Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

GEOTHERMAL POWER DEVELOPMENT IN GUATEMALA 1995-2000

Alfredo René Roldán Manzo and Julio Cesar Palma Ayala
EMPRESA DE GENERACION DE ENERGIA ELECTRICA
INSTITUTO NACIONAL DE ELECTRIFICACIÓN –INDE-
7ª. Avenida 2-29 zona 9. Guatemala, C. A. 01-009
E-mail **geotinde@guate.net**

ABSTRACT

Activities related to Geothermal Power Development in Guatemala during the period 1995-2000 include some work carried out by INDE, the Government institution in charge of the electricity in the country and some others by private companies.
INDE has five geothermal areas in reserve to develop, they are: Zunil, Amatitlán, Tecuamburro, San Marcos and Moyuta and is also working in Totonicapán.
From 1995 to 1997 INDE has been working in the maintenance of Zunil and Amatitlán, fields that were ready to produce 24 and 12 MW respectively, after feasibility studies.
Production of geothermal electricity in Amatitlán started in October 1998 with a 5 MW portable plant, operated by the Company Ingenieros Civiles Asociados (ICA). At that time, JICA also carried out a study to evaluate the extension and capacity of this field, drilling two commercial exploratory wells.
In August 1999 the Company Orzunil I S.A. started the production of electricity in Zunil I geothermal field with a 24 MW binary cycle power plant.
In addition a private company Bloteca is using direct heat to dry concrete blocks and has drilled three wells in Amatitlán to install a binary cycle power plant, also another company Agroindustria La Laguna is operating a direct use plant to dry fruits.
For the year 2000 it is expected to produce 75 MW of geothermal electricity and the equivalent of 10 MW of direct use of this kind of energy.

1. INTRODUCTION

Geothermal Power Development in Guatemala has been carried out since 1972 by INDE, the government institution in charge of the electricity production There are thirteen geothermal areas defined by OLADE (1982). After the new Electricity Law (established in 1996) INDE has five geothermal areas in reserve to develop, they are: Zunil, Amatitlán, Tecuamburro, San Marcos and Moyuta areas where has focused its investigation. As a result of these investigations, 58 MWe. has been proved and 398 MWe. more are estimated (Figure 1).
In 1996 INDE with cooperation of the International Atomic Energy Agency –IAEA- started preliminary studies in Totonicapán geothermal area, these studies include geological, geochemical and geophysical research.
The first geothermal power plant in Guatemala was built in Amatitlán geothermal area; a portable power plant of 5 MW is operating since October 1998.
The second plant is in Zunil Geothermal area and started its production in July 1999.

Based on the new Electricity Law, private companies can produce electricity and some companies are working in the development of geothermal industries.

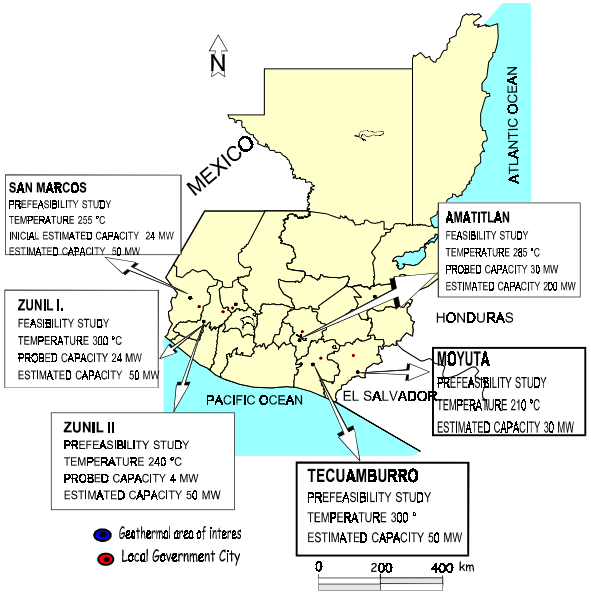

Figure 1. Geothermal areas of interes in Guatemala

2. AMATITLÁN GEOTHERMAL FIELD

Amatitlán geothermal area is located about 25 km by road to the south of Guatemala City (Figure 1) within the southern part of the Guatemala graben in the active volcanic chain.

