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GEOTHERMAL PRODUCTION AND DEVELOPMENT PLANS IN MEXICO

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ABSTRACT

Geothermal resources in Mexico are used mostly to produce electrical energy. Direct uses of geothermal are practically restricted to bathing and swimming pools. Up to present, the geothermal electric capacity is 755 megawatts (MW), which is installed in the Mexican geothermal fields of Cerro Prieto (620 MW), Los Azufres (93 MW) and Los Humeros (42 MW). Two geothermal electric projects are now under construction: Cerro Prieto IV (100 MW) and Las Tres Vírgenes I (10 MW). The first is expected to be in operation by July 2000, and the second by the beginning of 2001, so increasing the capacity by 15% to reach 860 MW. The annual geothermal production in Mexico (1999) is around 56 million metric tons of steam, at an annual average rate of 6,400 tons per hour. This amount of steam is produced by an average of 164 geothermal wells, whose depths vary from 600 to 3,500 meters. In the last five years, 51 new production wells were drilled, for a total of 123 kilometers. Twenty-seven geothermal power plants are operating in the three Mexican fields. They generated 5,619 gigawatts-hour (GWh) in 1999, with an annual average capacity factor of 86% and a specific consumption of 10 tons per megawatt-hour. Geothermal electricity generation represented 3.2% of the total electric energy produced in Mexico in 1999.

1. INTRODUCTION

Geothermal development in Mexico is focused almost exclusively on the production of electricity. The direct uses of geothermal heat, such as space conditioning, drying, greenhouses, etc., are restricted to few small pilot projects located at the Los Azufres and Los Humeros geothermal fields. There are many places where warm waters are used for recreation and therapeutic purposes, but there are no coordinated efforts to promote balneology, nor available information on investments.

Electricity production, transmission and distribution are still a public monopoly in Mexico and the Comisión Federal de Electricidad (CFE) is the utility in charge of the public service. Private projects are restricted to cogeneration, selfsupplying, and power plants that must sell their energy to the CFE. In the last years, new power plants for public service have been constructed with private financing, under BLT (Build, Lease and Transfer) contracts or IPP (Independent Power Production) schemes with a long term PPA (Power Purchase Agreement) signed with CFE. At present, 100 MW_e in Cerro Prieto and 10_e MW in Las Tres Vírgenes geothermal fields are being built under BLT contracts.

This report presents the exploitation activities and results in the Mexican geothermal fields in the period 1995 to 1999. It also includes the present and planned exploration and development activities to increase the geothermal power capacity in Mexico, and some information on geothermal direct uses.

2. EXPLORATION ACTIVITIES

The reconnaissance and inventory of thermal areas in Mexico was finished in 1987. As a result, 545 thermal localities were identified, grouping around 1,380 hot spots, including springs, shallow wells, fumaroles, steaming grounds, etc.

During 1995, CFE carried out geological, geochemical, and resistivity surveys in the Sangangüey Volcano, State of Nayarit, geothermal area (Fig. 1). No single well has been drilled yet in this area. In the same year, a volcanologic study was made in the Acoculco Caldera area, near by the Los Humeros field. A Miocene calderic structure was identified, lacking any presence of surface hydrothermal activity.

The El Molote, Nayarit, geothermal area (Fig. 1) was surveyed during 1998. The survey included geological, geochemical and gravimetric studies. The thermal anomaly is restricted to a single fault and is limited in extent. The San Diego, Nayarit, geothermal area (Fig. 1) was also covered with a geological survey, during 1998. In 1999, CFE carried out a geological, geochemical and resistivity survey in the Los Oteros, Chihuahua, thermal area, located in the Sierra Madre Occidental Fisiographic Province (Fig. 1).

Several medium size gradient wells were drilled in the period 1995-1999, looking for lower temperature resources to install small binary cycle plants for rural electrification. At least one well was drilled in the following zones: Santiago Papasquiaro, State of Durango (1997), San Antonio El Bravo and Piedras de Lumbre, State of Chihuahua (1997-1998), El Centavito, Agua Caliente, and Santispac, State of Baja California Sur (1996-1997), and Puertecitos in the State of Baja California (1997). As a result, CFE is currently installing a 300 kW power plant in Piedras de Lumbre.

