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GEOHERMAL-ELECTRIC DEVELOPMENT PROGRAM IN MEXICO

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ABSTRACT

Fifty-five million tons of steam were produced in Mexico in 1995, in the geothermal fields of Cerro Prieto, Los Azufres and Los Humeros. One hundred and seventy-three production wells were in operation, with an average production of 36.3 tons per hour of steam. Electric generation obtained with that steam was 5,682 GWh, with an annual average plant factor of 86.1%. The specific consumption of steam was 9.7 tons per MWh, as annual average. By the end of 1996 it is expected construction on the Marítaro (2 x 20 MW) project, at Los Azufres, will start, and the Cerro Prieto (100 MW) project will enter the bidding process. Other geothermal projects are almost ready for bidding announcements.

INTRODUCTION

Geothermal electric installed capacity in Mexico has not changed for the last four years. Currently it is still 753 MW, with 28 power units distributed in the fields of Cerro Prieto, Los Azufres and Los Humeros. Recently, however, two units of Los Azufres (5 MW each) have been moved to Miravalles, Costa Rica.

Two geothermal projects are going on line in the second half of this year: Marítaro (2 x 20 MW) in Los Azufres, and Cerro Prieto (100 MW). There are other geothermal projects in the Cerro Prieto, Los Azufres, Los Humeros, Las Tres Vírgenes and La Primavera fields.

The objective of this paper is to present the last production data from the Mexican geothermal fields under exploitation, and to describe, in general terms, the main program projects.

THE CERRO PRIETO GEOTHERMAL FIELD

Cerro Prieto is the oldest Mexican geothermal field. It is at the Northwestern portion of Mexico (Fig. 1). It has an installed capacity of 620 MW in its three sections: Cerro Prieto I (CP-I), CP-II and CP-III. Four power units 37.5 MW each and one of 30 MW, are in operation in the section of

CP-I. Two units of 110 MW each are installed in CP-II and two more power units, 110 MW each also, are operating in CP-III.

During 1995, 42.4 million tons of steam were produced in this field, at an average annual rate of 4,842 tons per hour (t/h). Around six million t/h were produced by a private company, after a contract signed with CFE (CFE, 1995). This Cerro Prieto steam production was 77% of the whole geothermal steam produced in Mexico in that year.

An annual average of 132 production wells were in operation in 1995, 113 of them managed by CFE and 19 by the private company. Average production per well was almost 37 t/h of steam (Table 1).

Generation of electricity during 1995 was 4,738 GWh, the monthly average was 395 GWh and the monthly peak was in December at 427 GWh. The annual average plant factor was 87.2%, which had its minimum in January (74.1%) and its maximum in December (92.5%) (CFE, 1995).

Steam specific consumption resulted in 8.6 tons per MWh (t/MWh) as the 1995 average, ranging from 9.5 t/MWh in January to 8.2 t/MWh in December.

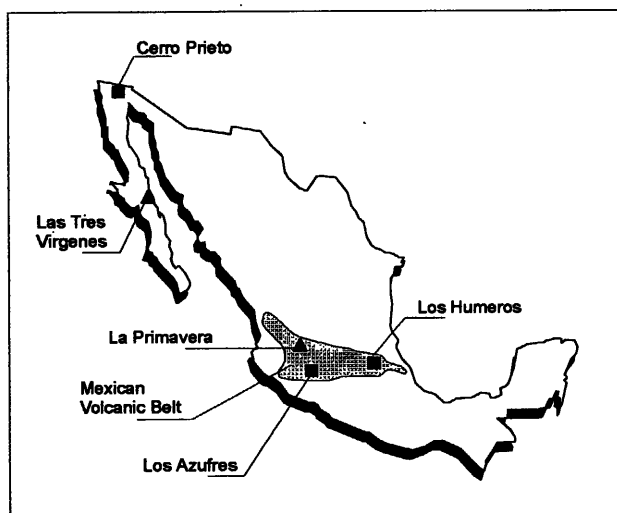


Fig. 1. Location of Mexican geothermal fields and zones.

In 1995 almost 2,000 GWh were exported by CFE to California, which represented a sale of 73 million dollars. However, 229 GWh were imported, representing a purchase of seven million dollars. Sales and purchases of electricity were done based on a contract between CFE and two American utilities. This contract concluded by August, 1996.

