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STATUS UPDATE OF GEOTHERMAL DEVELOPMENT IN GUATEMALA

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ABSTRACT

Guatemala's geothermal potential is estimated at 1000 MWe. Initial reconnaissance studies in 1981 identified many geothermal areas for potential development. In 1992 the Ministry of Energy and Mines (MEM) declared the areas with the highest potential Geothermal Reserves and granted INDE exclusive rights to explore and develop their geothermal resources. Lack of government policy and financial restrictions have prevented INDE from developing these fields. Now, the government begins to look at the private sector for geothermal development. In 2012, MEM published the Indicative Generation Expansion Plan, a dispatch model to forecast changes in the country's energy mix from new and available projects under development that utilize renewable and non-renewable resources. The forecast model predicts an increase of 300 MWe capacity from geothermal projects and gives a clear indication that the current government of Guatemala will seek to promote the development, through private investment, of its geothermal resources in the near future. In more recent years, the country has seen an increase in private investments steered towards the development newly discovered geothermal resources and new concessions have been awarded to carry out reconnaissance and exploration drilling to determine their potential.

1. INTRODUCTION

Geothermal resources in Guatemala are abundant and provide a sustainable source of energy at low cost. Guatemala's estimated geothermal potential is 1000 MWe. The first studies to identify geothermal resources began in the early 1970s. A reconnaissance study in 1981 identified many new geothermal areas. The areas with the highest potential for development were declared Geothermal Reserves by the Ministry of Energy and Mines (MEM) (Figure 1). In 1992, these areas were granted exclusive rights to the National Energy Authority (INDE) for exploration and development. Financial restrictions and lack of policy to promote the development of new renewable energy resources prevented INDE from harnessing the country's potential. Guatemala's geothermal installed capacity is 44 MWe and produced 259 GWh of energy in 2010, 3% of the country's total energy production. The current government is now beginning to look at the private sector for the development of new projects. In more recent years new geothermal areas have been discovered and new geothermal concessions been awarded to private investors to carry out reconnaissance and exploration drilling to determine their economic potential.

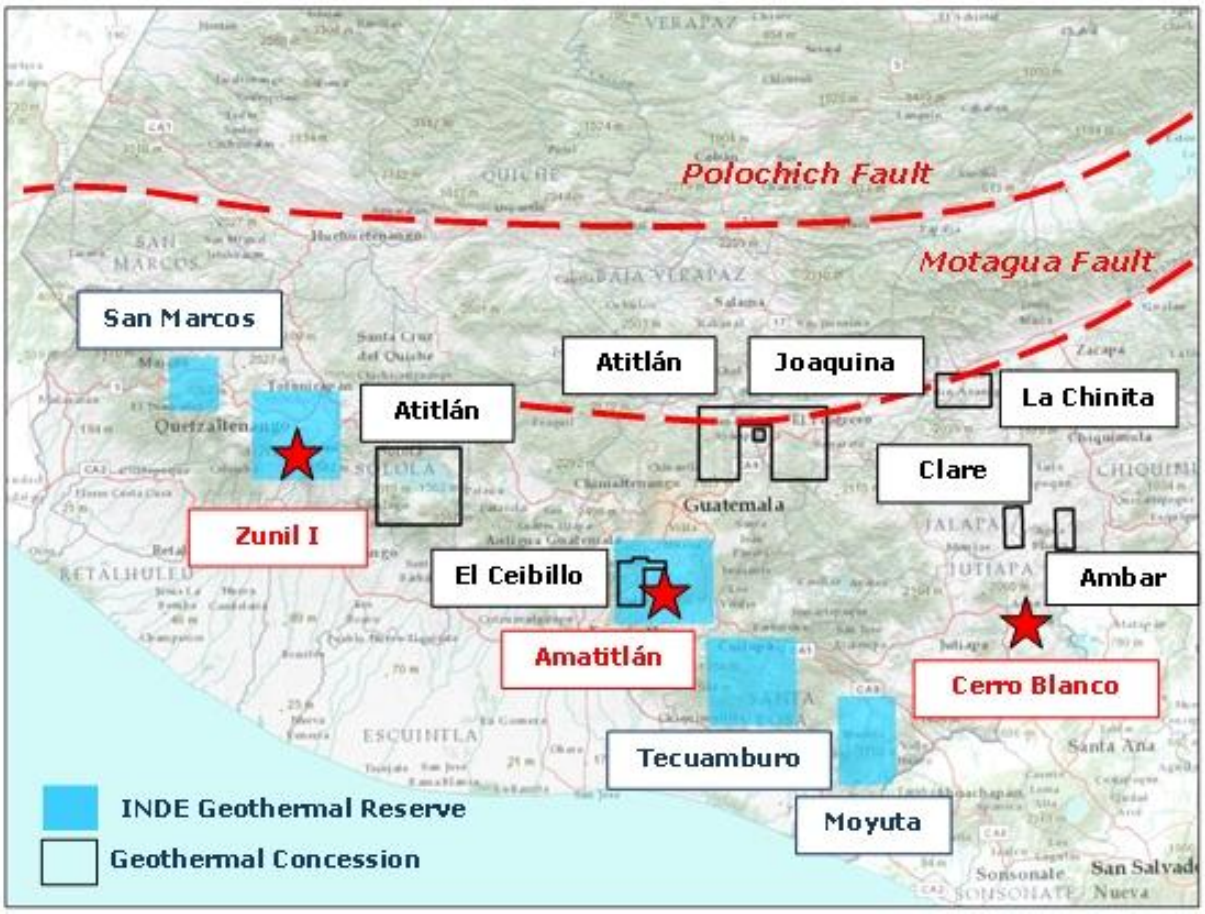

FIGURE 1: Map of Guatemala showing location of geothermal reserves, new geothermal concessions, and geothermal plants in operation and development

