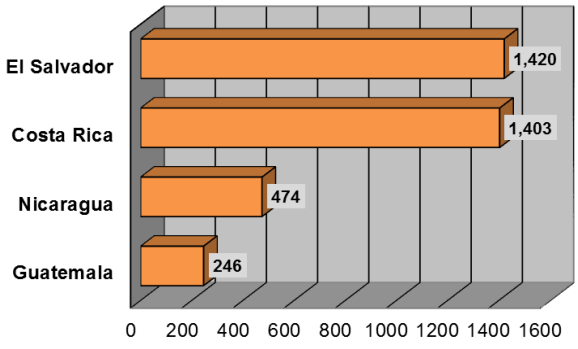

FIGURE 7: Geothermal energy production for electrical uses in 2012 (GWh)

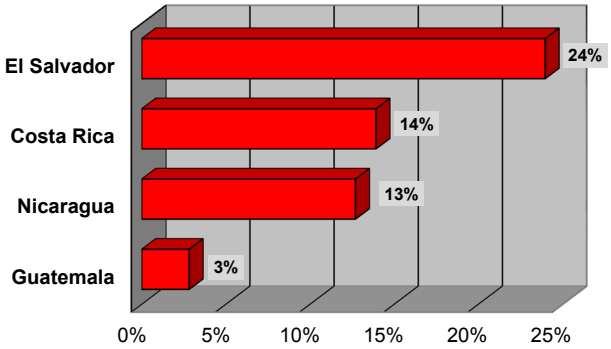

FIGURE 8: Percentage of contribution and electrical generation for 2012

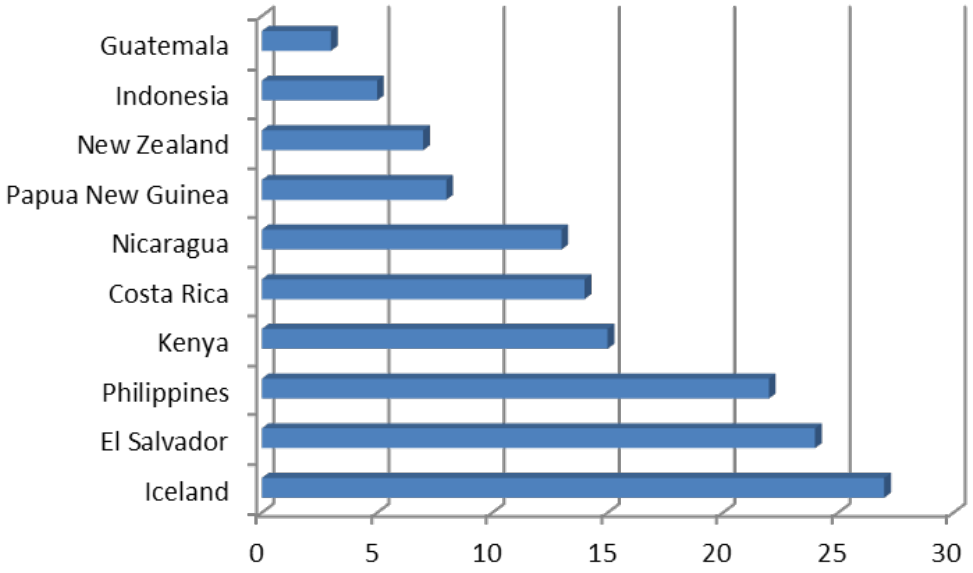

FIGURE 9: Top 10 countries with the highest percentage contribution of geothermal power to the national grid (modified from Bertani, 2007)

5. GEOTHERMAL DEVELOPMENT HISTORY

The geothermal development in Central America since 1975 is shown in Figure 10. The increase 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 3542 GWh in 37 years.

Worldwide, only 25 countries use geothermal power for electricity production (IGA). In 2010, total global capacity was 10,717 megawatts (Figure 11).

Even if Larderello (Italy) started the first commercial geothermal plant in the first part of twentieth century, within the last 50 years of commercial electricity generation, several plants installed in different countries have established and proven the geothermal industry as a cost-competitive renewable power generation technology.