The Cerro Prieto 100 MW Project

CFE has exploited the Cerro Prieto reservoir for 23 years. Much information has been obtained during that period, so to date the main features of the geothermal system are well known: where the recharge is coming from, areas where the steam is flowing, which zones produce more associated water, which ones have more gases, and which are adequate for injection.

In addition, several studies to assess the geothermal potential of the reservoir have been made by CFE personnel and by private consultants. An important conclusion from those studies is that Cerro Prieto

geothermal system can support at least an additional capacity between 160 and 180 MW (CFE, 1994a).

It is important to mention that all mathematical models applied in Cerro Prieto have been previously matched to the actual historical production obtained over past years. This allowed to make reasonable predictions on the further behaviour of the reservoir under different exploitation scenarios.

The Cerro Prieto 100 MW project consists of the construction and installation of four condensing, single flash, units of 25 MW each. Two of them will be at CP-II, probably around the well E-56, and two at CP-III, probably near well M-192 (Fig. 2). These locations were chosen to take advantage of the present superficial installations and steam gathering systems, to reduce environmental impacts, and to improve the management of the existing steam supply system.

Size of those units was selected considering the short time needed for their construction, and the possibility to make

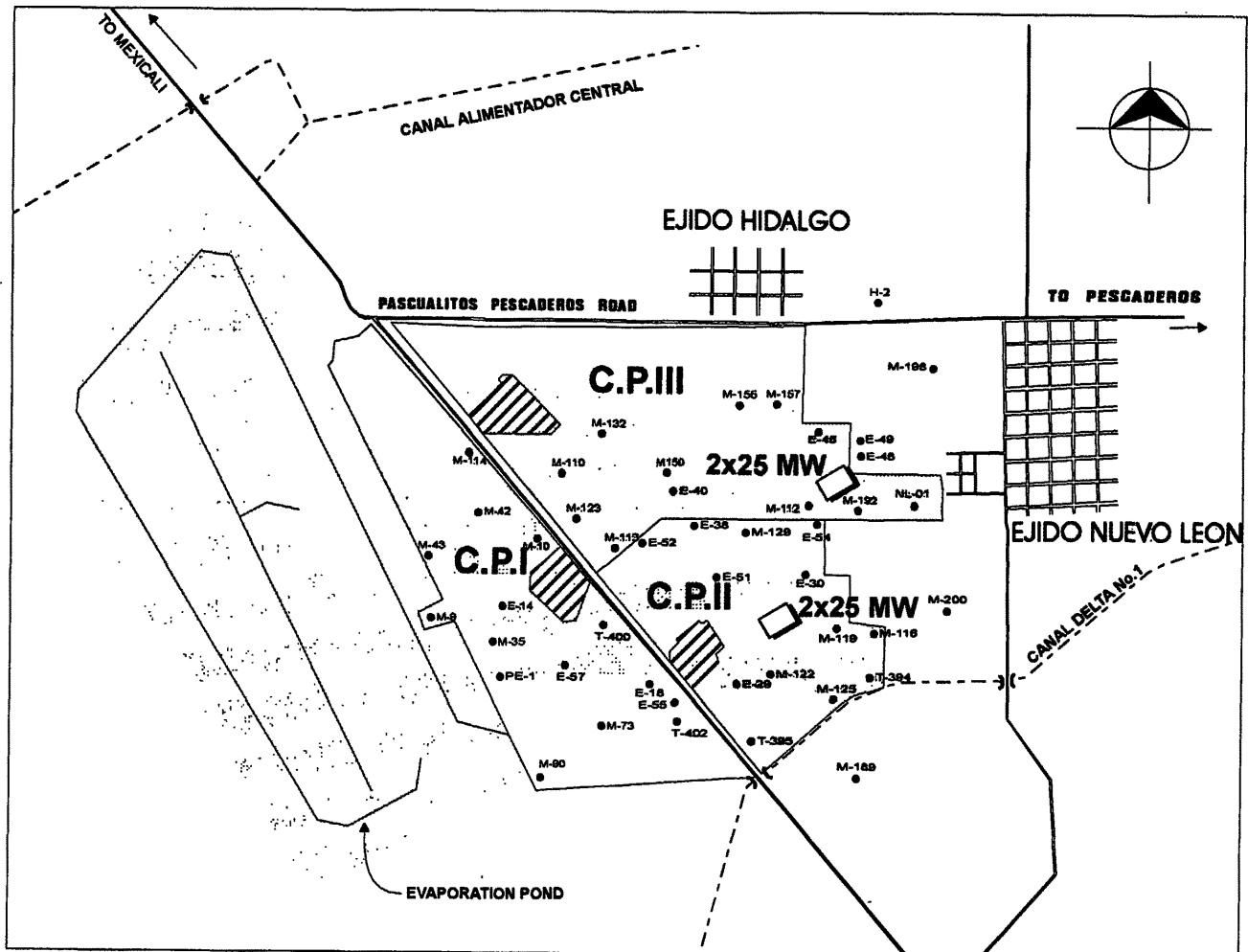


Table 1. Main data on geothermal production in Mexico in 1995.