In 1995 West Japan Engineering Consultants (West Jec) (1995) finished the feasibility study. As part of this study four deep four exploratory wells, named AMF-1 to AMF-4 were drilled from 1050 to 2058 m depth. Only two of them were capable of producing and where the fluids discharged were analyzed, the capacity of these two wells was estimated at 12 MW. Based on mathematical models, this field is capable of producing 25 MW for 30 years. (INDE 1995)

With the objective to make this field useful, INDE made a contract with the Company Ingenieros Civiles Asociados –ICA- to evaluate the reservoir during exploitation and production of the existing wells.
This contract includes the installation and operation of a 5 MW backpressure geothermal power plant. Electricity production of this plant started in November 1998 and will continue for three years

In addition, an agreement between the Ministry or Energy, INDE and the Japan International Cooperation Agency –

JICA- was signed in May 1998. This agreement includes geoscientific studies and two production wells that will be drilled one in 1999 and the other one in 2000, to evaluate the extension of the field. JICA also will make a feasibility study for the installation of a commercial geothermal power plant and the development plans of this field for the future.

In 1998 geological, geochemical and geophysics studies were carried out in Amatitlán area, based on the results of these studies, the site were the new production wells will be drilled was defined (West Jec 1999)

In the Amatitlán geothermal area, based on the new Electricity Law, the private company Bloteca is carrying out studies in a small area located to the southeast part of the field. As part of these studies they have drilled 4 exploratory wells, with recorded 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)

3. ZUNIL GEOTHERMAL FIELD

Zunil is located about 220 km by road, to the West of Guatemala City, close to Zunil town in Quetzaltenango. (Figure 1) The Samala River crosses the area of geothermal interest. Zunil geothermal area is divided in Zunil I and Zunil II; Zunil I is the most developed field to date.

During 1980-81 INDE drilled six exploratory wells, four of them were capable of producing 15 MW. (Cordon y Mérida, 1993) With the objective of increasing the capacity, three exploratory wells, named ZD1 to ZD3 were drilled in the area during 1991-92, all of them are capable of producing. The capacity of the field is actually 24 MW.

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. This power plant started production in August 1999, due to the conditions of the contract, it will be operated by ORZUNIL until 2019.

In 1999 four reinjection wells were drilled to have enough reinjection capacity for the plant operation.

4. OTHER GEOTHERMAL FIELDS

In the other geothermal fields that INDE has in reserve (San Marcos, Tecuamburro and Moyuta), the main activities during the period 1995-2000 were limited to geochemical monitoring. Only in Totonicapán Geothermal field INDE with the cooperation of the International Atomic Energy Agency –IAEA- has continued research studies in this period.

4.1 San Marcos Geothermal field

After the study made by OLADE (1982) INDE carried out preliminary investigations in the San Marcos Geothermal area, covering about 85 square kms. After that, in 1993, INDE received cooperation from the European Community to carry out the prefeasibility of the resource. The activities for this study began in September 1993.

The results confirm good reservoir temperatures for exploitation for electricity with an estimated capacity of 24 MW. (Roldán Manzo 1997, CEE 1997)

4.2 Tecuamburro Geothermal field

Tecuamburro geothermal area is located about 80 km from Guatemala City, beside the Tecuamburro volcano.

From 1988 the prefeasibility study of the area were carried out with the collaboration of Los Alamos National Laboratory. After geological, geochemical and geophysics studies a slim hole up to 800 m depth was drilled, temperature reached in this hole was 235 °C. (Goff et al, 1992)

Based on the prefeasibility study, the capacity of the field was estimated in 50 MW. (Janik et al, 1992)

4.3 Moyuta geothermal field

INDE started studies in Moyuta in 1972 covering 1,000 square kms, in 1975 INDE contracted the company Electroconsult who 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)

4.4 Zunil II geothermal field

After the division of Zunil geothermal area into Zunil I and Zunil II, a prefeasibility study of Zunil II was carried out in an area around 150 square kms. The study was made from 1989 to 1992 by West Jec, concluding that the estimated capacity of this area is 50 MW. (West Jec 1995)

4.5 Totonicapán geothermal field

Preliminary studies in Totonicapán geothermal field started in 1996 by INDE with the cooperation of the International Atomic Energy Agency –IAEA-. 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 1999).

With the aid of the International Atomic Energy Agency – IAEA- it is expected to conclude the prefeasibility study in this field.

5. PROJECTS FOR THE FUTURE

INDE as a government company and based on the new Electricity Law has decided not to invest in exploration any more, but is beginning to make arrangements with private companies to develop the geothermal field that has in

reserves. It is expected to develop all these fields in the near future.

ACKNOWLEDGEMENTS

The authors want to thank to Los Alamos National Laboratory, the International Atomic Energy Agency –IAEA- and the Japan International Cooperation Agency -JICA- by their cooperation in the Geothermal Power Development in Guatemala.

