Proceedings Ninth Workshop Geothermal Reservoir Engineering
Stanford University, Stanford, California, December 1983
SGP-TR-74

GEOTHERMAL FIELD DEVELOPMENT IN MEXICO

ING. HECTOR ALONSO ESPINOSA

COMISION FEDERAL DE ELECTRICIDAD
GERENCIA DE PROYECTOS GEOTERMOELECTRICOS
MORELIA, MICHOACAN, MEXICO.

ABSTRACT.

Mexico is a Country characterized by -- its diversified means of Power Genera - tion. Actual installed capacity is al- most 19 000 MW, of which 205 MW corres- ponds to Geothermal Plants, that is, -- 180 MW in Cerro Prieto and 25 MW of Por table Plants in Los Azufres.

To date, 346 areas with exploita - tion possibilities, are known. They -- are mainly distributed along the Volca- nic Belt where the most prominent are, - Los Azufres, La Primavera, Los Humeros, Ixtlan De Los Hervores and Los Negritos, among others. Proved reserves are 920 MW, and the accessible resource base are 4 600 MW identified and 6 000 MW undis- covered.

The long range construction studies- intends to achieve a total installed -- capacity of 100 000 MW, by the end of - this century, including 2 000 MW Geother- mal, through conventional and Portable- Plants. It is not a definite program,- but a development strategy. The carry- ing out of a definite program, will de- pend upon the confirmation of Hypothesis made in previous studies, and the econo mic decisions related to the financial- sources availability, and technologies- to be used in the future as well.

GENERAL ASPECTS OF ACTUAL POWER GENERATION.

The Comision Federal de Electrici- dad (CFE), is a Federal Government Agen cy created to generate and distribute - power in Mexico. Its main objectives - are basically:

- Planning the National Electric - System.
- Generation, Transmission and Dis tribution of Electric Power.
- Construction of all Power Plants. Installations and Works that re- quire Planning, Execution, ---- Operation and Maintenance of the National Electric System.
- Promote scientific research as - well as National Technology in - Electrical Aplications.
- Promote National Manufacturers - of Electrical Equipment and those related.

C.F.E. is organized basically in - five (5) operational interconnection -- systems, which are located geographically - as shown on Fig. 1, with an actual power generating capacity of 18 390 MW integra ted through different types of Power -- Plants as per Table 1, according to its capacity.

One Nuclear Plant (Two 654 MW Units) is under construction as well as multiple other installations for wind and solar- studies.

During the last year, the total -- Electric Energy Consumption was -- 73 200 X 10^6 KWH (73.2 TWH), that is - approximately 1 000 KWH/ person. The- source of this energy in 1982 and its - consumption since 1976, is shown on -- Tables 2 and 3.

If taken an average of 9% as a re- presentative of the values for the pre vious table, and in the case that only- half corresponds to a Power Generation, by means of Conventional Thermoelectrics, should be necessary to burn up almost - 1.8 X 10^6 barrels of oil per day, by the year 2010.. Growth in this manner can - not be afforded, since Hydro Generation could not go as much as three times its actual installed capacity, coal is very limited and Nuclear so expensive.

Therefore, it seems more convenient for Mexico to elaborate a short and long range planning, for the construction of Power- Plants, based on the availability of altern -- sources of energy, of which Mexico is plentiful.

fig. 1 ELECTRIC SYSTEMS & INTERCONNECTION MAIN LINES C.F.E.

SYSTEM	TYPE OF POWER PLANT							TOTAL
	HIDRO	STEAM	COMBINED CYCLE	TURBO GAS	DIESEL	GEOTHERM	COAL	
INTERCONECTADO DEL SUR (SIS)	6172	4091	791	572	9	25	—	11660
INTERCONECTADO DEL NORTE (SIN)	378	3505	432	753	—	—	300	5368
TIJUANA - MEXICALI	—	287	—	209	—	180	—	676
PENINSULAR (YUCATAN)	—	367	—	120	30	—	—	517
LA PAZ — SISTEMAS AISLADOS	—	75	—	32	62	—	—	169
TOTAL	6550	8325	1223	1686	101	205	300	18390

TABLE 1. POWER GENERATION (MW) As Of 1982

OIL AND COAL	49.2	TWH
GEOTHERMIC	1.3	TWH
HYDRO	22.7	TWH
TOTAL	73.2	TWH

TABLE 2.- ELECTRIC ENERGY CONSUMPTION BY TYPE OF SOURCE IN 1982.