2. GUATEMALA'S INDICATIVE GENERATION EXPANSION PLAN 2012-2021

The Ministry of Energy and Mines recently published the "Indicative Generation Expansion Plan for 2012-2021." The plan is an indicative dispatch model that predicts the projected changes in Guatemala's generation mix for the next 15 years (MEM, 2012a). The dispatch model is used to optimize all new and available electrical generation projects and predicts which projects or generation blocks will guarantee the lowest energy costs to the final consumers. It also calculates how it will affect the country's energy mix in the future. The model takes into account new projects that have been presented in different government institutions and have enough available technical and commercial information to model them. The projects included utilize renewable resources and non-renewable resources.

The model predicts that by 2021, power demand in Guatemala will grow by more than 1251 MW and reach a total demand of 2,785 MW, an increase of 85 MW/year (Figure 2). The energy demand is also expected to grow by more than 10,831 GWh, doubling the current energy demand, and reaching a total of 19,255 GWh, an increase of 722 GWh/year. Figure 2 also shows the available power capacity curve in MW calculated by the dispatch model optimization and clearly shows how available power capacity sufficiently cover the growing demand capacity; therefore no energy deficits are expected.

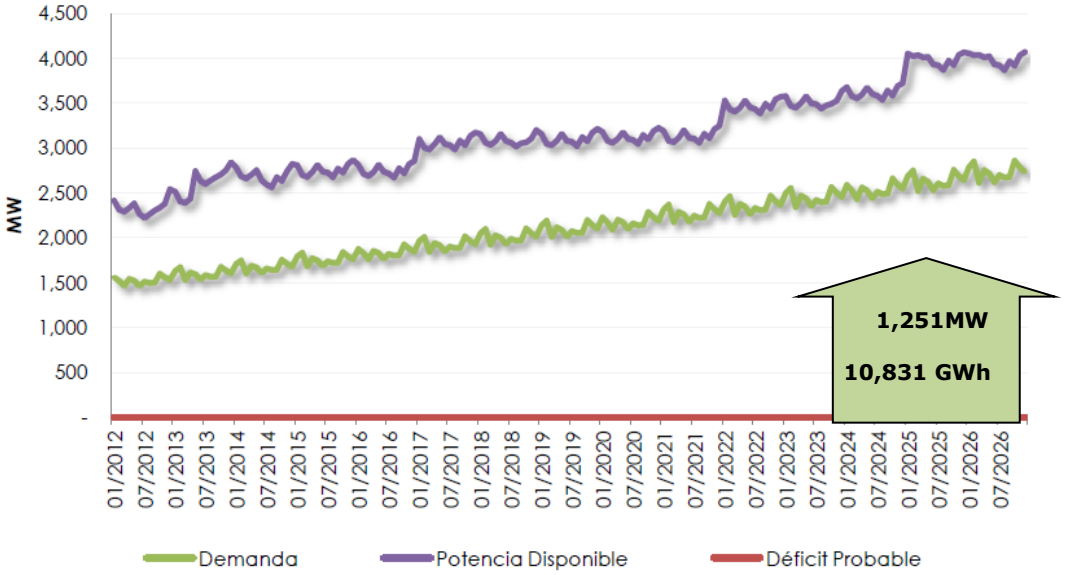

FIGURE 2: Available power (purple curve) vs. demand (green curve)

In particular, the dispatch model shows a dramatic change in Guatemala's generation mix with a total of 1,685 MW projected to be installed by 2021, 83.7% coming from renewable resources (1,110 MW from hydro, 300 MW from geothermal and 275 MW from Carbon). The geothermal capacity is expected to be online by 2017. This is a substantial increase in installed capacity and places geothermal as an important economic resource within Guatemala's energy mix (Figure 3).