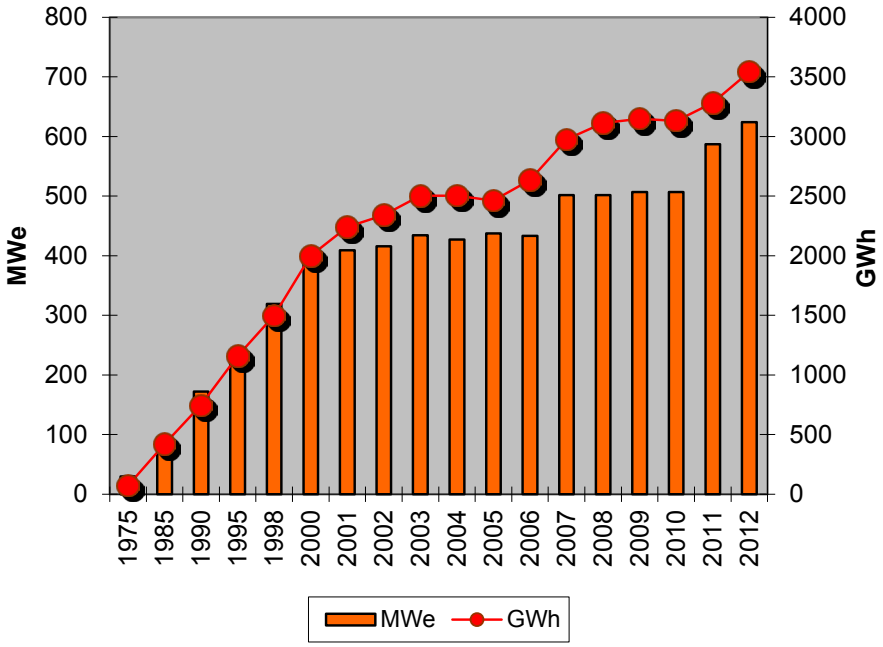

FIGURE 10: Geothermal development history and generation in Central America

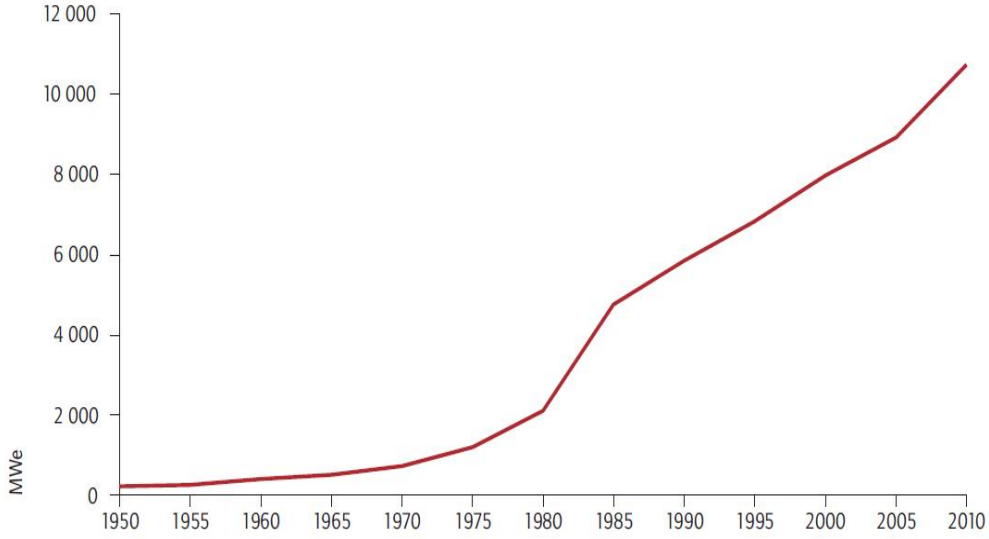

FIGURE 11: World geothermal development – Installed capacity

The majority of generation capacity is concentrated in a few countries: the U.S., the Philippines, Indonesia, Italy, Mexico, Iceland, Japan and New Zealand (Figure 12). After the first experiment of geothermal exploitation was carried out at Larderello in 1904, the first industrial power plant (250 kW) was put into operation in 1913, and geothermal power production has since increased continuously up to the present value of 810 MW installed capacity (711 MW running capacity). The first geothermal power plants in the U.S. were built in 1962 at The Geysers dry steam field, in northern California. It is still the largest producing geothermal field in the world, with a peak capability of nearly 1,100 MW, enough electricity to supply a city of over a million inhabitants. The largest field that generates the most electricity in Latin America is Cerro Prieto, Baja California, Mexico (720 MW).