Most of the exploratory efforts were dedicated to the development of the Las Tres Vírgenes field (Fig. 1). Three production and two injection wells were drilled between 1995 and 1997. Wells LV-3 and LV-4 were located 2.5 km south of the area that was explored in previous years, with excellent results. These wells present high temperatures and good production.

3. DRILLING ACTIVITIES

During the 1995-1999 period, 50 production wells and 5 injection wells were drilled in Mexico (Table 2). Most of these wells (42) were drilled in the Cerro Prieto geothermal field, while in the Los Azufres field the activity was restricted to one production well, besides two exploration wells to define the western limit of the reservoir. The measured temperatures in these wells were 187º C and 222º C at 1,870 and 2,200 meters depth. Four production wells and one injection well were drilled at the Los Humeros field, while in the Las Tres Vírgenes field three production wells, one

injection and one exploration well were drilled in the period. The total drilled meters, including exploratory wells, was 141,864.

In December 1994, 224 wells were reported in Cerro Prieto, representing 490,821 meters, 68 wells in Los Azufres (104,859 m) and 35 wells in Los Humeros (75,952 m) (Quijano-León and Gutiérrez-Negrín, 1995). Therefore, up to now there are 268 wells in Cerro Prieto (596,380 m), 72 wells in Los Azufres (112,609 m) and 40 wells in Los Humeros (87 352 m). This means that in the last five years 20% of all of the wells in the Cerro Prieto field has been drilled, while in the Los Azufres and the Los Humeros fields the drilling activity was considerably less.

Twelve among those 42 production wells drilled in Cerro Prieto between 1995-1999 were constructed and financed by a private drilling company that supplies around 30% of the steam produced in this field.

As a summary on the geothermal drilling work in Mexico, up to the present 422 deep wells have been drilled, excluding thermal gradient and shallow slim holes. These wells give a total of 856,954 drilled meters.

4. INSTALLED CAPACITY AND ELECTRICITY PRODUCTION

Table 1 shows in detail the installed capacity and energy production in the geothermal fields in 1999: Cerro Prieto, Los Azufres and Los Humeros.

Present installed capacity in Cerro Prieto is 620 MW distributed in three sectors: CP-I, CP-II and CP-III. Sector one includes five units, while sectors two and three are made up of two units each. At present four units of 25 MW each are under construction in CP-IV. The units will be on line in 2000.

Electricity production in Cerro Prieto in 1999 amounted to a total of 4,669.6 GWh. Generation in previous years is comparable to this figure, as can be seen in Figure 2.

In the Los Azufres geothermal field there are 11 units in operation: 8 backpressure units of 5 MW_e each one, one 50 MW condensing unit and two 1.5 MW_e binary cycle turbines. Unit 2 was recently re-installed in the field. Details are presented in Table 1, amounting to a total capacity of 93 MW_e. One backpressure unit, which used to be installed in Los Azufres is at present in the Amatitlán geothermal field in Guatemala. It started operation in November 1998, being the first geothermal power produced in Guatemala. The unit is used to evaluate the reservoir under exploitation. A similar project was carried out in the Miravalles geothermal field, Costa Rica, from 1996 to 1998, using two backpressure units (Unit 1 and Unit 2) from Los Azufres.

Los Azufres produced 598.0 GWh in 1999 (Table 1), while in the previous year it produced 457.4 GWh (Fig. 2). This value was rather high because Unit 7 presented several problems in 1997 and 1998.

It is foreseen to increase the installed capacity in Los Azufres with 4 units of 25 MW_e each by the year 2001 (Table 1). Reservoir assessment indicates that the total capacity of the field is of the order of 250 to 300 MW_e. Therefore, it is feasible to install 100 MW_e in addition to the units planned for 2001.