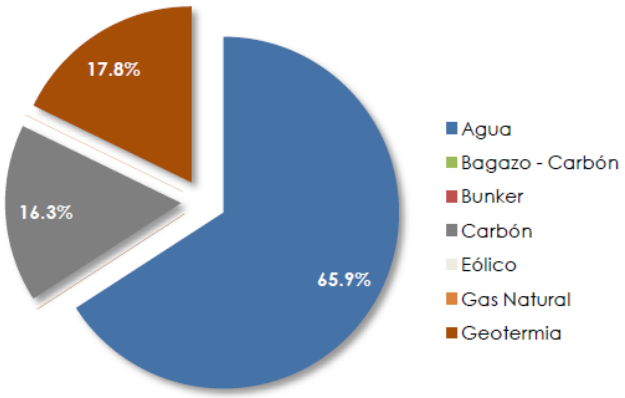

FIGURE 3: Total projected power capacity to be installed by resource percentage (300 MW are expected from geothermal)

The following recommendations are presented in the Indicative Generation Expansion Plan that gives an indication of the current government's energy policy in the near future. The recommendations are to develop and implement a political agenda and plan of action that will promote the development of new geothermal resources. The recommendations clearly states:

- Update the Indicative Generation Expansion Plan to include new expansion scenarios for geothermal energy;
- Evaluate the implementation of contract premiums for the purchase of geothermal energy to meet long term power and energy demands of local distributors;
- Evaluate new tender mechanisms aimed at promoting the development of new geothermal resources by the private sector.

It is clear that the current government of Guatemala intends to promote the development of new geothermal resources in the near future and expects a large increase of geothermal energy in the energy mix. Does Guatemala have sufficient resources and can they be developed on time under the current legal framework to cover the projected energy growth?

3. GEOTHERMAL PROJECTS IN OPERATION

3.1 Amatitlán Geothermal Project

The Amatitlán geothermal area is located 40 km south of Guatemala City (Figure 4). Deep drilling exploration confirmed the existence of a deep chloride rich geothermal system with a temperature of 285°C. In 2001 Ormat Inc. was awarded the concession of the Amatitlán geothermal field. Under the contract agreement the field capacity is expected to reach 50 MWe. In 2006 the company began the first phase of construction of a binary power plant with an installed capacity of 20 MWe. The plant was commissioned in August of 2007 producing a total of 340 T/hr of steam and brine from 4 production wells and reinjects at 100%. In 2010, the plant was taken out of service after sustaining damages from the eruption of nearby Pacaya Volcano. Following the repairs and maintenance, the plant was brought back online at full operating capacity in 3 months' time.

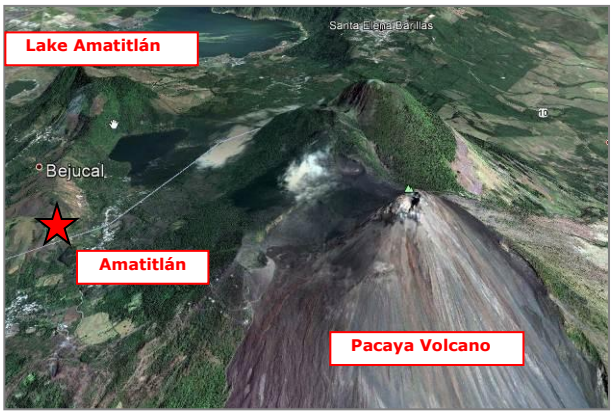

FIGURE 4: Ortitlan Geothermal power plant in Amatitlán

3.2 Zunil I Geothermal Project

Deep exploration in the Zunil I geothermal field began in 1981 with 6 deep exploration wells. Production was achieved from a two phase liquid dominated reservoir with a temperature of 280°C (Figure 5). In 1999, though a Power Purchase Agreement (PPA) between INDE and Ormat Inc., a 24 MWe geothermal power plant was commissioned. In the last years Zunil I field has seen a decline in production due to declining reservoir pressures. In the future more make up wells will need to be drilled to raise the production of the field. Make up wells drilled in 2005 have not been properly tested, initial tests were not favourable. Nevertheless, INDE in the future still plans to evaluate these wells before a decision is made to use their production to supply a 5 MW backpressure unit or to connect them to the existing Orzunil plant (Asturias, 2010).

FIGURE 5: Zunil I geothermal power plant in in Quetzaltenango

4. GEOTHERMAL PROJECTS IN DEVELOPMENT

4.1 Cerro Blanco Geothermal Project

Cerro Blanco is a moderate temperature geothermal system that was discovered in 1997 during gold exploration in south-eastern Guatemala. This system is associated with bimodal basalt-rhyolite volcanism, and occurs alongside (and overlapping with) the Cerro Blanco 2 million ounce epithermal gold deposit (Figure 7A). Fluids at temperatures up to 180°C were encountered in 150-400m deep gold exploration drillholes (Figure 6). Geothermometry on hot springs and well fluids indicated that most fluids were derived from the shallow 180°C reservoir, but that deep temperatures were at least

220°C. The shallow reservoir appears to be a localized outflow from a deeper, hotter system (White et al, 2010).

A comprehensive MT resistivity survey suggested that the deeper reservoir was to the northeast of Cerro Blanco, and gravity surveys indicated some very strong structural control on deep permeability (Figure 7B). Four 1000-1500 m deep slimholes were drilled in 2008-09 to confirm the nature of the deep reservoir. GoldCorp plans to develop the geothermal system to provide geothermal power for the proposed gold mine and surplus power for the national grid. In 2011, an environmental study was submitted to MARN for the construction of a geothermal power plant and development of the field.