While these established markets will continue to account for the geothermal growth in the short term, several regions, including Central America, the Caribbean and East Africa, and others countries like Chile, Argentina, Turkey, Russia and Canada are looking to exploit robust. geothermal resource potential as power generation demand and global fuel price increases (Stephure, T., 2009; Figure 12).

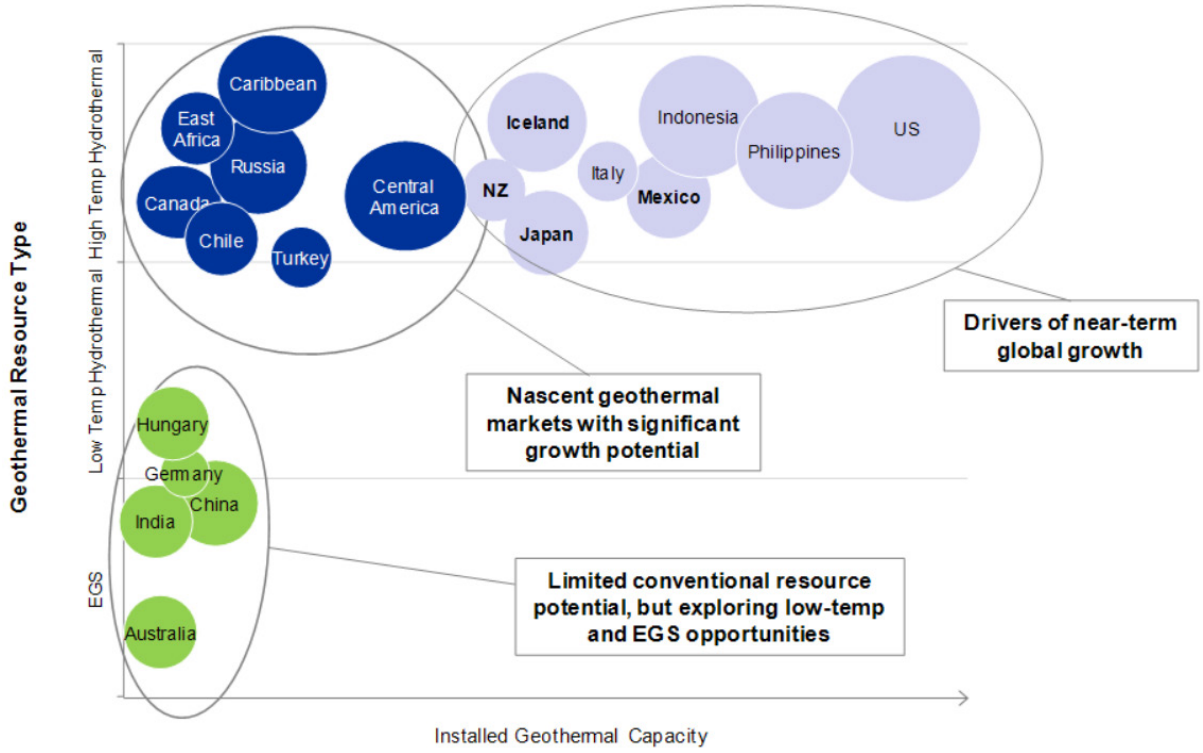

FIGURE 12: Global Geothermal Country Rankings by Installed Capacity and Pipeline.
Note: Bubble size reflects MW resource potential (Stephure, 2009)

The Figure 12, also shows other countries like Hungary, Germany, India, China and Australia exploring low enthalpy resources technology or with Enhance Geothermal system (EGS). Geothermal exploration is increasing, mostly due to improved technology and techniques. Several projects are underway around the world, but face financing, drilling risk, skilled labor shortages and other factors like environmental regulations mainly related to the location of geothermal resources in national parks that could limit the development over the next decade.

Figure 13 shows the world geothermal-electric installed capacity by 2012. The countries of Costa Rica, El Salvador and Nicaragua are currently placed in position ten, eleven and twelve in the geothermal world, respectively.