YEAR	TWH	GROWTH (%)
1976	44.6	—
1977	48.9	9.6
1978	53.0	8.4
1979	58.1	9.7
1980	61.9	6.5
1981	67.9	9.7
1982	73.2	7.8

TABLE 3.- ELECTRIC ENERGY CONSUMPTION SINCE 1976

GEOTHERMAL RESERVES.

To date in Mexico are known 346 -- areas with possibilites for Power Generation, most of them distributed along the Volcanic Belt as indicated on Fig. 2.

RESERVE	MW
PROVED	920
IDENTIFIED	4600
UNDISCOVERED	6000
TOTAL	11520

TABLE 4.- MEXICO GEOTHERMAL RESERVES

FIG. 2.- GEOTHERMAL LOCALIZATION OF GEOTHERMAL AREAS.

The application of multiple exploratory and production techniques as well as mathematical modeling to predict and evaluate Geothermal Potencial of such - areas, has permitted to classify the -- reserves as per Table 4.

The distribution of these reserves are:

- Proved reserves; determined through exploratory and production wells; and as a result of using mathematical model to evaluate potential- and assure no less than 20 years operation.

CERRO PRIETO	700 MW
LOS AZUFRES	165 MW
LOS HUMEROS	55 MW
TOTAL PROVED	920 MW

Within the accessible resource --- base, as defined by the U.S.G.S.:

- Identified reserves; characterized by drilling or by geochemical, - geophysical and geological evidence.

LOS AZUFRES MICH.	492 MW
LOS HUMEROS, PUE.	668 MW
LA PRIMAVERA, JAL.	148 MW
SAN MARCOS, JAL.	260 MW
CERRO PRIETO, B.C.	108 MW
SAN AGUSTIN, MICH.	260 MW
ARARO, MICH.	260 MW
SAN BARTOLOME, GTO.	460 MW
IXTLAN DE LOS HERVORES, MICH.	72 MW
TAXHIDO, HGO.	247 MW
LOS NEGRITOS, MICH.	143 MW
PUROAGUITA, GTO.	164 MW
HERVORES DE LA VEGA, JAL.	143 MW
LA CIENEGA, SIN.	143 MW
CULIACAN, SIN.	143 MW
OTHERS	857 MW
TOTAL IDENTIFIED	4,600 MW

-Undiscovered reserves; unspecified-concentratios of Geothermal Energy surmised to exist on the basis of broad geologic, and geochemical - knowledge and theory.

From all the rest of the 346 areas, was estimated 6 000 MW as possible.

POWER PLANTS CONSTRUCTION PROGRAM.

As of the moment, the program indicated on Table 5 is included in the --- construction and investment program of- the Electric Sector (POISE). Graphic - Representation is made in Fig. 3.

FIELD	CAPACITY		OPERATION	
CERRO PRIETO II	UNIT 1	110 MW	MAY.	1984
	UNIT 2	110 MW	OCT.	1984
CERRO PRIETO III	UNIT 1	110 MW	OCT.	1984
	UNIT 2	110 MW	JUL.	1985
CERRO PRIETO IV	UNIT 1	110 MW	MAY.	1992
LOS AZUFRES I	UNIT 1	55 MW	MAR.	1988
	UNIT 2	55 MW	JUN.	1988
LOS AZUFRES II	UNIT 1	55 MW	MAR.	1991
	UNIT 2	55 MW	JUN.	1991

TABLE 5.- POISE GEOTHERMAL POWER PLANTS. CONSTRUCTION PROGRAM

One year experience, operating 5 - MW portable units in Los Azufres, has - demonstrated the convenience of using - them especially as complement of Power- Plant with condenser.

One of the main attractives of --- using these plants is its relative small size and short time for hook up and running it after well completion, which -- saves money and gives very useful reservoir information before deciding the -- installation of a formal Power Plant.

