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Geothermal Power Development in Guatemala 2000-2005

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ABSTRACT

Activities related with Geothermal Power Development in Guatemala during the period 2000-2005 mainly include those carried out by Inde, the Government institution in charge of the electricity in the country and some others by private companies.

Since 1992, Inde has five geothermal areas in reserve to develop, they are: Zunil, Amatitlán, Tecuamburro, San Marcos and Moyuta.

From 1999 to date Inde has been working in the maintenance and operation of Zunil I and Amatitlán reservoirs.

There is a 24 MW binary cycle geothermal power plant operated by Orzunil I de Electricidad Ltda. in Zunil I, that has produced an average of 150 GW per year.

In Amatitlán, Inde is actually producing electricity with a 5 Mw portable plant.

For 2005 it's expected to produce 49.5 Mw of geothermal electricity, 24 MW in Zunil I, 5 MW in Zunil II and 20.5 MW in Amatitlán, and the equivalent of 10 Mw of direct use of this kind of energy.

1. INTRODUCTION

Inde, the government institution in charge of the electricity production in Guatemala has been carried out Geothermal Power Development since 1972. From 1998 Inde has five geothermal areas in reserve to develop, they are: Zunil, Amatitlán, Tecuamburro, San Marcos and Moyuta areas where has focused its investigations.

Inde has had the aid, with financial and technical cooperation, of international institutions in the process for development of geothermal energy, like: Latin America Energy Organization –OLADE-, International Atomic Energy Agency –IAEA-, Los Alamos National Laboratory –LANL-, Japan International Cooperation Agency –JICA-, ROCAP/AID, European Community and International Development Bank –IDB-.

Based on the Electricity Law established in 1997 that deregulates the electricity market, private companies can produce electricity and some of them are working in the development of geothermal resources.

Actors in the electricity market are: Ministry of Energy and Mines –MEM- as planner, National Electric Energy Commission –CNEE- as regulator, Wholesale Market Administrator –AMM-, and the production an distribution agents including the National Institute of Electrification –INDE-.(Bundschuh et al, 2002)

Production of electricity from geothermal resources starts in October 1998 with a 5 Mw portable power plant building in Amatitlán geothermal, field with the main objective of the evaluation of this field and was producing by three years.

The second plant is in Zunil Geothermal area and starts it´s production in July 1999, operated by Ormat Industries Ltda..

In 2001, Inde´s Board of Directors approved the Plan to Profit and Development the Geothermal Resources in Guatemala; one of the objectives of this plan is to develop, trough Inde, new geothermal areas up to feasibility level to attract local and foreign investors.

At the beginning of 2004 the new law called "Incentives for the Development of Renewable Energy Projects" Decree Number 52-2003 was published by the Guatemala Government, this law give tax exemption for the imports of machinery and equipment to be used in projects of energy based on renewable energy and ten years of income tax exemption after the initial date of production.

In 2001 Inde, trough the Ministry of Energy and Mines –MEM-, requested to the Global Environmental Facility technical and financial cooperation with the objective of carry out studies in geothermal areas with potential for electricity generation.

In January 2003 an agreement between the Guatemalan Government and IADB/GEF was signed for the development of the "Program for Exploitation of the Geothermal Resources of Guatemala for Electricity Generation Projects". The program is estimated to be developed in four years.

2. GEOLOGY BACKGROUND

Guatemala is located in the junction of three tectonic plates, the North American plate to the north, the Caribbean plate to the east and the Cocos plate to the south. (Figure 1)
Cocos plate is subducting the Caribbean plate and this process produces the active volcanic chain that crosses the country from west to east as part of the Ring of Fire0 that makes it an area with good conditions for high enthalpy geothermal resources.

On the other hand, the relative motion of the Caribbean plate and the North American plate with the active faults Motagua, Chixoy-Polochic and Jocotán gives conditions for the low to medium enthalpy geothermal systems.