Los Humeros geothermal field has a total installed capacity of 35 MW_e, made up of seven backpressure units of 5 MW_e each as nominal capacity. Details are also included in Table 1. During the last three years these units have been operating continuously at 6 MW_e without any trouble. Electricity production in 1999 was 351.0 GWh (Table 1). Similar figures were obtained in previous years (Fig. 2). An additional capacity of 50 MW_e is planned to start commercial operation by year 2002.

The Las Tres Vírgenes geothermal field is currently under development. Three production and two injection wells were drilled during the period 1995-1998 and the construction of two 5 MW condensing plants started in 1999. The commissioning date is February 2001. One more condensing unit of 15 MW is planned to be commissioned in 2002 (Table 1).

The La Primavera (Cerritos Colorados) geothermal field, located in La Primavera Natural Reserve near the City of Guadalajara, has a proven capacity of 75 MW. Nevertheless, the approval of the project by the environmental authorities is still pending. CFE plans to install the first 5 MW units, once the environmental issue has settled down (Table 1). A definite solution is foreseen by the end of 2000.

5. EXPLOITATION DATA

In 1999 44.8 million metric tons of steam were produced in the Cerro Prieto geothermal field (Fig. 3), at an average rate of 5,114 tons per hour (t/h). That amount of steam was accompanied by 64.1 million tons of brine that was disposed through the evaporation pond and 7 injection wells. The steam produced in 1999 was practically the same as in 1998 (44.7 million tons of steam; CFE, 1999) and 8% higher than in 1997, when 41.3 million tons were produced (Hiriart and Gutiérrez, 1998).

An average of 126 production wells were in operation during 1999, 31 of which were operated by the private drilling company that supplies part of the steam in Cerro Prieto. The annual average production per well was 40.7 t/h.

Taking into account the energy produced by the power plants in Cerro Prieto in 1999, it is possible to get the average specific consumption of steam per megawatt-hour, which was 9.59 tons, slightly higher than in 1998, when it was 8.74 tons (CFE, 1999). Of course, the oldest and less efficient units of CP-I have a specific consumption higher than the average, and the more recent ones of CP-III present a lower consumption.

Production of steam in the Los Azufres field was 6.75 million tons in 1999 (Fig. 3), at an annual average rate of 771 t/h. The associated brine was 3.3 million tons, which was totally injected to the reservoir by means of 6 injection wells. The production of steam was 14% higher than in the previous year, but 8% lower than in 1997 (Fig. 3). This reduction was caused by taking Unit 7 out of the system during several months of 1997 and 1998 (Hiriart and Gutiérrez, 1998), and since then it has been de-rated to 40 MW_e.

Production wells in operation in 1999 were 19 (two more than in 1998; CFE, 1999), presenting an average production of 41.5 t/h per well. All of the production and injection wells are operated by the CFE.

The specific consumption of steam during 1999 in Los Azufres was 11.29 tons per megawatt-hour (MWh), 11% lower than in 1998 (CFE, 1999) and practically the same as in 1997 (Hiriart-Le Bert and Gutiérrez-Negrín, 1998). This consumption results 18% higher than the average consumption of the Cerro Prieto power units.

In the Los Humeros field, 4.76 million tons of steam were produced during 1999. The annual rate was 543 t/h in average, and the associated brine was 1 million tons. This separated water was fully injected into the reservoir through two injection wells in operation. The amount of produced steam was almost the same as in previous years (Fig. 3).

Twenty production wells were in operation in 1999, with an average production of 27.4 t/h per well. This production is remarkable lower than the average production of the wells at Los Azufres and Cerro Prieto. The reason is the low secondary permeability of the production rocks (mainly andesites) in Los Humeros, whose fracture and fault planes seem to be filled by hydrothermal minerals such as calcite, quartz, chlorite, epidote and garnet (Hiriart-Le Bert and Gutiérrez-Negrín, 1998).

As in Los Azufres, all of the production and injection wells of Los Humeros are operated by the CFE.

The specific consumption of steam in Los Humeros was 13.56 tons per megawatt-hour, 11% higher than in 1998 (CFE, 1999), but practically the same as in 1997 (Hiriart-Le Bert and Gutiérrez-Negrín, 1998).