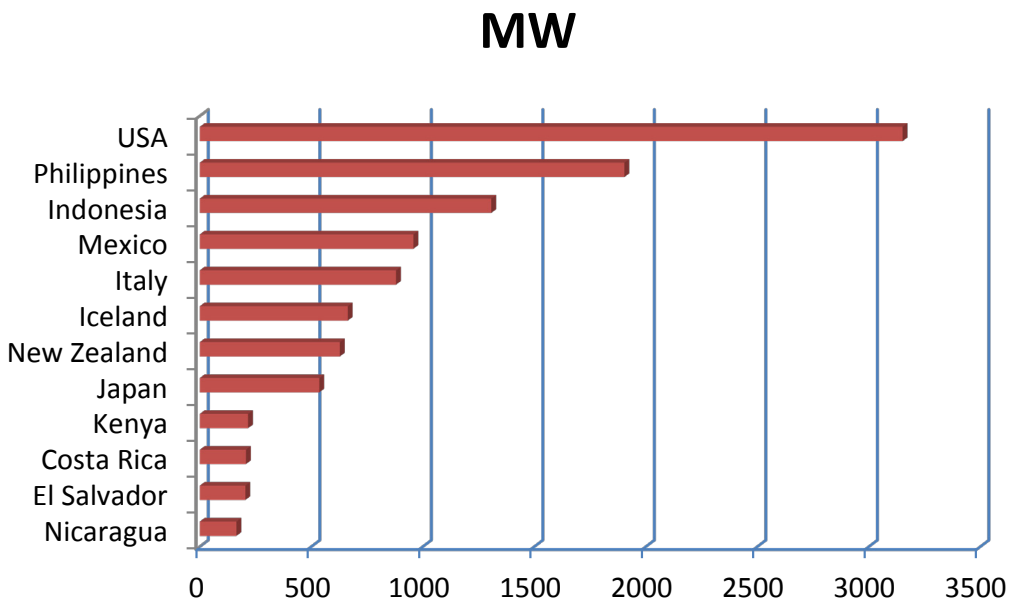

FIGURE 13: World geothermal installed capacity (modified from IGA, 2012)

6. FUTURE DEVELOPMENT IN CENTRAL AMERICA

According to Earth Policy Institute (EPI) estimates 2007 (www.earthpolicy.org), the MW required to meet the total demand for electricity in each country for 2010 are shown in Figure 14. The importance for the governments and private companies to accelerate research and development of geothermal resources in the region should be noted. As mentioned earlier, the potential resources in Central America has been estimated very close to the total amount currently used in electric power that was reported for EPI, about 4317 MWe (5057 MWe for the year 2012).

Figure 14, shows the MWe required from geothermal resources in the Central American countries to achieve the annual current total demand of electricity by 2010 (according to EPI 2007). See Table 1.

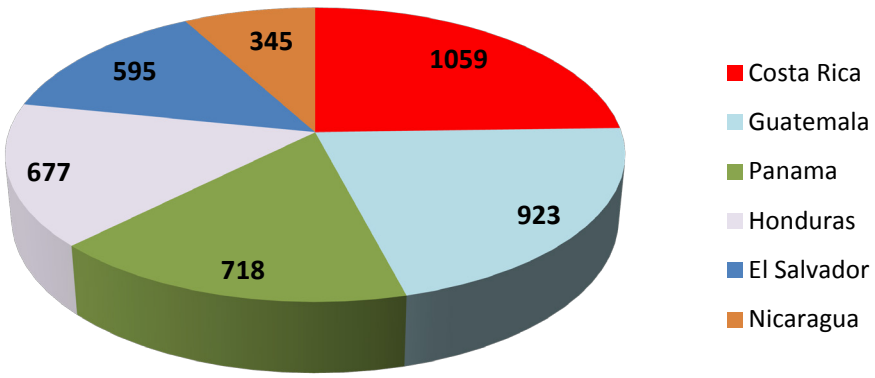

FIGURE 14: MWe required from geothermal resources in the Central American countries to achieve the annual current total demand of electricity by 2010 (EPI, 2007)

Bertani (2010) presents a forecasting for the geothermal installed capacity in Central American countries by the year 2015 as shown in Table 3. These estimations gave an increase in installed capacity of 261 MWe over the coming years (considering the total installed capacity by 2012 of 624 MWe).

Some new projects that are underway and will be developed in the near future are described in Table 4, which would imply an increase in geothermal capacity in the region of about 352 up to 649 MWe over the coming years.