3. GEOTHERMAL RESOURCES AND POTENTIAL

In 1981 INDE and BRGM of France, with INDE´s funds and donation from OLADE carried out recognize studies at regional level in 13 areas (Figure 2) located along the volcanic chain that is to the south and crosses the. Country.

These studies showed that to the Zunil, and Amatitlán areas, at that time as first priority, the areas of San Marcos, and Tecuamburro must be added. In priority order follows Los Achiotes in Santa Rosa province, Moyuta in Jutiapa and Ixtepeque-Ipala in Chiquimula. In third category, Palencia, Retana, Ayarza, Atitlán and Motagua were classified. In 1993, with the technical cooperation of the International Atomic Energy Agency –IAEA- the Totonicapán geothermal area was also identified as priority area. (OLADE 1982)

Zunil, located to the west of Guatemala City, is divided in Zunil I and Zunil II; Zunil I is the most developed field until now. Zunil I, with temperatures up to 300 ºC has 24 MW proved capacity and an estimated capacity of 50 MW whereas Zunil II with 240 °C of temperature has 4 MW proved and an estimated of 50 MW capacity.(West Jec, 1995)

Amatitlán geothermal area is located about 25 km to the south of Guatemala City within the southern part of the Guatemala graben in the active volcanic chain. Studies carried out in Amatitlán reveal that the actual capacity of this field with 285 ºC of temperature, based on mathematical models, is capable to produce 25 Mw during 30 years.(INDE 1995), with an estimation of a total capacity of 200 MW.

Based on the new Electricity Law, the private company Bloteca were carrying out studies in a small area located to the southeast part of the field, as part of this studies they have drilled 4 exploratory well, getting temperatures around 200 °C at 200 m depth. These results are in agreement with previous studies that have concluded that there is a possibility of a second geothermal reservoir independent of the reservoir that is actually in exploitation (Roldán Manzo 1993)

Prefeasibility studies in San Marcos, to the west of the country, confirm that there is a good reservoir temperature (255 °C) for exploitation for electricity with an estimated capacity of 24 Mw. (Roldán Manzo 1997, CEE 1997)

In Tecuamburro geothermal area, located about 80 km from Guatemala city beside Tecuamburro volcano, the prefeasibility study, carried out in 1988 with the collaboration of Los Alamos National Laboratory; that included geological, geochemical and geophysic studies and a slim hole up to 800 m depth where temperature reached was 235 ºC. (Goff et al, 1992) defined an estimated capacity of the field of 50 Mw. (Janik et al, 1992)

For Moyuta geothermal field, to the east of Guatemala City, the company Electroconsult determined that the resource had capability to produce electricity. (ELC Electroconsult 1977).

In 1990 a reevaluation of the resource was carried out by Inde with the cooperation of Los Alamos National Laboratory concluding that this field could be commercial exploited. (Goff et al 1991)

Preliminary studies in Totonicapán geothermal field started in 1996 by Inde with the cooperation of the Atomic International Energy Agency –AIEA-. These studies include geological, geochemical and geophysical research. Geological and geochemical results show that there is a reservoir with good conditions to produce electricity.(Arnorsson 1997, Roldán Manzo and Ortiz 2001).

In the others areas identified by OLADE there are no more studies an it is necessary to carry out prefeasibility studies to define their capacity.

4. GEOTHERMAL UTILIZATION

In 1993 INDE signed a contract with ORZUNIL I de Electricidad Limitada (ORZUNIL) to install and operate during 25 years a 24 Mw power plant (Table 2). This power plant starts it´s production in August 1999 and will be operated by ORZUNIL until 2019. From 1999 until now this plant has produced an average of 150 GW-hr per year.

In Amatitlán geothermal field, the 5 MW (Table 2) portable power plant installed to evaluate the field, produced during the period from 1998 to 2001 a total of 95.155 GW-hr. After that, Inde bought and reinstalled the plant and it is producing from February 2003 an average of 2.9 GW-hr per month.