The global production of steam in Mexico in 1999 was, therefore, 56.3 million tons, at 6,428 t/h in average. This amount of steam was produced by an average of 164 production wells, with a unitary production of 39.2 t/h per well. The 27 geothermal power plants operating in the three fields generated 5,619 GWh, with a capacity factor of 85.5% and a specific consumption of 10 tons per megawatt-hour.

6. GEOTHERMAL ENERGY IN THE MEXICAN ELECTRICAL GENERATION AND PLANS

As mentioned above, the nominal capacity of geothermal power plants in Mexico is 748 MW_e. Nevertheless, the real capacity is 755 MW_e, a little higher, because of the extra operating capacity of the Los Humeros units. In November 1999, the total installed capacity for public service in Mexico was 35,652 MW_e (Table 3). There was an additional capacity of cogeneration and selfsupplying power plants of the order of 2,700 MW_e. Therefore geothermal capacity represents 2.12% of the total capacity of the CFE.

On the other hand, hydropower capacity is 9,663 MW_e (27.1%), capacity based on fossil fuels is 23,923 MW_e (67.1%), nuclear power amounts to 1,309 MW (3.7%) and wind power is only 1.58 MW_e (Table 3).

In the twelve months between December 1998 and November 1999, the CFE produced a total amount of 179,748 GWh. The relative amounts according to plant type are as follows (Table 3): Hydroelectricity, 31,876 GWh (17.7%); electricity produced with fossil fuel, 135,671 GWh (75.5%); geothermal energy, 5,681 GWh (3.2%), nuclear energy, 9,514 GWh (5.3%) and wind energy 6.3 GWh.

Table 3 also shows the capacity under construction and the total capacity projected by 2005. There are no plans to increase the nuclear capacity. Most of the extra capacity under construction is based on fossil fuels, particularly on gas burning combined cycle plants, amounting to a total of 3,371 MW_e. This figure includes ten projects, five under the IPP scheme and five under the BLT financial scheme. As already mentioned, an additional capacity of 110 MW_e using geothermal steam is under construction (CP-IV and Las Tres Vírgenes I projects, Table 1).

By the end of 1999, another five projects of combined cycle power plants were under bidding: Altamira II (450 MW_e), Monterrey III (450 MW_e), Campeche (225 MW_e), Naco-Nogales (225 MW_e) and Rosarito 10 and 11 (450 MW_e), totaling 1,800 MW_e. All of them are IPP projects. A geothermal electric project was planned for bid under a BLT scheme: Los Azufres II (100 MW_e). They are reported in Table 3 in the third row (not yet under construction in January 2000).

Eleven additional projects based on fossil fuels were planned for bidding by October 1999. They were: Tula (combined cycle/gas) with 150 MW_e, Valle de México (cc/g) with 280 MW_e (repowering), El Sauz (cc) with 150 MW_e, Francisco Villa (cc) with 150 MW_e (repowering), Tuxpan III and IV (cc) with 900 MW_e, Altamira III and IV (combined cycle/coal) with 900 MW_e Laguna I (cc) with 225 MW_e, Baja California Sur I (diesel) with 37.5 MW_e, Río Bravo III (cc) with 450 MW_e, Noreste I (cc) with 225 MW_e, and Baja California I (cc) with 225 MW_e. These projects add 3,692.5 MW_e, and are included in the total projected use by 2005 in Table 3.

Two hydroelectric projects were also planned for bidding: San Rafael (24 MW_e) and Chicoasén (900 MW_e), which are included by 2005 in Table 3.

The total projected use of geothermal power plants by 2005 in Table 3 includes the projects Las Tres Vírgenes II (15 MW_e), La Primavera I and II (50 MW_e) and Los Humeros (50 MW_e).

7. PROFESSIONAL PERSONNEL IN GEOTHERMAL ACTIVITIES AND INVESTMENTS

In Table 4 the personnel with a university degree allocated to geothermal activities only is reported, including the changes in the last five years.