TABLE 3: 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 are two operating geothermal fields, Miravalles in which five power plant units are operated with a total installed capacity of 163.5 MWe. In the second half of 2011 (25th July) the first plant in the Las Pailas geothermal field was commissioned, located on the Pacific side on the slopes of the Rincón de la Vieja Volcano in the Guanacaste province, with a gross capacity of 42.5 MWe and 35 MWe net power (Sánchez, ICE, 2013). The power plant is formed by two ORMAT binary units with a net generation of 150.6 Gw/h in 2011 and 285 GWh in 2012 (Mainieri, ICE 2012; Castro ICE, 2013). Instituto Costarricense de Electricidad (ICE) is also exploring two steam fields in the country's west, financed by the Japanese government, under an agreement of understanding between the Costa Rican Electricity Institute (ICE) and the International Cooperation Agency of Japan (JICA) in order to install two new geothermal plants, called Las Pailas II and Borinquen.

TABLE 4: Future development projects in Central America

Country	New Geothermal Development
Costa Rica	Las Pailas II 35-55 MW; Borinquen 55-110 MW; Tenorio; Arenal
El Salvador	Chinameca 50 MWe, San Vicente 30 MWe; Berlin U5, 28 MWe + Binary Cycle 2, 5.7 MWe; Optimization Ahuachapán Phase III 5 MWe
Guatemala	Amatitlán 20-50 MWe; Tecuamburro; Moyuta; San Marcos; La China; La Gloria; Joaquina; Atitlán
Nicaragua	San Jacinto Tizate Binary Cycle 10 MWe; Casitas-San Cristóbal 33-225 MWe; El Hoyo-Monte Galán; Managua-Chiltepe; Mombacho; Caldera de Apoyo
Honduras	GeoPlatanares 35 MWe; Azacualpa 20 MWe; Pavana 20 MWe
Panamá	Barú Colorado 5 MWe

El Salvador has increased its total geothermal power capacity since 2007 from 151.2 MWe to 204.4 MWe, building two new units in the Berlin area and the optimization project in Ahuachapán which has reached levels of up to 85% of total capacity installed. El Salvador is continuing to develop geothermal energy projects in the areas of San Vicente and Chinameca, where drilling to confirm the resource and exploitation is scheduled to continue in 2012-2014, where temperatures of about 250 ° C and 230 ° C respectively have been recorded in the recently drilled wells in both fields.

For Guatemala, the potential of geothermal energy has been estimated at 400 MWe, has been successfully utilized so far in the Zunil and Amatitlan fields. Feasibility studies are conducted in the Tecuamburro, San Marcos and Moyuta geothermal fields. In addition, the 30 MWe expansion of Amatitlán is planned. The government of Guatemala has granted four concessions in 2011-2012, which will focus on analyzing the potential for possible development. The concessions are the Atitlan, Joaquina, La Chinita, El Ceibillo and La Gloria projects.

In Nicaragua, in addition of Momotombo, the exploitation of the geothermal field of San Jacinto-Tizate property of Polaris Energy Nicaragua (PENSA) has begun, with the installation of two wellhead units with a total installed capacity of 10 MWe. Actually, two more units have started operation by 2012, expanding the gross installed capacity to 87 MWe. Concessions have recently been given to the Mombacho volcano, Caldera de Apoyo and San Cristóbal-Casitas.

Honduras will develop its first geothermal power plant in the Platanares geothermal field, located in a different geological structure of the typical features of high-temperature fields associated with volcanic

structures. Geoplatanares, the company that holds the concession will in the future start to drill exploration wells to confirm the feasibility and proceed to commercial development. Exploration activities are on the way in the Azacualpa and Pavana geothermal areas. In the future, the completion of feasibility studies, environmental and financial, exploration drilling, production drilling, infrastructure adequacy of access, connection to the national transmission system, supply of equipment, plant construction and commercial operations are programmed.

In Panamá, the Government is structuring Terms of Reference for the assessment of geothermal potential in the country and a pre-feasibility study for electricity production of a Barú-Colorado geothermal field by Centram Geothermal INC. (5 MW) near the Barú Volcano. Preliminary studies suggest a country potential from 100 MW to 450 MW.

In Central America, geothermal constitutes the second most important renewable energy source in the region. To date, there has been progress such as the exploration, development and exploitation potential of this resource estimated in the order of 3000-4000 MW distributed among Costa Rica, Guatemala, El Salvador and Nicaragua; in the case of Panama and Honduras, there are only preliminary estimates, but the geological-tectonic point of view, indicates that there are also potential resources for electricity generation, but probably at a limited scale compared with the others due to the volcanic activity.