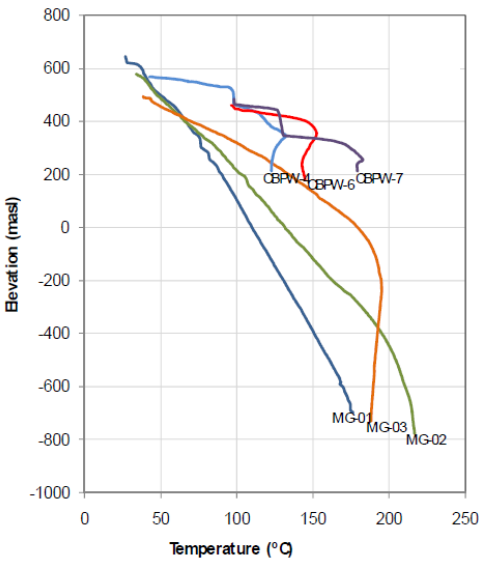

FIGURE 6: Temperature profiles of 4 shallow wells and 2 deep wells drilled at Cerro Blanco

4.2 El Ceibillo Geothermal Project

The El Ceibillo geothermal project is located 14 km south of Guatemala City near the town of Amatitlán in the department of Guatemala. Reported potential is an estimated 25 MW. The project consists of 7 shallow wells ranging from 170 - 600 m in depth. Four of the existing wells (B-4, B-6, B-7 and B-8) will be deepened to a target depth of 1000 m to evaluate the deeper reservoir. The resource was first discovered in the 1990's when Blotequa, S.A., a private company that manufactured construction blocks, drilled into the resource and discovered a low temperature reservoir with a temperature of 185-204°C. Two wells where used produce hot water and used in the block curing process. This project was the first direct utilization of geothermal energy in Central America.

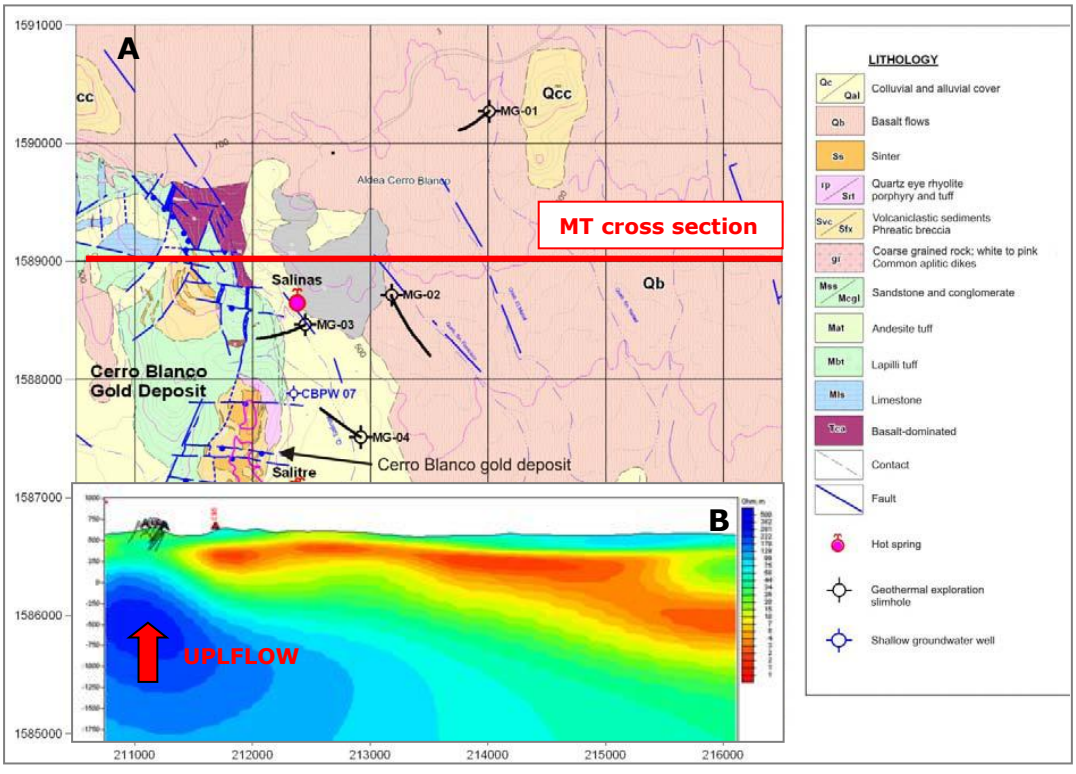

FIGURE 7: A) Geologic map of Cerro Blanco area and B) E-W cross section of MT resistivity survey showing geo-electric a structure interpreted as geothermal system

In 2009 US Geothermal, S.A. was granted an environmental permit by the Ministry of Environment and Natural Resources (MARN) to re-drill the 4 wells. In 2010 the project was awarded a geothermal concession covering a total area 100 km^2. The concesion is located within the Amatitlán Geothermal Reserve. The development of El Ceibillo area has been possible due to a success negotiation with the local energy authority for the rights to the project (Figure 8). Recently, US Geothermal announced that it was developing a PPA for the El Ceibillo project and looking for a minority sale of equity to a local qualified partner (BNamericas, 2011).

