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CCE/SC.5/GRIE/III/3  
October 1975

ORIGINAL: ENGLISH

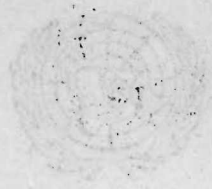
ECONOMIC COMMISSION FOR LATIN AMERICA  
ECONOMIC COOPERATION COMMITTEE  
OF THE CENTRAL AMERICAN ISTHMUS  
SUB-COMMITTEE ON ELECTRICAL POWER  
AND WATER RESOURCES  
Regional Group on Electrical Interconnection

REVIEW OF PROGRAMME FOR GEOTHERMAL ELECTRIC POWER  
DEVELOPMENT IN THE CENTRAL AMERICAN ISTHMUS,  
1975-1985

Report prepared by Mr. James Healy, Consultant to Project RLA/74/083,  
Electrical Power Interconnection in Central America.

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ORIGINAL: ENGLISH  
1973-1982

Regional Group on Biological Interconnection  
and Water Resources  
of the Central American Isthmus  
Biological Interconnection for Latin America  
Regional Commission for Latin America

DEVELOPMENT IN THE CENTRAL AMERICAN Isthmus  
1973-1982

Biological Interconnection for Latin America  
Regional Commission for Latin America  
1973-1982

## CONTENTS

	<u>Page</u>
Foreword	1
1. Introduction	2
2. Interconnection study - Programme of Plant Additions	2
a) Development of geothermal energy	2
b) Development in the Central American Isthmus	6
i) Guatemala	6
ii) El Salvador	6
iii) Nicaragua	7
iv) Costa Rica	8
v) Panama	8
vi) Honduras	9
3. Summary of conclusions and recommendations	9

CONTENTS

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20

Introduction

1. Inter-American Study - Treatment of Human Relations

2. Development of Inter-American Relations

3. Development in the Central American Region

4. Guatemala

5. El Salvador

6. Nicaragua

7. Costa Rica

8. Panama

9. Honduras

10. Summary of Conclusions and Recommendations

FOREWORD

The Economic Commission for Latin America, Mexico City Office, is carrying out a study on electrical power interconnection feasibility in the Central American Isthmus. The United Nations Development Program and the Central American Bank for Economic Integration, are providing financial assistance to this study. (RLA/74/083).

As part of the basic investigation required for the study, it was decided to review each national programme for generating plant addition, including hydropower and thermoelectric sources.

This report describes the review pertaining to the programme for geothermal power development. It has been prepared by Mr. James Healy from the New Zealand Geological Survey, who was recruited as Consultant for the Central American project.

1. Interconnection study - Programme of Plant Addition

Development of geothermal energy

In any country geothermal energy development is preceded by reconnaissance of the known hydrothermal occurrences and assessment of potential, on the basis of surface indications of relative potential combined with other factors such as location of demand, proximity of transmission lines, ease of access, etc. Preliminary reconnaissance has to varying extent, been carried out in the Central American countries and is not further discussed in this section.

In a field selected for development, this proceeds in stages which for logistic purposes can be summarized as follows:

1. Scientific exploration	1 - 1.5	years
2. Exploratory drilling	1 - 1.5	years
3. Preliminary assessment	3	months
4. Production drilling	1	year
5. Feasibility survey	3 - 6	months
6. Plant construction and installation	2 - 3	years
	6 - 11.5	years

1. Introduction

## 1. Introduction

Following arrival in Mexico City on 18 September 1975 and discussions with several ECLA Officials, it was decided that The Consultant should travel to Central America for consultation with the appropriate agencies to obtain the necessary information to:

- i) Review the proposed times for development of geothermal power stations in relation to the interconnection programme, and
- ii) Assist in the preparation of a preliminary proposal for a regional study of geothermal resources in Central America.

In company with Mr. Ricardo Arosemena, Head of the Energy and Natural Resources Section, The Consultant left Mexico on 21 September and visited Costa Rica, Panama, Nicaragua, El Salvador and Guatemala in that order, returning to Mexico on 1st October.