Related with geothermal direct heat uses; Bloteca, also in Amatitlán field, a plant that produces construction blocks and use geothermal steam in the curing process. It has an installed capacity of 1.60 MW and since 1998 is using an equivalent of energy to 11.2 MW-hr per year. On the other hand, close to Bloteca, Agroindustrias la Laguna use geothermal energy in dehydration process through a downhole heat exchanger to supply heat to the dehydration plant. It has an installed capacity estimated in 0.5 MW with and is using the equivalent of 3.4 GW-hr per year. (Mérida 1999, Table 3).

There are also some places in several areas that are using geothermal water for swimming pools and baths but they have not been evaluated among quantity of energy.

5. DISCUSSION

The geothermal installed capacity in Guatemala is only 1.7 % and the electricity produced by geothermal plants is around 3 %, these values are relatively low, however it is expected to increase these values in the near future with the plant of 20.2 MW to be installed in Amatitlán geothermal field (Table 1).

On the other hand, with the results to be obtained whiting the program to be developed by Inde with the technical and financial cooperation from the Global Environmental Facilities –GEF- in the next four years and taking in to account that the oil prices are increasing, the investment in geothermal projects will be attractive for private companies, in addition, the Decree Number 52-2003 “Incentives for the Development of Renewable Energy Projects” must increase the attractive condition for the development of geothermal power projects.

The geothermal potential for electricity generation in Guatemala is relatively big an could generate more than 20 % of the power requirements.

Direct heat use is very low, however it is also expected that with high oil prices, investments in direct heat use will be growth in tourism installations, balneology, agriculture and industry.

6. FUTURE DEVELOPMENT AND INSTALLATIONS

Between the Plan to Profit and Development the Geothermal Resources in Guatemala approved by Inde´s Board of Directors, the development of the Amatitlán Geothermal field was included, it consider installation of 50 MW in the next five years, the first step is a 20.5 MW

hybrid type geothermal power plant that must start its production at the end of 2005. After that the 5 MW power plant that is actually producing in Amatitlán will move to Zunil II geothermal field.

Two production and one reinjection well must be drilled in 2004-2005 to connect this power plant.

As the project to be developed with Global Environmental Facilities –GEF- includes feasibility studies in new geothermal areas, activities of geoscientific research including geochemistry, geophysics, geology, reservoir engineering and drilling of commercial diameters wells will be carried on in the near future.

7. ACKNOWLEDGMENTS

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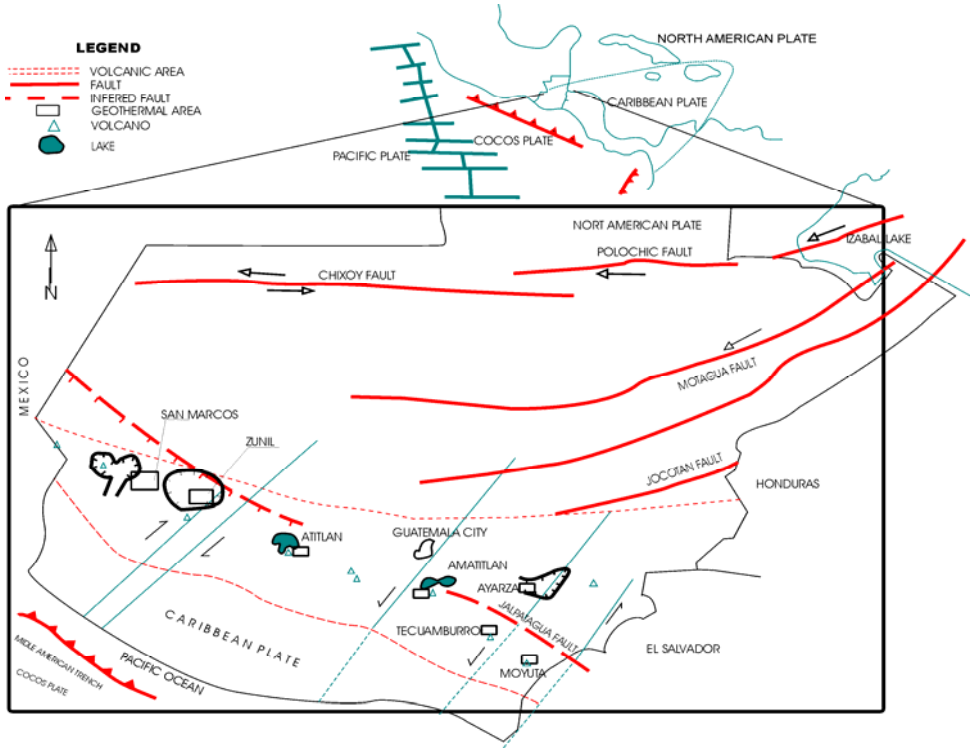