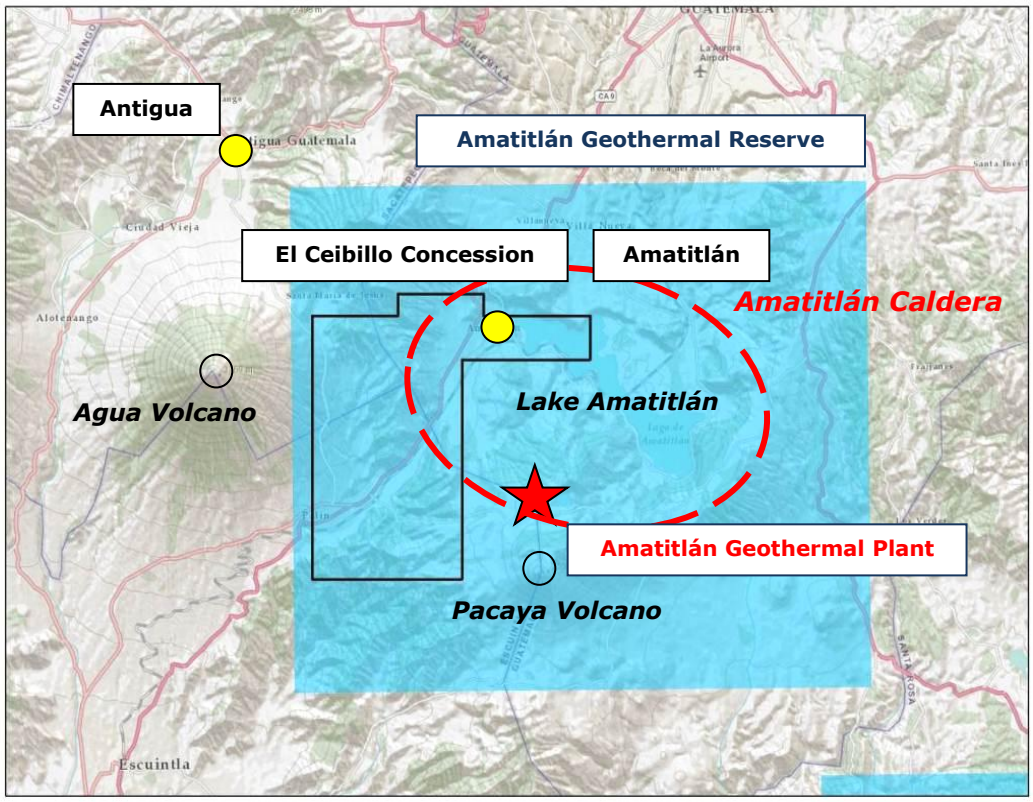

FIGURE 8: Map of the Amatitlán geothermal area showing location of the Amatitlán geothermal plant and El Ceibillo concession area, all within the Amatitlán Geothermal Reserve. Outline of the Amatitlán Caldera is show as a red dashed line

4.4 Joaquina Geothermal Project

Joaquina is located in the central portion of Guatemala about 35 km northeast of Guatemala City and near the small towns of Santo Domingo and San Jose del Golfo in the department of El Progreso (Figure 11). The area contains Mesozoic meta-volcanic and meta-sedimentary formations overlain to the south by Tertiary and Quaternary volcanics. The Joaquina area contains several boiling hot springs along the La Cañas River. Transform deformation along the Motagua Fault to the north has resulted in an extensional setting and provides structurally controlled NE-SW faults and lineaments that are favourable conditions for the circulation of deep geothermal fluids. The Resource temperature is calculated to be 180°C based on geothermometers from hot springs (MEM, 2012b). This will have to be confirmed with a new geochemical evaluation. In 2011, MEM awarded Recursos del Golfo, S.A. a temporary concession of 9 km^2 to carry out surface exploration studies in order to define the characteristics of the geothermal resource (Diario de Centro America, 2011a). In 2012 the company plans to start a drilling program to confirm the resource.

4.5 Atitlán Geothermal Project

The Atitlán geothermal area is located in the western portion of Guatemala about 100 km west of the City of Guatemala at Atitlan Lake in the department of Sololá (Figure 9). The Atitlán area contains a large Quaternary caldera structure. Three Quaternary composite volcanoes, Atitlán, Tolimán, and San Pedro Volcano, are situated on the southern and south-western margins of the caldera and have produced volcanic material that includes lavas and pyroclastic deposits of andesitic composition. A lava flow on the northern flank of Tolimán Volcano is believed to be as young as a few thousand years based on thickness of sediment accumulated on the sublacustral part of the flow. Several areas with hot springs are found along the banks of the Atitlán Lake. Geochemical analysis of waters from hot springs indicate a resource temperature of 185°C but this will have to be confirmed with new studies (MEM, 2012b). A temporary concession was awarded in 2011 and covers 483 km^2 for geothermal exploration (Diario de Centro America, 2011). The company has stated that field reconnaissance work will take a year to complete (BNAmericas, 2011b).