## 2. Interconnection study - Programme of Plant Additions

### a) Development of geothermal energy

In any country geothermal energy development is preceded by reconnaissance of the known hydrothermal occurrences and allotment of priorities, on the basis of surface indications of relative potential combined with other factors such as locations of demand, proximity of transmission lines, ease of access, etc. Preliminary reconnaissance has, to varying extent, been carried out in the Central American countries and is not further discussed in this section.

In a field selected for development, this proceeds in stages which for logistic purposes can be summarized as follows:

1. Scientific exploration	1 - 1.5	years
2. Exploratory drilling	1 - 1.5	years
3. Preliminary assessment	2	months
4. Production drilling	1	year
5. Feasibility survey	3 - 6	months
6. Plant construction and installation	2 1/2 - 3	years
<u>Total:</u>	<u>6 - 7 1/2</u>	<u>years</u>

/The stages

The stages may follow without break or may overlap to some extent, depending on local conditions, and apply to the period from commencement of exploration to the time the first power unit comes on line. Breaks normally occur at times of obtaining finance and equipment before drilling and plant installation, especially during the initial development in a country.

Scientific exploration includes geological, geochemical and geophysical surveys, hydrological studies, and any other surveys considered to be of value, e.g. remote sensing. Drilling of a few shallow holes is usually required to check geophysical interpretations and obtain water or steam samples for chemical analysis. The average time involved is about one year, but can be longer if terrain conditions are difficult and the field complex, or if there is delay in obtaining personnel and equipment. It includes preparation and integration of reports, on which the following stage is based.

Exploratory drilling is planned to test steam production, extent of the field, and conditions in it generally. The number of holes should be at least three, sufficiently cored and spaced to establish the geological stratigraphy, and supplemented by others considered necessary. The depth of drilling is suggested by the preliminary survey, but may be modified by results. The holes are commonly 500-800 meters deep, drilled to a diameter of 4 inches by a slim-hole machine, but it is often found more economical to drill deeper and larger diameter holes of 8 inches diameter to 1 000 meters depth with a large machine, especially if steam is encountered. Drilling is accompanied and followed by downhole studies of cores, temperature, pressure, and geochemistry of the water and steam. The stage occupies a nominal year, but will be longer in an extensive field or, for example, in a hot water field of low permeability.

Preliminary assessment includes preparation of reports based on the results of drilling and of steam production tests, and recommendations of sites for production wells. Environmental problems are identified, such as ground subsidence and effluent disposal, and attention is given to hydrological conditions which influence reinjection proposals. The production drilling programme is planned, and the size of wells and

/machine decided,

machine decided, if this has not already been done. Casing specifications are prepared, and the probable size of initial plant determined, so that the amount of steam required can be calculated. The time required is 2 months.

Production drilling occupies a period of one year for, say, a 30 MW plant. If conditions are optimum the time may be less, but longer if permeability and success rates are low. In a new field, wells are usually 8 or 9 5/8 inches in diameter and range from 500 to 1 500 meters in depth.

The feasibility survey stage includes also the final well tests and preparation of the final reports and environmental report. The economic factors are reviewed, and recommendations for plant development and any further work required are made. This stage can take 3 to 6 months.

Plant construction and installation includes ordering the plant, the design and construction of the power house and ancillary structures during the plant delivery period, transport to site, and installation and testing of the plant. Delivery time can range from 15 to 20 months. Environmental requirements such as disposal of effluent are also dealt with during this stage. The total time is 2.5 to 3 years.

The above drilling times apply to the use of a single machine during each stage and could be reduced if more were used. However, all times do not include delays normally experienced in arrival of personnel, equipment and plant, in approval of reports and obtaining finance, or due to mechanical failures during drilling. A reasonable minimum total time for all stages, is in practice, 7 years in a new field. For the development of additional units stages 1-3 are not required, and if the steam has been obtained from wells drilled during the above construction and installation stage for the first unit, ordering of plant can be advanced and the time reduced to 2 years. However, if insufficient exploratory drilling was done initially, more may be required before production drilling continues.