An intermediate alternate is the - utilization of 10 MW small plants with- condenser. These are not as portable - as the 5 MW plants but more efficient.

The possibility of using small --- plants looks attractive for Mexico, --- since National Manufacturers are able - to produce them not totally but in great part.

In table 6, is shown the alternative to modify the Geothermal Power --- Plants construction of POISE, but subject to financial and economical relation -- ships of the country.

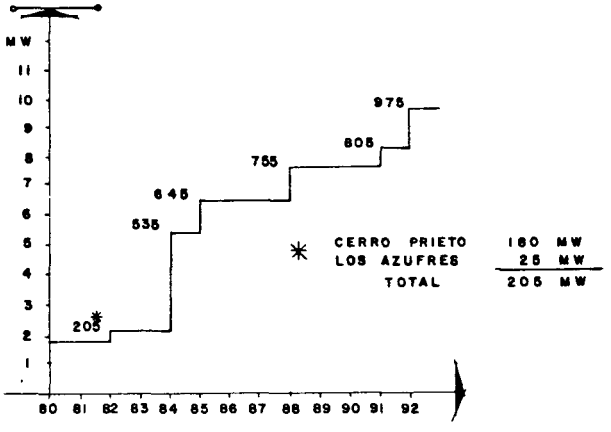
The installation cost per KW for - the different types of plants is as --- follows:

COST IN USCY/KW

	POWER PLANT	WELLS
100 MW	500	200 (1)
55 MW	700	400 (2)
5 MW	350	500 (2)

(1) TAKEN FROM CERRO PRIETO II

(2) TAKEN FROM LOS AZUFRES



3.- GRAPHIC REPRESENTATION OF CONSTRUCTION POROGRAM.

YEAR	POWER (MW)		ACUMMULATED POWER (MW)		TOTAL
	SMALL PLANTS	FORMAL PLANTS	SMALL PLANTS	FORMAL PLANTS	POWER TO INSTALL
ACTUAL	25	180	25	180	205
1983	—	—	25	180	205
1984	20	330	45	510	555
1985	20	110	65	620	685
1986	20	—	85	620	705
1987	20	—	105	620	725
1988	20	110	125	730	855
1989	25	—	150	730	880
1990	30	—	180	730	910
1991	35	110	215	840	1055
1992	40	110	255	955	1205
1993	45	—	300	950	1250
1994	50	55	350	1005	1355
1995	55	—	405	1005	1410
1996	60	110	465	1115	1580
1997	60	—	525	1115	1640
1998	60	110	585	1225	1810
1999	60	—	645	1225	1870
2000	60	110	705	1335	2040

TABLE 6.-ALTERNATIVE TO CONSTRUCTION PROGRAM OF POISE

In order to attain an energy generation as mentioned before, it will be necessary to drill at a pace of 30 to 35 wells per year as an average.

Drilling and related activities such as exploration, reservoir engineering and surface installations design, will require an adequate training program of human resources.

The forecasts obtained for the year 2000 have been based on the following presumptions:

EXPLORATION.

Sustainment of the exploration activities utilizing five groups each consisting of 1 Geologist, 1 Geophysicit, 1 Geochemist and 1 Reservoir Engineer, besides the auxiliary nonspecialized personnel.

According to our present organizational diagram, interpretation and evaluation of the compiled data, would take place at the Central Offices where 5 Geologists, 3 Geophysicist, 5 Specialists in Petrography and 5 in Hydrology would be required.

DRILLING.

If one equipment is considered to drill 3 1/2 wells per year, 10 drilling equipments will be necessary in order to achieve the established annual goal of 35 wells. This means for CFE to have 10 Drilling Engineers, 30 Supervisors, 10 Specialists in Electric Well Logs plus some 50 Technicians able to handle the logging equipments. On each field where drilling is taking place it will be required in addition, 1 Geologist, 1 Geochemist, 1 Environmental Protection Engineer, 2 Reservoir Engineers and 2 Well Termination Specialists. To this we must add the respective Field and Laboratory Technicians.