Data	Cerro Prieto	Los Azufres	Los Humeros	Total
Installed capacity (MW)	620.0	98	35	753
Steam production (million of tons)	42.4	8.2	4.5	55.0
Steam production rate (tons/hour)	4,842	933	509	6,284
Wells in production (average)	132	24	17	173
Average well production (tons/hour)	36.7	38.9	29.9	36.3
Electricity generation (GWh)	4,738	658	286	5,682
Plant factor (%)	88.6	76.7	93.2	86.1
Steam specific consumption (t/MWh)	8.6	10.0	12.5	9.7
Field O&M cost (Pesos/kWh)	0.038	0.030	0.050	0.042

most of the final necessary tests in the factory, before transport to the site. Each pair of units will be installed in the same building (housepower).

Each unit will include a direct contact barometric condenser, and a cooling tower. The project also includes an electrical substation in each unit. The probable admission conditions for the steam in the turbine would be as follows: 700 kPa (7 bar) of pressure, and 99.9% as minimum quality (Fig 3). Specific consumption is calculated in 8.5 t/MWh (CFE, 1994a).

The construction/financing scheme will probably be BLT (build, lease and transfer), and the bid is expected to be launched in the last quarter of 1996.

THE LOS AZUFRES GEOTHERMAL FIELD

This field is located in the middle portion of Mexico, at the Northern part of the State of Michoacan. It lays in the physiographic province of the Mexican Volcanic Belt (Fig. 1). Ten power units are in operation: seven back-pressure units of 5 MW each, one condensation unit of 50 MW, and two binary units of 1.5 MW each. Two power units of 5 MW were dismantled and transported to the Miravalles geothermal field, Costa Rica, in order to accomplish a services contract signed between CFE and the Instituto Costarricense de Electricidad (ICE). The total installed capacity is, therefore, 88 MW.

In 1995 Los Azufres wells produced 8.2 million tons of steam for an average annual rate of 933 t/h (CFE, 1995). This represented around 15% of the geothermal steam produced in Mexico. Twenty-four production wells were in operation in 1995, then the average production per well was almost 39 t/h of steam (see Table 1).

Generation of electricity during 1995 was 658 GWh. The

monthly average was almost 55 GWh, with a maximum of 71.7 GWh in December and a minimum of 29.4 GWh in April. The annual average plant factor was 76.7%, which was at its minimum in February (60.9%) and its peak in November (99%, the highest in the history of Los Azufres) (CFE, 1995). For the early months of 1995, the 50 MW unit was down and under repair, which explains the low production of electricity.

Specific consumption of steam resulted in 12.5 tons per MWh (t/MWh) as the 1995 average, ranging from 15 t/MWh in January to 11.4 t/MWh in December.

The Marítaro 40 MW Project

Los Azufres has been in production for fourteen years. CFE has made several studies on the field and the reservoir. To date, the best production and injection areas are well known at both zones in which the field has been divided: South Zone and North Zone.

The present steam availability exceeds the consumption of the eight power units in operation (two more units are binary, using hot water). In addition, the more recent mathematical models conclude that it is possible to install at least 130 more megawatts in the field (Table 2) (CFE, 1994b).

The Marítaro project involves the construction and installation of two condensing, single flash, units of 20 MW each. One of them will be installed in the South Zone, near the 50 MW unit, and another in the North Zone, near the well A-5 (Fig. 4). Locations were decided taking in account the availability of wells and the present steam gathering system (CFE, 1994b).