REFERENCES

Arnorsson S**.** 1997, Geochemical And Isotopic Reconnaissance Survey Of The Totonicapán Geothermal Field, Guatemala. Report on an expert mission to Guatemala, September 28 to October 11, 1997 .Science Institute, University of Iceland, Dunhagi 3, 107 Reykjavík, Iceland

CEE, 1997. Estudio de Prefactibilidad del Area Geotérmica de San Marcos (Guatemala). Instituto Nacional de Electrificación –INDE- Guatemala.

Cordón y Mérida Ings. & MK-Ferguson Company, 1993. Planta Geotermoeléctrica de 15 MW, Proyecto Zunil I Quetzaltenango. Instituto Nacional de Electrificación –INDE- Guatemala.

ELC- Electtroconsult, 1977, Proyecto Moyuta, Estudio de Factibilidad Preliminar. Presented to Instituto Nacional de Electrificación -INDE-

Goff S.M., Goff, F. Janik, C. 1992, Tecuamburrro Volcano, Guatemala: Exploration geothermal gradient drilling results. Geothermics, Vol. 21, No. 4, pp 483-502.

Janik, C.J., Goff, F., Truesdell, A., Adams, A., Roldán Manzo, A.R., Chipera, S.J., Trujillo P.E., and Counce, D., 1992. Hydrogeochemical Exploration of Geothermal Prospects in the Tecuamburro Volcano Region Guatemala. Geothermics, Vol. 21, No. 4, pp 447-481.

OLADE - BRGM 1982 Estudio de Reconocimiento de los Recursos Geotermicos de Guatemala, Informe final.
INDE (1995) Proyecto Geotérmico de Amatitlán Estudio de Factibilidad. West Japan Engineering Consultants, Inc and Telectro, S.A.

Roldan Manzo, A. R. 1993 Geochemical Reevaluation of Amatitlan Geothermal Area. Instituto Nacional de Electrificacion. Guatemala.

Roldán Manzo, A. R. 1997 Geochemical and isotopic evaluation of San Marcos geothermal area, Guatemala. In Proc. of the 18th PNOC-EDC Geothermal Conference, Makadi City, Philippines, 377-381.

West Jec, 1995. West Japan Engimeering Consultants y Telectro S.A. Proyecto Geotérmico de Zunil II. Estudio de Pre-Factibilidad. Instituto Nacional de Electrificación INDE, Guatemala C.A.

West Jec, 1999. Amatitlán Geothermal Development Project. Progress Report. Japan International Cooperation Agency and Instituto Nacional de Electrificación.

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICTY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specifiy)		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 January 2000	**29**	**215.934**	**732**	**5450.47**	**25**	**175.2**					**1992**	**14605.1**
Under construction In January 2000												
Funds committed, But not yet under Construction in January 2000			**240**	**1787.04**							**240**	**1787.04**
Total projected Use by 2005	**29**	**251.934**	**972**	**7237.51**	**519**	**3637.15**					**2232**	**16392.2**

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 1999

1) **N = Not operating (temporary), R = Retired. Otherwise leave 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 (please specify)

3) **Data for 1999 if available, otherwise for 1998. Please specify which.**

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Unit Rating MWe	Total Installed Capacity MWe	Annual Energy Produced 1999[3)] GWh/yr	Total under Constr. or Planned MWe
Amatitlán	**Calderas**	**1998**	**1**		**back pressure**	**4.7**	**5**	**35**	
Zunil	**Zunil I**	**1999**	**6**		**B**	**7.1**	**28.4**	**44676**	
Total			**7**				**33.4**	**44711**	

TABLE 3. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1995 TO DECEMBER 31, 1999

[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)	3				0.6
Production	>150° C	1				1.5
	150-100° C					
	<100° C					
Injection	(all)				4	4.315
Total		4			4	6.415

TABLE 4. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES **(Restricted to personnel with a University degress)**

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributied Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	14			4	1	1
1996	12			2	1	1
1997	9			1	1	1
1998	5				5	2
1999	5			1	3	3
Total	45			8	11	8

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 1999

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

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°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]
Space Heating[4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish and Animal Farming			
Agricultural Drying[5]	0.500	12.094	0.767
Industrial Process Heat[6]	1.600	40.416	0.801
Snow Melting			
Bathing and Swimming[7]			
Other Uses (specify)			
Subtotal	2.100	52.510	0.793 ..
Geothermal Heat Pumps			
TOTAL	2.100	52.510	0.793

[4] Includes district heating (if individual space heating is significant, please report separately)
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology

Note: **please report all numbers to three significant figures.**