PRODUCTION.

During the exploitation of a field, permanent activities of well repair, maintenance, hydrology, evaluation of the reservoir evolution and field operations are required. For this purpose we are considering for each field being exploited, 2 Drilling Engineers, 8 Technicians on Well Repair, 3 on Geochemistry, 2 on Reservoirs, 12 on Production/Generation and 4 on Specialized Maintenance (Instrumentation).

PRELIMINARY PLANS:

With the purpose of interpreting the geothermal data and studying the most adequate technical options for exploitation, it is necessary to carry out the appropriate factibility studies and preliminary plan where the thermodynamic cycle, separation and well head pressures, and policies for best resource exploitation be established. This involves the participation of Engineers Specialists on Geothermal Preliminary Plans in addition to the Mechanical, Civil, Chemical and Electrical Engineers.

SCIENTIFIC SUPPORT:

As in geothermics exceptional cases are the common rule, it will be necessary to count on a group of high level specialists dedicated to the study and solving of the specific problems arising on each field. This group must include at least one Specialized Engineer on each of the following areas: Reservoirs, Thermodynamics, Corrosion, Geohydrology, Geochemistry, Geophysics, Drilling, Environmental Protection, Chemistry and Mechanics.

We are considering that the plant design and construction activities could be performed by the highly qualified personnel the Central Organization should have for the execution of a construction program.

All human resources mentioned until now are intended to continue receiving the support of companies dedicated to the research of subjects related to Geothermics and of those Institutions, National or International, involved as producing, coordinating or research and development entities.

Moreover, our experience seems to indicate that for Mexico it would be very enticing to manufacture, and to a certain degree design with its own technology, geothermal turbogenerators of small capacity to be used as important complement to the future geothermal development.

We will conclude saying the panorama we have presented over the geothermal development in Mexico is ambitious but realistic. To be able to carry out the proposed plan it will be necessary to carefully establish a program for the formation of qualified personnel which includes formal room instruction as well as practical field training.

PERSONNEL	EXPLORATION	DRILLING	PRODUCTION	TOTAL
GEOLOGIST	10	1		11
GEOPHYSICIST	8			8
GEOCHEMIST	5	1	3	9
PETROLEUM ENGINEER		10	2	12
RESERVOIR SPECIALIST	1	2	3	6
PETROLEUM SPECIALIST	5			5
ENVIRONMENTAL SPECIALIST		1		1
GEOHYDROLOGY SPECIALIST	5		2	7
WELL TERMINATION SPECIALIST.		2		2
WELL REPAIRING SPECIALIST			8	8
PRODUCTION SPECIALIST			12	12
MAINTENANCE SPECIALIST			12	12
INSTRUMENTATION ESPECIALIST			2	2
WELL LOGS SPECIALIST		10		10
TOTAL	34	27	44	105

REFERENCES.

(1) "SITUACION ACTUAL Y PROGRAMA FUTURO DE LOS APROVECHAMIENTOS GEOTERMICOS DE LA REPUBLICA MEXICANA". — ING. HECTOR ALONSO ESPINOSA, COMISION FEDERAL DE ELECTRICIDAD, COORDINADORA EJECUTIVA DE CERRO PRIETO.

(2) "DESARROLLO DEL MERCADO ELECTRICO (1977-1991)". — COMISION FEDERAL DE ELECTRICIDAD SUBDIRECCION DE CONSTRUCCION.

(3) "ELECTRIC POWER DEVELOPMENT PLANS IN MEXICO". — ING. RAFAEL MOLINAR CESEÑA, COMISION FEDERAL DE ELECTRICIDAD, COORDINADORA EJECUTIVA DE CERRO PRIETO.

(4) "ASSESMENT OF GEOTHERMAL RESOURCES OF THE UNITED STATES 1978". — L. JP. MUFFLER AND MARIANNE GUFFANTI.

(5) "ESTADO DE LA GEOTERMIA EN MEXICO-RESERVAS Y ESTRATEGIAS DE DESARROLLO". — COMISION FEDERAL DE ELECTRICIDAD GERENCIA DE PROYECTOS GEOTERMOELECTRICOS.