In cases like El Salvador and Nicaragua, where a third unit is to be installed to use low pressure steam flashed from the water discharged from the first two units, the final effluent is discharged under atmospheric

/conditions, and



conditions, and in reinjected cannot be at temperatures above 100°C and must be reinjected away from the field. Also, before designing a plant to use the low pressure steam it is desirable to study the operations of the higher pressure units for a reasonable time period. This has been the experience in Mexico and New Zealand. It is required to give careful consideration to the economic factors involved.

Additional development is often based on preliminary estimates of field potential, by one of three methods. The simplest one is based on measurement of the natural heat discharge from a field; this gives a minimum value which is always exceeded. The second method is based on data obtained from the preliminary investigation and drilling, which permit volumetric calculation of the field reservoir and its heat content, from which a rate and quantity of heat extraction are calculated. The resource is considered as stored heat in the hot rock and water. The third method is based on reservoir mechanics in the same manner applied to oilfields, using the discharge characteristics of a number of wells.

This last method has been applied with reasonable success to the steam reservoir of the Geysers field in California, where an output of 510 MW has been progressively developed from an extensive zone of homogeneous rocks. The first and second methods were initially applied to the hot water field of Wairakei in New Zealand, which of its type has been in production for the longest period. It is now known that the production there is almost entirely from recharge by hot water rather than from extraction of heat from the portion of the reservoir intersected by the wells. Behaviour of a field in production is an important factor in estimating potential, which cannot at present be estimated in advance with certainty.

Estimation of geothermal field potential will in time become more refined, and the potential is likely to be increased by artificial stimulation and reinjection, neither of which has as yet been developed as standard procedure, though stimulation has been successfully developed in Iceland. However, the above considerations need to be applied in planning progressive development in geothermal fields.

/b) Development

**b) Development in the Central American Isthmus**

To review the programmes for development in the six countries each will be considered in relation to the stages of development outlined in the preceding section.

i) Guatemala. Progress to date is outlined in a feasibility study by INDE and Direccion General de Minería e Hidrocarburos, dated July 1975. This is a comprehensive report covering the investigations of stage 1, and provides for specifications for deep drilling and finalization of the drilling contract to be completed by November 1975, the first deep well to be commenced within the period March/June 1976, and the first unit of 30 MW to be installed by mid-1980. The exploratory and production drilling are to be combined and stages 2-6 allegedly completed in 4 years, which is nearly 2 years less than the average stated in the previous section.

The official date for the installation of the first unit in the development programme is 1981, which is more reasonable and would be possible if there is a high success ratio in drilling and no other delays. The second unit could, without delays, follow in 1983 but if the third one is a low pressure unit, it could be delayed beyond 1985, for reasons given earlier.

ii) El Salvador. The first unit of 30 MW is now generating power at Ahuachapan, but not to full capacity because --although part of the effluent is being reinjected-- the total balance can be discharged into Rio Paz only during the wet season. The channel to carry the entire effluent to the sea will not be completed until early 1977. Construction has commenced for the second unit of 30 MW, for which steam for approximately 20 MW is already available but not completely tested. Additional wells have been sited but, considering the poor success ratio of wells at Ahuachapan, drilling could take 6 to 9 months. However, this unit also cannot function successfully until the channel is completed in 1977, one year later than the official programme states.

The third unit of 30 MW will use low pressure steam flashed from the hot water discharged from the first two units. This steam will become totally available only when the channel to the sea is completed and all the hot water effluent can be discharged to the atmosphere. The date

of 1980 for the third unit seems satisfactory. Whether a fourth unit can be added at Ahuachapan in the future will depend on the behaviour of the field under production and on the drilling of additional test wells outside the production area. If pressures decline in the field, more wells might be required to maintain the level of production, or further steam might be obtained by stimulation of existing non-productive wells.