Data from public utilities (third column) refer only to the CFE, particularly to the Gerencia de Proyectos Geotermoelécricos (Geothermal Electric Projects division), whose professional personnel practically have no changes in the period. Data from universities (fourth column) include research centers like the IIE (Electrical Research Institute) and the National University (UNAM). Except for the CFE, the rest of the data in Table 4 are estimates.

Table 5 shows the total investments in geothermal activties in the last decade. All of the investments are of public type, and

specifically investments of the CFE, and were focused on electrical utilization of geothermal energy. Data from former years were not available, nor information on direct use investments (which are almost entirely private).

8. DIRECT USES OF GEOTHERMAL ENERGY

Except at the Los Azufres field, where the CFE operates some pilot projects, the direct uses of geothermal energy in Mexico are limited to bathing and swimming pools in resorts developed through governmental and private investments in several states of the country.

There is no complete nor precise information about the characteristics of these resorts, but Table 6 includes our best estimations on geothermal bathing and swimming pools resources in Mexico, based on the regional reconnaissance of geothermal resources in the whole country. According to this survey, there is in Mexico an installed capacity of approximately 164 MWt in more than 160 sites with tourist or resort installations, distributed in 19 states of the country. Most of them are private developments, whose economic resources and investments are unknown up to date. The pilot projects in Los Azufres and Los Humeros are also included in Table 6. Table 7 presents ae summary of geothermal direct uses in Mexico.

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Table 1. Utilization of geothermal energy for electric power generation in Mexico as of 31 December 1999

Locality	Power Plant Name	Year Com-missioned	No. Of Units	Status[1]	Type of Unit[2]	Unit Rating MWe	Total Installed Capacity (MWe)	Annual[3] Energy Produced (GWh/yr)	Total Under Const. Or Planned (MWe)
Cerro Prieto	CP-I U-1	1973	1		1F	28.6	37.5	250.23	
	U-2	1973	1		1F	30.8	37.5	270.05	
	U-3	1979	1		1F	34.8	37.5	304.90	
	U-4	1979	1		1F	30.9	37.5	270.84	
	U-5	1982	1		2F	14.0	30.0	122.69	
	CP-II U-1	1986	1		2F	96.2	110.0	842.54	
	U-2	1987	1		2F	96.9	110.0	848.51	
	CP-III U-1	1986	1		2F	95.7	110.0	838.75	
	U-2	1987	1		2F	105.1	110.0	921.07	
	CP-IV 1-4	2000	4	N	1F				100.0
Los Azufres	U-2	1982	1	N	O	0	5.0	0.00	
	U-3	1982	1		O	5.1	5.0	47.70	
	U-4	1982	1		O	5.1	5.0	44.48	
	U-5	1982	1		O	4.9	5.0	42.66	
	U-6	1986	1		O	4.6	5.0	40.64	
	U-7	1988	1		1F	37.6	50.0	329.74	
	U-8	1989	1		O	4.2	5.0	36.70	
	U-9	1990	1		O	0.8	5.0	7.19	
	U-10	1992	1		O	4.5	5.0	39.23	
	U-11	1993	1		B	0.6	1.5	5.35	
	U-12	1993	1		B	0.8	1.5	7.33	
	L.Az. II	2001	4	N	1F				100.0
Los Humeros	U-1	1990	1		O	5.0	6.0	43.92	
	U-2	1990	1		O	6.0	6.0	52.94	
	U-3	1991	1		O	6.0	6.0	52.51	
	U-4	1991	1		O	5.8	6.0	51.20	
	U-5	1992	1		O	5.7	6.0	50.20	
	U-6	1994	1		O	5.7	6.0	49.69	
	U-7	1993	1		O	5.8	6.0	50.55	
Las Tres Vírgenes	U-1, 2	2001	2	N	1F				10.0
	U-3	2002	1	N	1F				15.0
La Primavera	U-1, 2	2002	2	N	O				10.0
	U-3, 4	2005	2	N	1F				40.0
Total			**42**			**641.2**	**755.0**	**5,618.61**	**275.0**

1) N: Not operating (temporary), R: Retired. Blank if the unit is presently operating.