General characteristics and steam admission conditions for those units will be similar to those for the Cerro Prieto project, except the size (Fig. 3). Specific consumption of

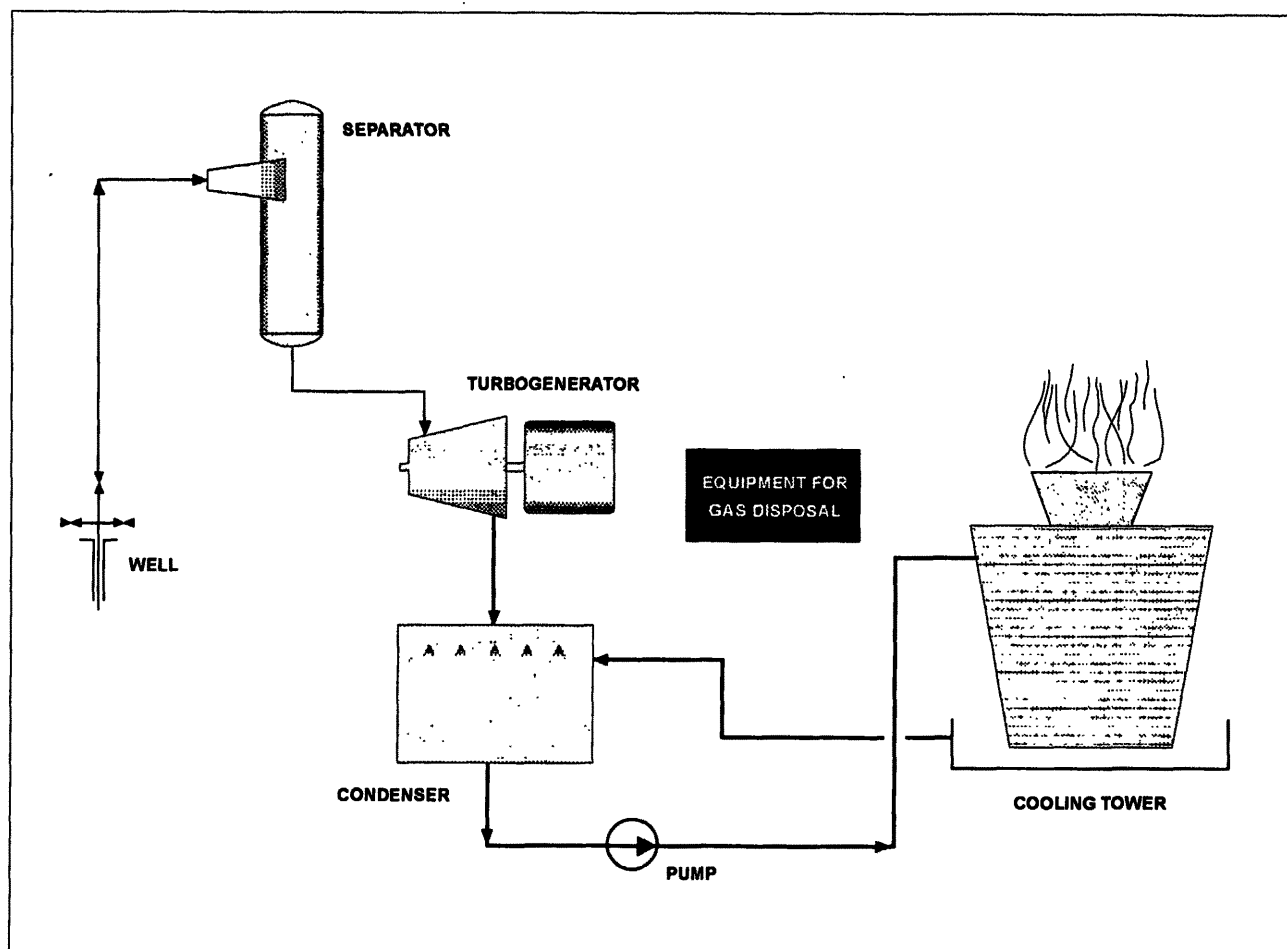


Fig. 3. Diagram for a power unit of 20 or 25 MW.

steam is calculated in 9 t/MWh.

Marítaro Unit 1 will be installed at the South Zone. Fourteen production wells are integrated in the Southern steam gathering system. Considering the present production of those wells and the before mentioned removal of two 5 MW units, there is steam enough for Marítaro Unit 1. No new wells are necessary.

Marítaro Unit 2 will be located in the North Zone. It will

Table 2. Geothermal electric potential at Los Azufres.

Zone	Potential	Installed Capacity*	Additional Capacity*
North	145 MW	25 MW	110 MW
South	90 MW	70 MW	20 MW
Total	235 MW	95 MW	130 MW

* Except binary units.

be fed by the available excess steam from wells connected to units 3, 4 and 5. So, no further wells are necessary for this unit, but one existing well needs repair (CFE, 1994).