In the fields of Berlin, San Vicente and Chinameca, explorations covering stages 1 to 3 will start shortly and is to be completed by the end of 1977. Assuming that the results are successful in at least one field, the fourth unit planned for completion in 1982 can be developed. It is as yet too early to state its capacity with certainty, but 30 MW is assumed. Whether a fifth unit will be available in 1983 depends on its location. It seems unlikely, if it is located in the same field as the fourth, because any delays affecting the fourth would put that unit into 1983; so the fifth unit is put tentatively into 1984.

iii) Nicaragua. Drilling to date has been confined to the Momotombo field, where stages 1 to 3 have been completed with the drilling of three wells. One failed to produce, the second has a tested production capacity of 6 MW, and the third is also a producer but has not yet been tested. The first of four additional production wells is now being drilled. If these are successful, there is a proposal to install a 25 MW pilot station as soon as sufficient steam is obtained, but if they are not successful the drilling will shift to San Jacinto where stage 1 exploration has been completed.

The official programme is for the development of 135 MW from three plants of 45 MW each, to come on line by March 1979, June 1980 and October 1981, respectively. Assuming satisfactory drilling results, steam production and feasibility survey could be completed by the end of 1976, leaving 27 months for obtaining and installing plant and dealing with the problem of waste disposal. For a 45 MW plant the time required from ordering to coming on line is about 2 3/4 years, reducible by 3 months if already designed plants of 37.5 MW are ordered. The time could be reduced slightly if the feasibility on which the raising of finance is based was completed in advance of all the steam being obtained.

/The extent

The extent of the field and permeability within it have not been tested by exploratory wells, so a high success rate is not yet assured. As in El Salvador at Ahuachapan, Momotombo is a hot water field producing from saline water which presents a disposal problem. If the third plant is to use low pressure steam flashed from the separated water of the first two plants, then the final effluent must be disposed off under atmospheric conditions of pressure and temperature, either in injection wells outside the field, in the lake, or in the sea. No consideration has yet been given to drilling and testing of injection wells, and the possible times stated above do not include reinjection development.

Assuming that the effluent is discharged into Lake Nicaragua, and that drilling is successful, the first unit is possible only in late 1979 or 3 months earlier if the size is reduced to 37.5 MW. Assuming that drilling continues after steam for the first plant is obtained, and construction of the second plant follows the first immediately, it could be ready in early 1981. The low-pressure third plant requires study of the operations of the first two before it is ordered. It is suggested 1984 for its completion.

iv) Costa Rica. The official programme for Costa Rica is for 30 MW plants to be completed in 1983, 1985 and 1986 but to increase the spacing, the first plant completion has been tentatively moved forward to 1981. In the Guanacaste district the scientific exploration of stage 1 is about 50 per cent completed and will be finished by the end of 1976 in the fields of Las Pailas and Las Hornillas. This leaves 5 years for the remaining stages, which is possible if there are no delays involving equipment, plant and finance; however, it is suggested that 1982 is a more suitable date for completion of the first unit. The planned date of 1985 for second unit is satisfactory, and could possibly be advanced to 1984.

v) Panama. There is no official programme for the production of electric power from geothermal steam in Panama before 1985. In the Cerro Pando field in western Panama the scientific investigation is about 30 per cent completed (Mr. W. A. J. Mahon, personal communication). If this were completed by the end of 1976, installation of a first unit could be possible by the end of 1982 or early 1983, in which case a second unit could be developed by 1985.

/vi) Honduras

vi) Honduras. Honduras similarly has no plan for power from geothermal steam by 1985. There appears to be no information as yet on the nature of the geothermal manifestations in Honduras. The proposed regional survey of resources should clarify the position there.

### 3. Summary of conclusions and recommendations

The stages in the average period of 7 years in the development of a geothermal from the start of investigation to the production are discussed and used as a basis for recommending dates for installation of geothermal power plants in Central America to the year 1985. By that time the estimated total output could reach 465 MW. The recommended development is summarized in the accompanying table.

While the timing is based on the present activities and on experience in other countries under similar conditions, delays have been minimized because account has been taken of the urgency being exhibited by various governments in geothermal developments following the increases in the price of oil. It is obvious that the Central American Isthmus, with its growing demand for energy, possesses appreciable geothermal resources and that it is economically desirable that they be developed as soon as possible.

The electrical interconnection programme will enable immediately and better advantage to be taken of installation of geothermal power plants. The planning of geothermal development will receive necessary aid from the proposed regional energy resources survey which is being formulated at the present.



