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Geothermal Energy Could Enable Central America to Eliminate Petroleum Imports for Power Generation by 1980

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ABSTRACT

Central America has large reserves of geothermal energy and hydropower, but has to import all fossil fuels. Sixty-three percent of the demand for electric energy in 1973 was supplied by hydropower.

Since 1963 the United Nations assisted the governments in geothermal development; and they completed one exploration project in El Salvador in 1971 and started another one in Nicaragua where technical assistance is still being provided.

The quadrupling of petroleum prices in 1973 to 1974 had a disastrous impact on the economy of the region. A United Nations Development Programme fact-finding mission in 1974 concluded that Central America could become independent of petroleum imports for power generation in 1980 by stepping up geothermal developments, since these require shorter lead times than new hydroelectric projects. The mission recommended acceleration of interconnections between the national power systems as well as of hydro projects already planned for this period.

El Salvador will complete its first 30-MW geothermal power station early in 1975, followed by 2 × 30 MW completed in 1977, at which time the country will need no more petroleum for electric power.

Nicaragua has reorganized the geothermal project and started deep drilling. Guatemala will expand geothermal exploration from early 1975. It is expected that these two countries can eliminate petroleum imports for electric power in 1980. Costa Rica and Panama are considering geothermal exploration.

Preliminary studies of nonpower applications of geothermal energy for district air conditioning and refrigeration and/or heating in processing of agricultural products and in other industries are in progress.

A possible obstacle to rapid development of geothermal energy in Central America lies in the shortages here as elsewhere of trained experts in the countries considered separately. This obstacle could probably be overcome by a regional approach to the problems, in which the several countries and the UN could cooperate.

INTRODUCTION

The United Nations Conferrence on New Sources of Energy in 1961 was a milestone in the development of geothermal energy. The conference made it clear that geothermal energy was a proven natural resource which had been exploited successfully for a convincingly long time by a number of countries, albeit few. Its strong economic competiveness as compared to other energy sources was demonstrated, and the prolific literature published at the conference demonstrated that the geothermal resources are more widespread over the world than most people had realized up to that time.

It was concluded that geothermal energy would be of special interest and importance for developing countries in possession of the resource. In the years following the conference, a number of fact-finding missions were organized by the United Nations to a number of countries at the request of their respective governments in order to evaluate geothermal prospects. This led to the organization of three Technical Assistance Projects in El Salvador, Turkey, and Chile for the purpose of carrying out preinvestment exploration and feasibility studies of geothermal resources.

The projects were managed by the United Nations in cooperation with the governments who provided local support. The United Nations provided foreign experts, specialized equipment, and training opportunities for local personnel. The first projects, in El Salvador and Turkey, became operational in 1966. Later similar projects were organized in Ethiopia, Kenya, and Nicaragua.

The El Salvador project was completed successfully in 1971, and the government decided immediately to construct a 30-MW geothermal power station which will be commissioned in April or May, 1975.

The neighboring countries in Central America, all of which have geothermal resources, have followed the development in El Salvador with interest; and Nicaragua, which started geothermal exploration with support of the U.S. in 1969, requested a United Nations Technical Assistance project with financial support from the United Nations Development Programme (UNDP) which was started in 1972. This project, however, had to be curtailed as a consequence of the disastrous earthquake in Managua in December 1972, and the limited work program was completed a year later. Guatemala has been carrying out geothermal prospecting with a national staff since 1971, and with limited bilateral assistance from Japan.

In the meantime the general energy crisis in the world, and particularly the petroleum crisis which started in late 1973, has completely changed the picture. All the Central American countries with the exception of Costa Rica are

dependent on oil imports for roughly 50% of the electric power. The quadrupling of the oil prices has been economically disastrous for those countries.

A joint mission of the UNDP, the Economic Commission for Latin America (CEPAL), and the Secretariat for Economic Integration of Central America (SIECA) visted the area in early 1974 in order to study the impact of the petroleum crisis in the region. Among other measures, this mission recommended to the governments that they concentrate their efforts on developing geothermal resources, since geothermal energy could be harnessed in shorter time than most hydropower resources.

El Salvador has decided to construct two additional 30-MW geothermal power stations before the end of 1977, in which year the country is expected to become independent of fuel-oil imports for electric power. The initative of the government of El Salvador in starting geothermal exploration at an early date, and the technical assistance of the United Nations in this connection, are thus becoming more beneficial to the country than was anticipated, due to the petroleum crisis.

This situation and the results in El Salvador have had a great impact on the neighboring countries. Nicaragua reorganized the geothermal exploration in 1974 and is currently carrying out exploration drilling. Guatemala is reorganizing and stepping up the exploration activity, and both Costa Rica and Panama have started geothermal reconnaissance on their own.

Much experience has been gathered under the UN Technical Assistance program in Central America which may be of value in other developing countries. The purpose of this paper is to describe the background of this work, the potential role of geothermal energy in the region, and to discuss certain problems that have arisen and their solution.

The views set forth in the paper are those of the author based on his more than five years' experience, and have not been cleared with the United Nations or other organizations concerned with the development work.