The Marítaro 2 x 20 MW project was bid sometime ago. The winner was a Mexican construction company, who was asked to modify the original financial scheme into a build, lease, transfer (BLT) scheme. At this time the contracts are in the signature process, and it is expected that the construction works will start during the last quarter of 1996.

THE LOS HUMEROS GEOTHERMAL FIELD

Los Humeros is located in the Central-Eastern part of Mexico, at the border between States of Puebla and Veracruz, within the Mexican Volcanic Belt (Fig. 1). There are seven back-pressure power units of 5 MW each in operation.

During 1995 the production wells produced 4.5 million tons of steam, representing around 8% of the geothermal steam produced in the country. The annual average

production rate was 509 t/h. There were 17 wells in production, in average, along that year (CFE, 1995). Thus, each well had an average production of 29.9 t/h of steam (Table 1).

Electricity generated in 1995 was 286 GWh. The average monthly generation of electricity was almost 24 GWh. There was a maximum of 25.3 GWh in July, and a minimum of 22 GWh in April. There was an excellent annual average plant factor of 93.2%, with a minimum of 85.5% in March and a maximum of 97% in July (CFE, 1995).

Specific average consumption of steam in 1995 was 15.7 t/MWh.

The next project in Los Humeros is the construction and installation of two 25 MW power units. These units will be similar of those to be installed at Cerro Prieto (Fig. 3). Although many aspects of the project have been decided, the bid has not been advertised yet (CFE, 1994c).

FURTHER PROJECTS

Besides the mentioned projects in Cerro Prieto, Los Azufres and Los Humeros, there are some additional projects in these fields and in other Mexican geothermal fields. Bids for most of them will probably be under the BLT or IPP (Independent Power Producer) financial schemes, but some joint-venture or joint-investment schemes (CFE-private) will be included.

In the Cerro Prieto field, additional projects are as follows (CFE, 1994a):

□ CP-I (25 MW). This project includes the repowering of units number 1, 2, 3, 4 of CP-I, which are the oldest of the field. These units have a specific consumption of 11 t/MWh. After their repowering it is expected the specific consumption to be 9 t/MWh. The excess steam would be enough for a condensing unit of 25 MW.

□ CP-IV (2 x 25 MW). This project consists of the construction and installation of two condensing units, 25 MW each, in that section of Cerro Prieto known as CP-IV. This is located to the east of CP-II and CP-III. Several deep exploratory wells have been drilled in that zone, obtaining