2) 1F: Single Flash, 2F: Double Flash, B: Binary (Rankine Cycle), O: Other (Back-pressure)

Table 2. Wells drilled for electrical, direct and combined use of geothermal resources in Mexico from 1 January 1995 to 31 December 1999

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other	
Exploration[1]	(all)	11	0	0	0	13.406
Production	>150°C	50	0	0	0	121,879
	150-100°C	0	0	0	0	0
	<100°C	0	0	0	0	0
Injection	(all)	5	0	0	0	6.579
Total		**66**	**0**	**0**	**0**	**141,864**

1) Include thermal gradient wells, but none less than 100 m deep.

Table 3. Present and planned production of electricity in Mexico

	Geothermal		Fossil Fuels		Hydro		Nuclear		Wind		Total	
	Capac-ity [1]	Gross Prod. [2]	Capac-ity [1]	Gross Prod. [2]	Capac-ity [1]	Gross Prod. [2]	Capac-ity [1]	Gross Prod. [2]	Capac-ity [1]	Gross Prod. [2]	Capac-ity [1]	Gross Prod. [2]
In operation in January 2000	755	5,681	23,923	135,671	9,663	31,876	1,309	9,514	2	6	35,652	179,748
Under construction in January 2000	110		3,371		0		0		0		3,481	
Funds committed but not yet under construction in January 2000	100		1,800		0		0		0		1,900	
Total projected use by 2005	1080		35,187		10,624		1,309		100		48,300	

1) MWe
2) *GWh/year (December 1998-November 1999)*

Table 4. Allocation of professional personnel to geothermal activities in Mexico(restricted to personnel with a university degree)

Year	Professional Person-Years of Effort						
	Government	Public Utilities	Universities	Paid Foreign Consultants	Contributed Through Foreign Aid Programs	Private Industry	Total
1995	0	220	40	0	0	19	**279**
1996	0	230	42	2	0	22	**296**
1997	0	240	40	2	0	24	**306**
1998	0	235	42	0	0	35	**312**
1999	0	230	45	0	0	35	**310**

Table 5. Total investments in geothermal energy in Mexico in 1999 (US Dollars)

Period	Research & Development including surface exploration & exploratory drilling (Million US$)	Field development including production drilling & surface equipment (Million US$)	Utilization		Funding Type	
			Direct (Million US$)	Electrical (Million US$)	Private %	Public %
1985-1989						
1990-1994	33.04	245.61	0	278.65	0	100
1995-1999	11.50	385.77	?	397.27	0	100

Table 6. Utilization of geothermal energy for direct heat applic<ations in Mexico at 31 December 1999

Locality or State	Type[1]	Maximum Utilization			Capacity[2] (MWt)	Annual Utilization		
		Flow Rate (kg/s)	Temperature (°C)			Ave. Flow (kg/s)	Energy[3]	Capacity Factor[4]
			Inlet	Outlet				
Los Azufres, Mich.	A	0.100	77.0	60.0	0.007	0.080	0.179	0.801
Los Azufres, Mich.	B	38.000	72.0	55.0	2.703	31.000	69.511	0.815
Los Azufres, Mich.	G	0.050	60.0	40.0	0.004	0.040	0.105	0.793
Los Azufres, Mich.	H	0.060	80.0	50.0	0.008	0.045	0.178	0.753
Los Humeros, Pue.	O*	2.778	75.0	60.0	0.174	2.500	4.946	0.901
La Primavera, Jal.	B	63.000	48.0	31.0	4.481	59.000	132.296	0.936
Aguascalientes*	B	265.000	43.0	30.0	14.414	150.000	257.205	0.566
Chiapas*	B	1,000.000	36.0	29.0	29.288	800.000	738.640	0.800
Chihuahua*	B	38.000	39.3	25.0	2.274	28.000	52.813	0.736
Coahuila*	B	56.000	32.0	25.0	1.640	30.000	27.699	0.536
Durango*	B	34.000	52.5	38.0	2.063	15.000	28.688	0.441
Guanajuato*	B	293.000	40.8	29.0	14.466	225.000	350.195	0.768
Hidalgo*	B	271.000	41.5	32.0	10.772	228.000	285.695	0.841
Jalisco*	B	368.000	37.8	30.0	12.010	285.000	293.214	0.774
México*	B	103.000	35.1	25.0	4.363	80.000	106.575	0.755
Michoacán*	B	161.000	44.5	33.0	7.721	135.000	204.775	0.841
Morelos*	B	95.000	45.0	30.0	14.466	225.000	350.195	0.768
Nuevo León*	B	295.000	38.0	30.0	9.874	218.000	230.034	0.739
Querétaro*	B	770.000	31.8	26.5	17.259	585.000	408.956	0.751
San Luis Potosí*	B	292.000	36.8	31.0	7.054	198.000	151.474	0.681
Sinaloa*	B	7.000	72.5	61.0	0.337	4.3000	6.522	0.614
Tlaxcala*	B	10.000	35.0	28.0	0.293	7.5000	6.925	0.749
Veracruz*	B	42.000	65.0	48.0	2.987	35.000	78.481	0.833
Zacatecas*	B	163.000	36.6	28.5	5.532	125.000	133.549	0.766
TOTAL		**4,366.988**	**49.0**	**36.5**	**164.190**	**3,466.465**	**3,918.850**	**0.757**