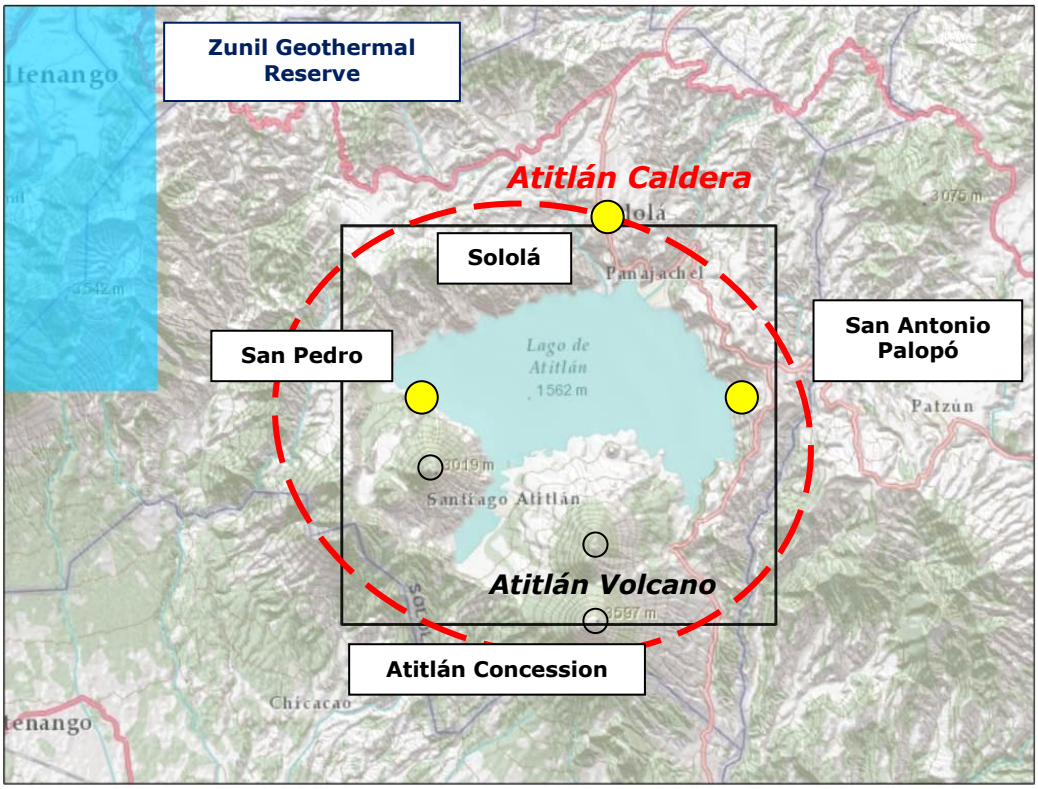

FIGURE 9: Map of the Atitlán geothermal concession. Outline of Atitlán caldera is shown as dashed red line

4.6 La Chinita Geothermal Project

The La Chinita Project is located in the central portion of Guatemala about 180 km northeast of Guatemala City near the towns of San Cristobal Acasaguastlán and Cabañas in the departments of El Progreso and Zacapa. The study area is located along the Motagua Fault System, a left lateral strike slip fault. Paleozoic meta-sedimentary and meta-volcanic formations outcrop in the mountains to the north and south of the Motagua river valley. The valley is filled with Quaternary volcanoclastic and sedimentary rock units. Geochemical analysis of waters from hot springs indicate a resource temperature of 160°C but a new geochemical survey will need to be carried out to confirm this value (MEM, 2012b). There are no volcanic structures large enough to constitute a heat source and based

on geological characteristics of the area, the geothermal system is a result of deep waters under high pressures along the transform fault (Figure 10). In 2011, MEM awarded Recursos del Golfo, S.A. a temporary concession of 135 km^2 to carry out surface exploration studies in order to define the characteristics of the geothermal resource (Diario de Centro America, 2011c).