The Figure 15 shows the total estimated geothermal potential (from Table 1, Essen 2013) and the geothermal potential that could be developed in the future. If we can assume an average of the total estimated geothermal potential of 3510 MWe and taking into account the installed capacity by 2012, the geothermal potential to be developed in the future could reach about 2886 MWe (82% of the total estimated). Although currently the geothermal energy in Central America has been successfully developed in several countries, there is still much work to do according to estimates of existing geothermal potential in the region.

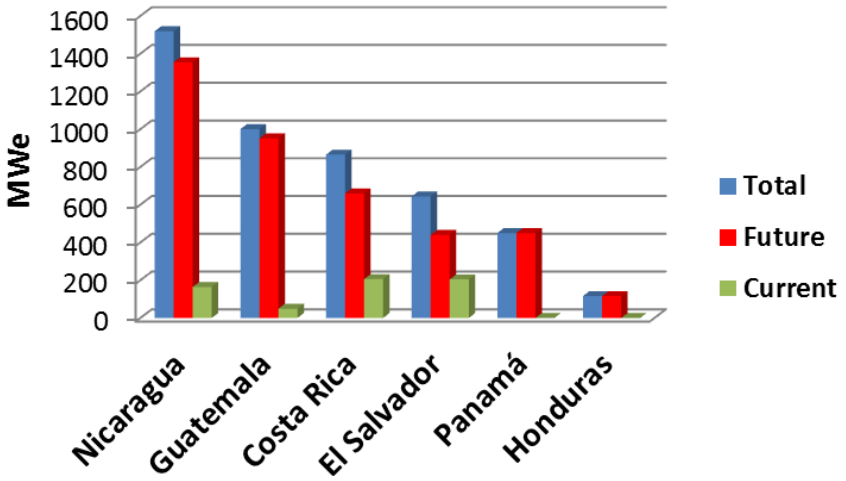

FIGURE 15: Total estimated geothermal potential and to be developed in MWe (modified from IILA, 2010)

The potential resource in Central America, has been estimated very close to the total amount currently used in electricity power generation, which is about 5057 MWe (CEPAL, 2012).

7. DIRECT USE OF GEOTHERMAL ENERGY IN CENTRAL AMERICA

Direct use of geothermal energy is well known in ancient times, in Central America pre-Columbian cultures used the hot springs for medicinal, culinary, religious or social purposes. Some of the sites are currently geothermal areas in El Salvador, and were known to the Indians who inhabited these areas as "ausoles". The word according to some historians, comes from the Nahuatl "atl" (water) and "Soloni" (loud boiling sound) as the Dictionary of the Royal Academy of Spanish Language (RAE) which considers salvadoreñismo to mean loud boiling water, because the soil water boiling springs form impressive fumaroles (Jose Perez Bouza: Spanish Influences on the Nahuatl of El Salvador 1994).

In general, direct use of geothermal energy currently used in Central America include mostly the drying of fruits, cement blocks and pools or hot springs.

Due to the warm temperate climate of Central America there is no current application of heating systems for buildings and greenhouses, but a few research studies for cooling spaces have been made.

More specifically, some studies have been performed and are using the resource for moderate to low temperature use as follows:

- Costa Rica, practically limited to the use of thermal pools, although there are technical studies for drying fruits and grains in the geothermal field of Miravalles;
- El Salvador has thermal baths and some tests in domestic application in the drying of fruits in the Berlin geothermal field in a natural dehydration process;
- Guatemala has thermal baths at different sites also applies to industrial drying of fruits and concrete blocks in the geothermal field of Amatitlán;
- Honduras has several places with hot springs in Copan and Gracias; and
- In Panamá, thermal water has been used in the touristic industry. Natural thermal baths are very famous in El Valle de Antón.

Lund et al (2010) has estimated that in Central America there is currently a total installed capacity of 7.2 MW thermal, with a total amount of energy use of 162.5 TJ / year equivalent to 45.1 GWh per year (Table 6).