Notes:
* Includes the total flow rate of all of the bathing and swimming sites in the state, and the average inlet & outlet temperature.
1) A: Agricultural drying, B: Bathing and swimming, G: Greenhouse, H: Space heating, O: Others (Mushroom breeding).
2) Capacity (MWt) = Max. flow rate (kg/s) [inlet temp. (°C) – outlet temp. (°C)] x 0.004184
3) Energy use (TJ/year) = Average flow rate (kg/s) [inlet temp. (°C) – outlet temp. (°C)] x 0.1319
4) Capacity factor = [Annual energy use (TJ/year) x 0.03171]/Capacity (MWt)

Table 7. Summary table of geothermal direct uses in Mexico as of 31 December 1999

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/year)	Capacity Factor[3]
Space Heating	0.008	0.178	0.753
Greenhouse Heating	0.004	0.105	0.793
Agricultural Drying	0.007	0.179	0.801
Bathing and Swimming	163.997	3,913.442	0.757
Other Uses (Mushroom breeding)	0.174	4.946	0.901
TOTAL	**164.190**	**3,918.850**	**0.757**

Notes:
1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) [inlet temp. (°C) – outlet temp. (°C)] x 0.004184
2) Annual Energy Use (TJ/year) = Average flow rate (kg/s) [inlet temp. (°C) – outlet temp. (°C)] x 0.1319
3) Capacity Factor = [Annual energy use (TJ/year)/ Capacity (MWt)] x 0.03171