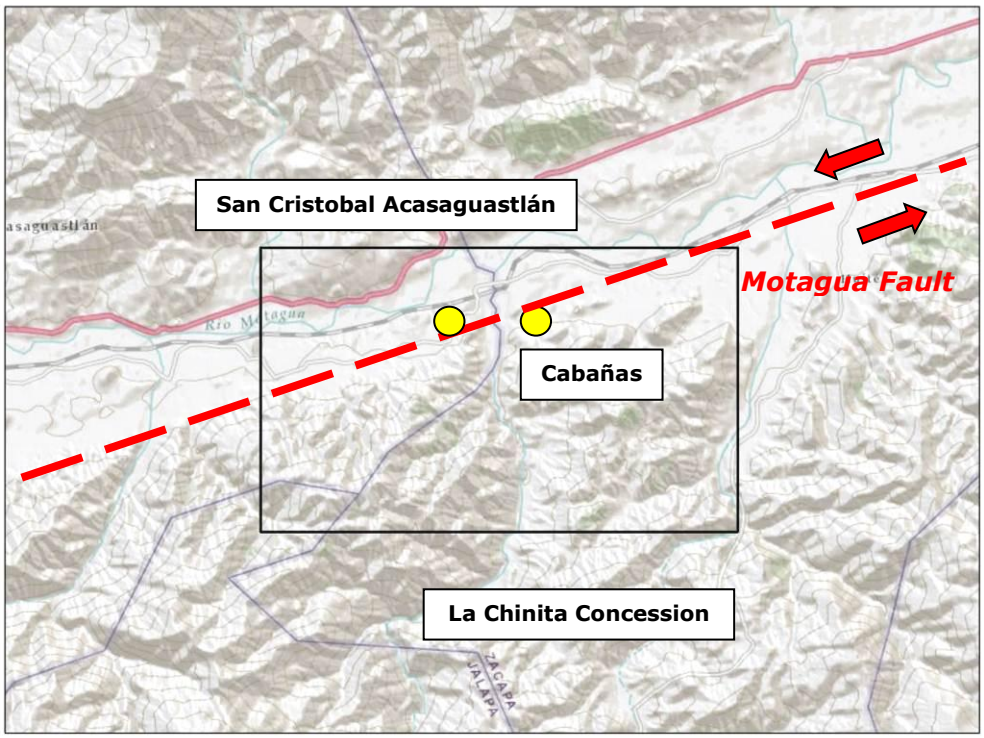

FIGURE 10: Map of the La Chinita geothermal concession. The strike-slip Motagua Fault system is shown as a dashed red line; arrows indicate sense of movement along the fault

4.7 Gloria Geothermal Project

Gloria is located in the central portion of Guatemala about 35 km north east of Guatemala City near the towns of Palencia and Sanarate in the departments of Guatemala and El Progreso. The study area contains Tertiary and Quaternary volcanic rocks that overlay Mesozoic meta-sedimetary and meta-volcanic formations. The study area contains Cerro El Volcan, the largest volcanic structure in the area, and several other basaltic cinder cones to the north. Transform deformation along the Motagua Fault to the north has resulted in an extensional setting and provides structurally controlled NE-SW faults and lineaments that are favourable conditions for the circulation of deep geothermal fluids. Geothermometers from sampled hot springs indicate a resource temperature of 185°C but a new geochemical survey will need to be carried out to confirm this value (MEM, 2012b). In 2011, MEM awarded Recursos del Golfo, S.A. a temporary concession of 565 km^2 to carry out surface exploration studies to define the geothermal resource (Diario de Centro America, 2011d).

4.8 Clare Geothermal Project

The Clare geothermal project is located in eastern Guatemala approximately 100 km east of Guatemala City and near the towns of Ipala and Quetzaltepeque in the department of Chiquimula. The geothermal area is located in Eastern Guatemala, a tectonically active region with a complex tectonic setting that has created an extensional rift zone in the western portion of the Caribbean Plate. The rift zone is located in Eastern Guatemala and extends N-S from the volcanic arc to the Motagua and Jocotán transform fault systems. The area contains a broad basin that extends for 70 km from north to south along its central axis. The concession area is located on the eastern flank of the Ipala Volcano, a

large stratovolcano of basaltic composition located in the central portion of the graben, several younger Quaternary cinder cones and fissure vents are found throughout the graben. Tertiary volcanic formations flank the graben to the east and Quaternary volcanoclastic sedimentary units fill the basin (Figure 12). Geothermometers from surface manifestations indicate a resource temperature of 155°C (MEM, 2012b). This will have to be confirmed with new studies. In 2011, MEM granted Recursos Del Golfo, S.A. a temporary concession of 55 km^2 to carry out surface exploration studies in order to define the characteristics of the geothermal resource (Diario de Centro America, 2011e).