TABLE 5: Direct uses in Central American countries (Lund et al, 2010)

Country	Capacity MWt	Annual TJ/año	Annual GWh/año	Capacity factor
Costa Rica	1.0	21.0	5.8	0.67
El Salvador	2.0	40.0	11.1	0.63
Guatemala	2.3	56.5	15.7	0.78
Honduras	1.9	45.0	12.5	0.74
Total	7.2	162.5	45.1	0.71

REFERENCES

Bertani, R., 2007: *Long term projections of geothermal-electric development in the world*. Enel Green Power, Italy 2007.

Bertani, R., 2010: Geothermal power generation in the world 2005–2010 Update Report. *Proceedings World Geothermal Congress 2010 Bali, Indonesia*, 41 pp. Website: http://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/0008.pdf

Castro, S., 2013: *Personal communication*. Instituto Costarricense de Electricidad (ICE), February 2013.

CEPAL, 2007: *Estrategia energética sustentable Centroamericana 2020*. Naciones Unidas - Comisión Económica para América Latina y El Caribe (CEPAL) and Secretaría General Sistema de Integración Centroamericano (SICA), report LC/MEX/L.828, 115 pp. Website: http://www.enee.hn/PDFS/EstrategiaCentroamericana2020.pdf

CEPAL, 2012: *Centroamérica: Estadísticas del subsector eléctrico, 2012*. Naciones Unidas - Comisión Económica para América Latina y El Caribe (CEPAL), report LC/MEX/L.1039, 89 pp. Website: http://www.eclac.org/publicaciones/xml/3/49833/Centroamerica-EstadisticasdeProduccion.pdf

DeMets, C., 2001: A new estimate for present-day Cocos-Caribbean plate motion: Implications for slip along the Central American volcanic arc. *Geophysical Research Letters, 28*, 4043–4046.

IGA, 2012: *IGA News*. International Geothermal Association, Quarterly No. 90, 15 pp. Web: http://www.geothermal-energy.org/publications_and_services/iga_newsletter.html

IILA, 2010: *Estado actual y desarrollo de los recursos geotérmicos en Centro América*. Instituto Italo Latino Americano (IILA). Cuadernos IILA Nueva Serie Técnico-Científica n°5.

Lippmann, M.J., 2006: United Nations Millennium Development Goals and geothermal development in Central America. *Presented at "Workshop for decision Makers on Geothermal Projects in Central America", organized by UNU-GTP and LaGeo in San Salvador, El Salvador*, 7 pp. Website: http://www.os.is/gogn/unu-gtp-sc/UNU-GTP-SC-02-02.pdf

Lund, J.W., Freeston, D.H., Boyd, T.L., 2010: Direct Utilization of Geothermal Energy 2010 Worldwide Review. *Proceedings World Geothermal Congress 2010 Bali, Indonesia*, 23 pp. Website: http://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/0007.pdf

Mainieri, A., 2011: *Personal communication*. Instituto Costarricense de Electricidad (ICE), February 2011.

Montalvo, F., 2011: Current status of geothermal resources development in Central America. *Presented at "Short Course on Geothermal Drilling, Resource Development and Power Plants", organized by UNU-GTP and LaGeo, in Santa Tecla, El Salvador*, 10 pp. Website: http://www.os.is/gogn/unu-gtp-sc/UNU-GTP-SC-12-03.pdf

Montalvo, F., 2012: Current status of geothermal resources development in Central America. *Presented at "Short Course on Geothermal Development and Geothermal Wells", organized by UNU-GTP and LaGeo, El Salvador*, 13 pp. Website: http://www.os.is/gogn/unu-gtp-sc/UNU-GTP-SC-14-04.pdf

Montalvo, F., 2013: Current status of geothermal resources development in Central America. *Presented at "Short Course on Conceptual Modeling of Geothermal Systems", organized by UNU-GTP and LaGeo, El Salvador*, 14 pp. Website: http://www.os.is/gogn/unu-gtp-sc/UNU-GTP-SC-16-03.pdf

Quintanilla, A., 2013: *Personal communication.* Polaris Geothermal Inc., February 2013.

Sánchez, E., 2013: *Personal communication*. Instituto Costarricense de Electricidad (ICE), November 2013.

SICA, 2007: *Alianza en energía y ambiente con Centroamérica. Guía Centroamericana de financiamiento de carbono*. Secretaría General Sistema de Integración Centroamericano (SICA), 2da edición, 153 pp.

Stephure, T., 2009: *Geothermal development expands globally*. Website: http://www.renewablesbiz.com/article/09/05/geothermal-development-expands-globally