Figure 1: Tectonic frame work for Guatemala

Figure 2: Location of geothermal areas in Guatemala

Table 1: Present and planned production of electricity (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2004	33.6	195	1325	4189	621.9	2177					1980.5	6561
Under construction in December 2004	20.5	162			15	53					35.5	215
Funds committed, but not yet under construction in December 2004	29.5	233			50	175					79.5	408
Total projected use by 2010	83.6	590	1325	4189	686.9	2405	0	0	0	0	2095.5	7184

Table 2: Utilization of geothermal energy for electric power generationas of December 31, 2004. 1) N = Not operating (temporary), R = Retired. Otherwise left blank if presently operating. 2) 1F = Single Flash,2F = Double Flash, 3F = Triple Flash, D = Dry Steam, B Binary (Rankine Cycle), H = Hybrid, O = Other 3) Data for 2003

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe	Annual Energy Produced 2004[3)] GWh/yr	Total under Constr. or Planned MWe
Zunil	Orzunil I	1999	7		B	28	173*	
Amatitlán	Calderas	2003	1		backpressure	5	39*	
Total						33	0	

*** Data for 2003**

Table 3: Utilization of Geothermal energy for direct heat as of December 31 2004 (Other than heat pumps)

[3)] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184 (MW = 10^{6} W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[4)] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

[5)] Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (^{o}C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity Factor[5)]
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	
Amatitlán	I						1.600		40.400	0.801
Amatitlán	A						0.500		12.100	0.767
TOTAL							2.100		52.500	

Table 4: Summary of geothermal direct heat uses as of December 31 2004

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^{6} W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]	0.500	12.100	0.767
Industrial Process Heat[6]	1.600	40.400	0.801
Snow Melting			
Bathing and Swimming[7]			
Other Uses (specify)			
Subtotal	2.100	52.500	
Geothermal Heat Pumps			
TOTAL	2.100	52.500	

[4] Other than heat pumps
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology

Table 6: Wells drilled for electrical. Direct and combined use of geothermal resources from January 1, 2000 to December 31, 2004 (Excluding heat pump wells)

[1] **Include thermal gradient wells, but not ones less than 100 m deep**

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)					
Production	>150° C	5				8.07
	150-100° C					
	<100° C					
Injection	(all)					
Total						8.07

Table 7: Allocation of professional personnel to geothermal

ACTIVITIES **(Restricted to personnel with University degrees)**

(1) Government

(2) Public Utilities

(3) Universities

(4) Paid Foreign Consultants

(5) Contributed Through Foreign Aid Programs

(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	5				2	2
2001	6				2	2
2002	6					2
2003	6					3
2004	5					3
Total	28				4	12

Table 8: Total investments in geothermal in (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1990-1994	1.5	0.5			25	75
1995-1999	1	4.50		60	7	93
2000-2004	0.6	11.5		2	82	18