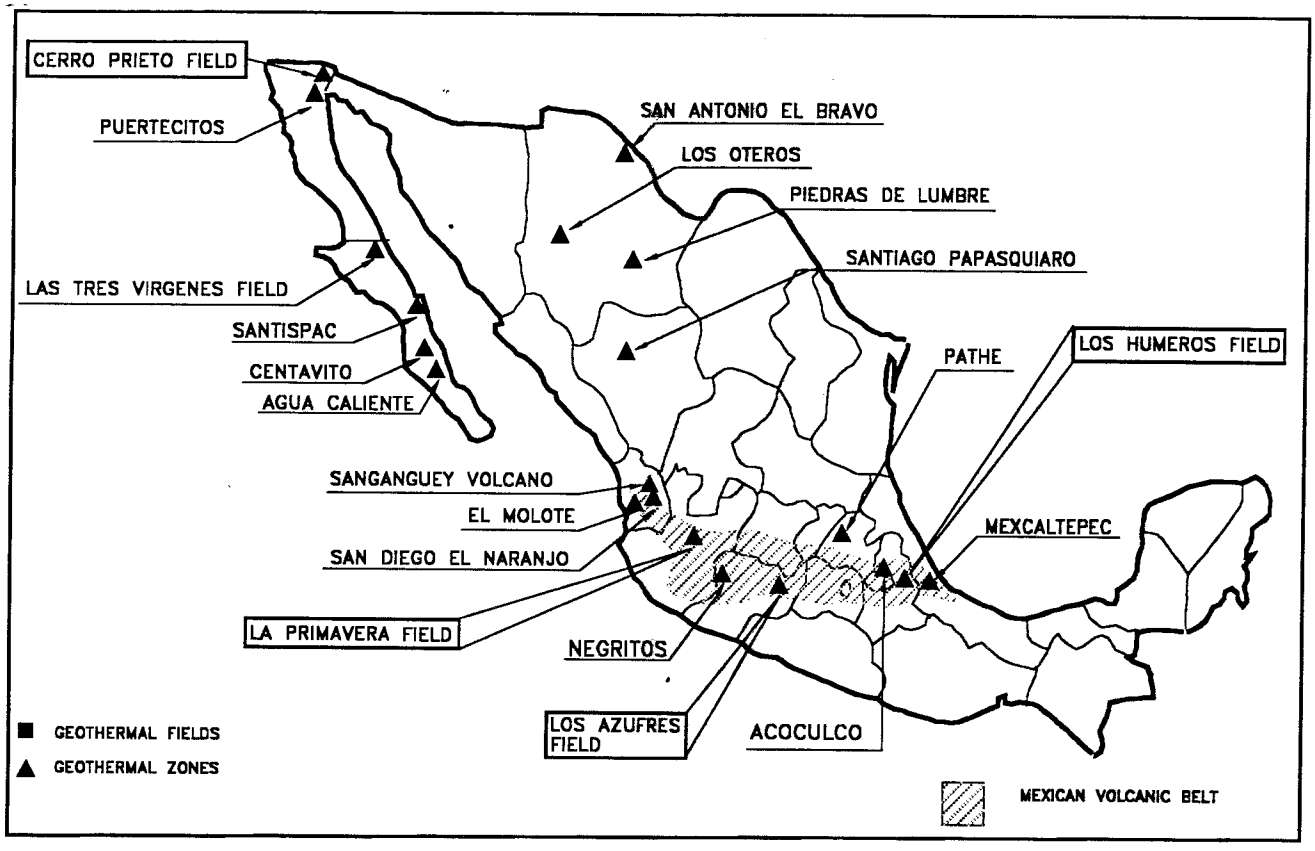

Fig. 1. Geothermal fields and zones in Mexico

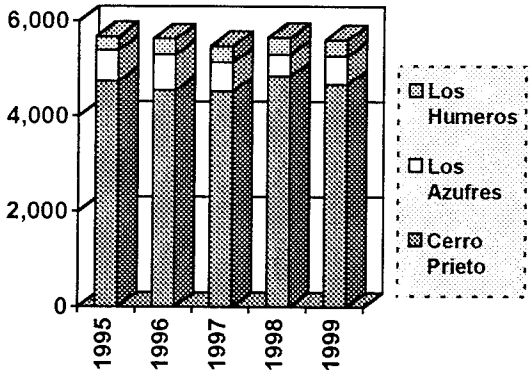

Fig. 2. Geothermal-electric generation in the last five years in Mexico (figures en GWh/year)

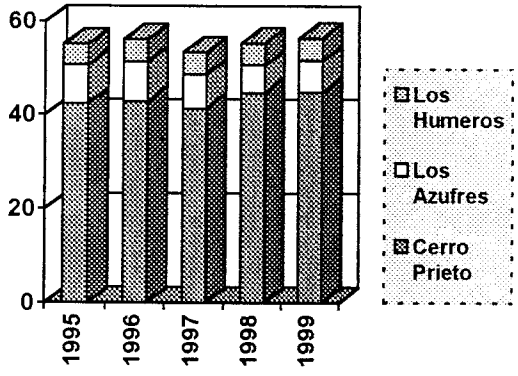

Fig. 3. Steam production in the last five years in Mexico (figures in million of metric tons)