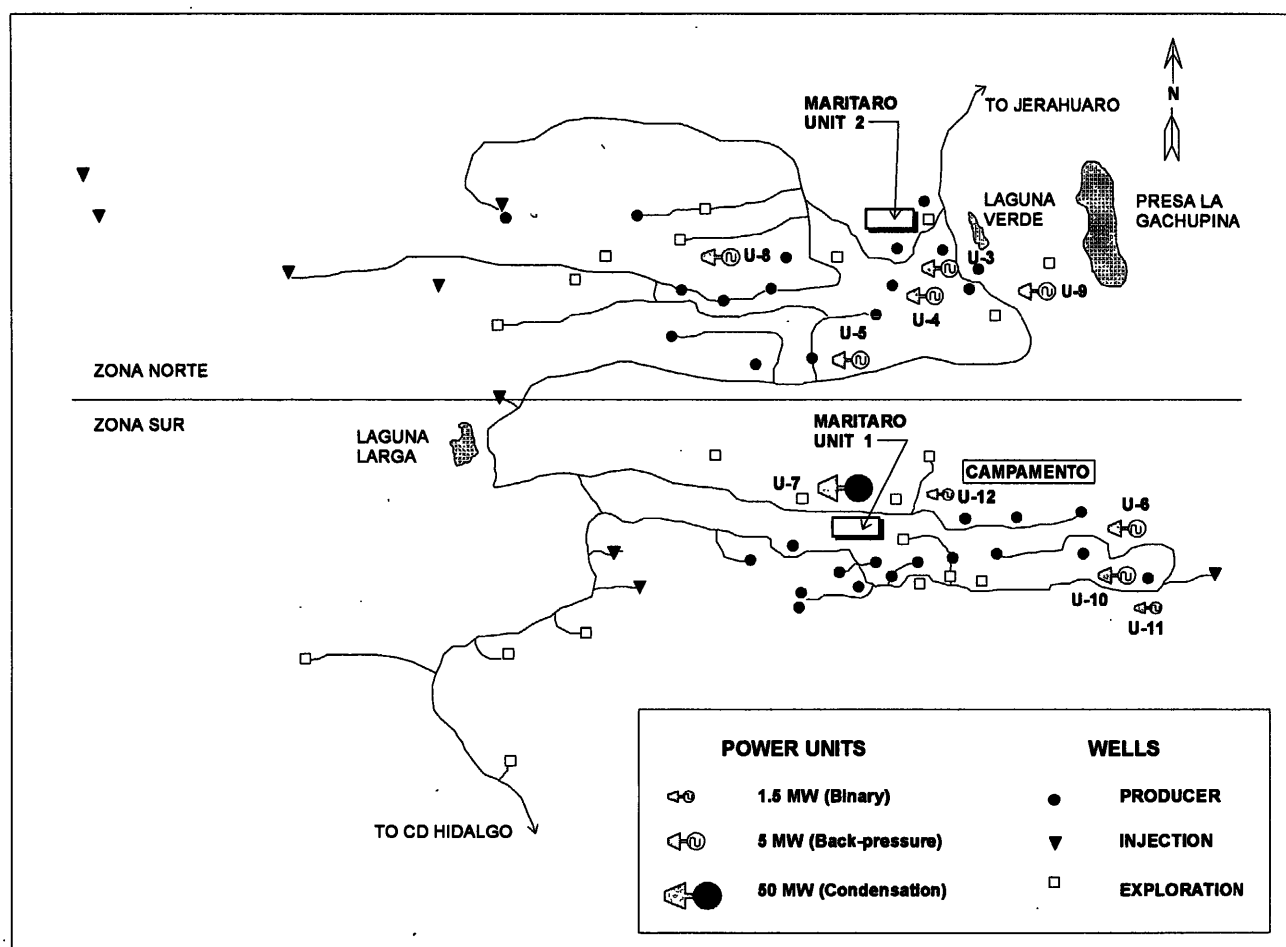


Fig. 4. Location of power units for the Maritaro project in Los Azufres.

production averages of 40 t/h of steam.

□ *The biphase pilot plant.* After an agreement signed between CFE and the private companies Biphase Energy Co. and Biphase de México, a small biphase turbine is going to be installed on a well at Cerro Prieto. If the plant works appropriately, several similar turbines would be installed in other wells (Oropeza and Hays, 1996).

In the Los Azufres field, other projects are (CFE, 1994b):

□ *El Chino (2 x 25 MW).* The project is composed of two 25 MW each power units, located in the North Zone to take advantage of its potential (Table 2). Several existing wells would be used to supply the necessary steam, some of which need repairs.

□ *Nopalitos (2 x 25 MW).* This is a project similar to El Chino. Both 25 MW units will be in the North Zone. Several wells would be used to feed these units, after repairing.

Projects to develop in other geothermal fields are:

□ *Las Tres Vírgenes.* Recent preliminary assessment of this field, in the middle of the Baja California Peninsula (Fig. 1), indicates 25 MW of geothermal potential. CFE has planned to develop this potential in two stages: one of 10 MW and a second of 15 MW. CFE has drilled some wells; other wells are being drilled. More exploration studies will be undertaken, to evaluate the possibility of installing 50 additional MW.

□ *La Primavera.* CFE has drilled 13 wells in this field (see Fig. 1 for location). Its geothermal potential has been assessed at 75 MW. Development plans have been stopped since 1989, due to environmental problems, but eventually they will be satisfactorily solved (Hiriart-Le Bert and Gutiérrez-Negrín, 1984). Two projects, La Primavera I (2 x 5 MW) and La Primavera II (3 x 20 MW), are being considered.

SOME CONCLUSIONS

The last geothermal-electric units in Mexico were installed in 1992. For the last four years, construction of new power

units has been stopped, despite the plans for several geothermal-electric projects.

That situation is beginning to change. It is expected that the Marítaro project will be in construction, and the Cerro Prieto project in bidding, by the end of 1996. Additional projects for Cerro Prieto, Los Azufres, Los Humeros, Las Tres Vírgenes and La Primavera are almost ready for bid. In all cases, they are technically and economically feasible projects.

CFE is not able to come up with the whole investment for these projects. All of them will be constructed and installed with private investment. The financial schemes for those investments will be BLT, IPP, or some kind of combination like joint-ventures or limited partnerships between CFE and private investors or developers.

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