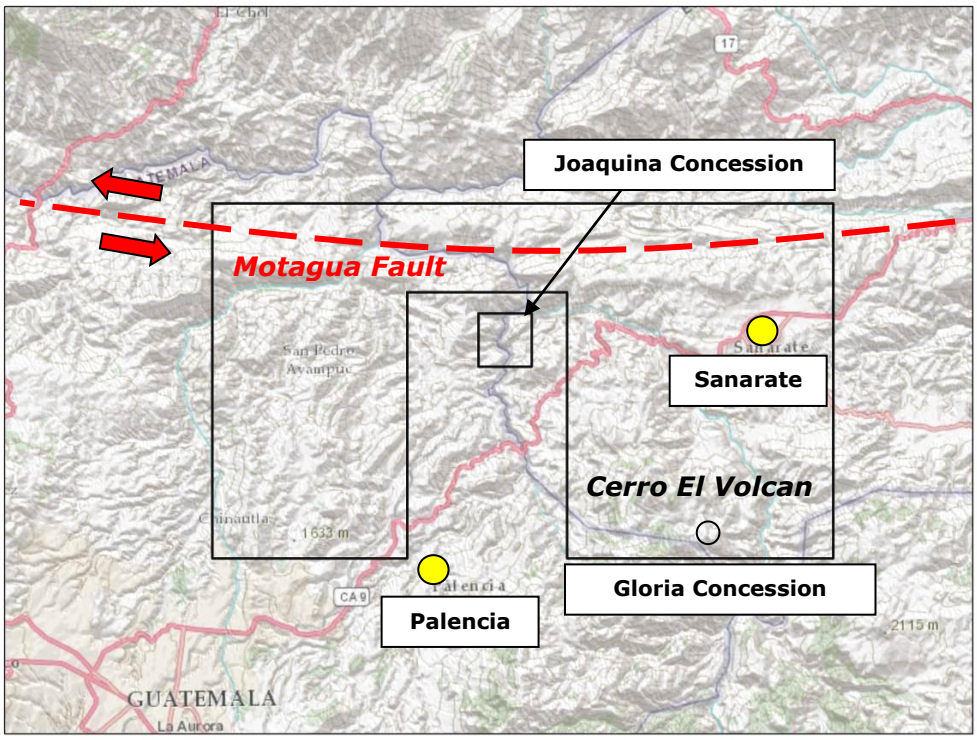

FIGURE 11: Map of the Gloria and Joaquina geothermal areas and respective geothermal concessions. The transcurrent Motagua Fault is shown as a dashed red line; arrows indicate sense of movement along the fault

4.9 Ambar Geothermal Project

The Ambar geothermal project is located in eastern Guatemala approximately 100 km east of Guatemala City and near the towns of Agua Blanca, Ipala y San Luis Jilotepeque, in the departments of Jutiapa, Jalapa and Chiquimula. The area is located on the western flank of the Ipala Volcano in the in the Ipala Graben extensional graben. The area contains Tertiary volcanic formations that flank the graben to the west and younger Quaternary volcanic formations of basaltic andesitic composition erupted from fissure vents, cinder cones. Volcanoclastic formations are also found within the graben (Figure 12). Geochemical analysis of waters from hot springs give a resource temperature of 155°C but new studies are needed to confirm this value (MEM, 2012b). A temporary concession of 55 km^2 was granted to Recursos Del Golfo S.A. in 2011 by MEM to carry out surface exploration studies and evaluate the resource (Diario de Centro America, 2011f).

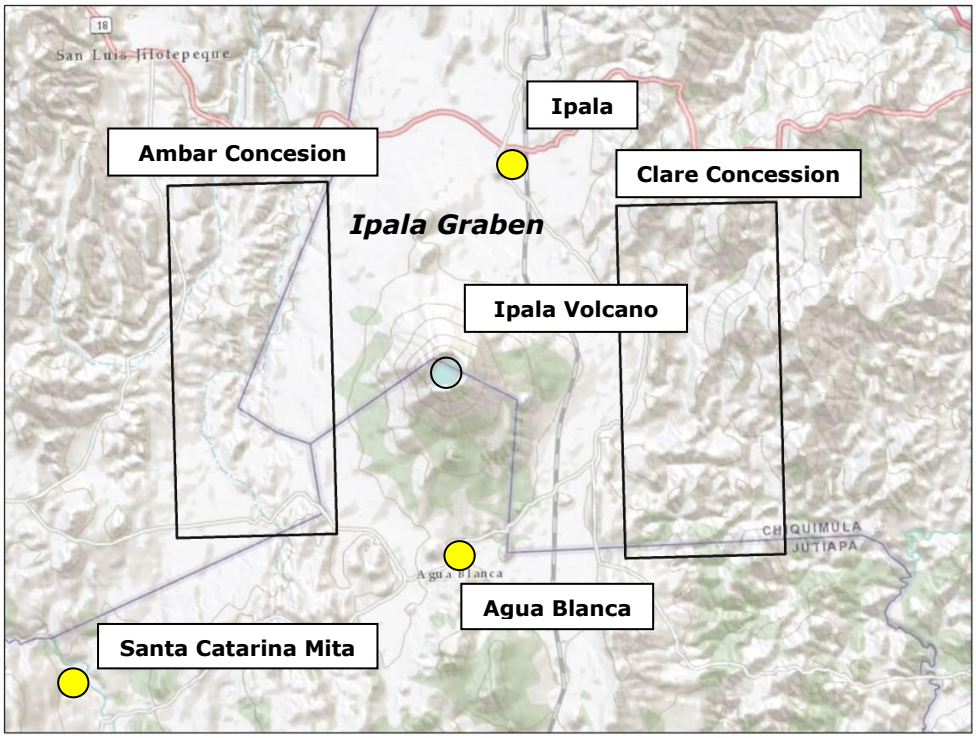

FIGURE 12: Map of the Clare and Ambar geothermal concessions

5. CONCLUSIONS

- The "Indicative Generation Expansion Plan for 2012-2021" published recently by the Ministry of Energy and Mines is a projection of the country´s energy mix based on a dispatch model that guarantees the lowest cost of energy. The model predicts an increase 300 MWe capacity from new geothermal projects. This is a clear and direct indication that the current government of Guatemala will seek to promote private investment for the development of geothermal resources and may possibly adopt new policies to promote the resource, such as a new tender mechanisms and contract premiums to promote geothermal development.

- In recent years, private investment has been stepped up and steered towards development the development of new projects, their success has sparked new interests from other private investors are who are looking at new geothermal areas have not been extensively studied in the past, and are looking to carry out exploration studies to determine the economic potential of the resources. In 2011 MEM awarded 6 new temporary concessions for geothermal exploration.

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