BACKGROUND

Some Geographic Data

The five Central American republics and Panama are located on the isthmus connecting the North and South American continents. The total area is approximately 507 000 km^2 and the population is about 16 million. The population growth rate is quite high, and was 3.1% during the period 1950 to 1970.

The climate is tropical and the economy is principally agricultural, but considerable industrialization is taking place, utilizing the markets within the economic community of the five Central American Republics, El Salvadór, Guatemala, Honduras, Nicaragua, and Costa Rica.

Geologically the northern part of the isthmus is considered an extension of the North American continent, while the southern part is linked through Panama to the South American Continent (Dengo, 1973). A belt of volcanoes of Quaternary age, many of which are active, runs largely parallel to the Pacific Coast from Mexico into Panama, and extends generally less than 100 km inland. Geothermal surface activity is found in numerous places within this volcanic zone.

Apart from lignite deposits in Honduras and indication of petroleum possibilities in nothern Guatemala, no commercial fossil-fuel deposits are as yet known in the area.

The isthmus has, however, significant hydropower potential which has been estimated to amount to 17 800 MW (Montaño, 1973), but only a small fraction has been developed as yet. Some of the principal hydropower sites are on the Atlantic side of the isthmus, whereas the main demand for electric power is on the Pacific side.

The national power systems are relatively small (150 to 330 MW) and have not been interconnected yet. The hydrological conditions are adverse because of highly seasonal rainfall (dry season 6 mo/yr). These factors have hitherto hampered large-scale exploitation of hydropower within the area, except in Costa Rica.

Demand for Energy in Central America

Tables 1 to 3 show statistical data on the use of various sources of primary energy in different sectors of consumption for the entire isthmus from 1950 to 1970 (Montaño, 1973). The figures given represent 1000 tons petroleum equivalent (for electricity 1 kWh is set equivalent to 330 g oil; that is, 1 kWh is equivalent to 3500 kcal).

Table 1 shows quite rapid growth of the demand in all sectors of consumption, especially the demand for electricity. Table 2 shows that the domestic sector leans heavily on firewood and charcoal, which are indigenous fuels, but the use of imported hydrocarbons is growing quite rapidly. The industrial sector is a large consumer of petroleum (Table 3), but the sugar industry uses bagasse extensively as fuel. The consumption of electric energy per capita is still very low, as shown in Table 4 for 1970.

Energy Supply

The discussion of the energy supply in this paper will be limited to those sectors of consumption where geothermal energy could play a role, that is, the electricity sector and the industrial sector.

Electric energy. Tables 5 and 6 show the installed generating plant and estimated generation of electric energy respectively in the various Central American countries for the year 1974. The following significant facts can be read from the tables:

1. Hydropower can supply up to 52% of the maximum power demand for the area as a whole, and about 67% of the demand for energy. The balance has to be supplied by thermal power. Three of the countries—El Salvador, Guatemala and Nicaragua—depend on imported oil for more than 50% of the power and energy demand.
2. The national systems are relatively small and vary

Table 1. Utilization of prime energy in various sectors of consumption, 1950–1970 (Montaño, 1973).

	1950	1960	1965	1970
	(Tons petroleum equivalent)			
Electricity	194	493	802	1284
Domestic use	1322	1788	2098	2545
Industrial use	473	835	1140	1672
Transportation	221	657	776	1027
Total	2210	3773	4822	6528

Table 2. Utilization of primary energy for domestic use, 1950 to 1970 (Montaño, 1973).

Year	Total	Firewood and charcoal	Kerosene	Liquefied gas
		(Tons petroleum equivalent)		
1950	1322	1283	39	—
1960	1788	1644	137	7
1965	2098	1868	202	28
1970	2545	2148	325	72

Table 3. Utilization of primary energy for industrial purposes, 1950 to 1970 (Montaño, 1973).

Year	Total	Sugar cane bagasse	Use in refineries and losses	Bunker oil	Diesel oil	Bunker and diesel oil in thermo-electric plants
			(Tons petroleum equivalent)			
1950	473	142	6	333	92	100
1960	835	271	18	493	286	233
1965	1128	377	102	585	461	397
1970	1633	525	155	864	657	568

Table 4. Consumption of electric energy per capita per year, 1970 (based on data by Montaño, 1973).

Country	kWh
El Salvador	190
Guatemala	130
Honduras	115
Nicaragua	260
Costa Rica	535
Panama	325
The Central American Isthmus	215

Table 5. Installed electric generating plant in megawatts, 1974 (UNDP/CEPAL/SIECA Mission, 1974, and other sources).

Country	Total	Hydro-electric	Steam turbines	Gas turbines and diesel
El Salvador	225	97	63	65
Guatemala	197	88	63	46
Honduras	144	70	—	74
Nicaragua	200	100	75	25
Costa Rica	330	225	10	95
Total	1096	580	211	305

Table 6. Estimated generation of electric energy (GWh), 1974 (UNPD/CEPAL/SIECA Mission and other sources).

Country	Total	Hydro	Thermal
El Salvador	886	450	436
Guatemala	850	295	555
Honduras	448	408	40
Nicaragua	772	395	377
Costa Rica	1330	1270	60
Total	4286	2818	1468

between 144 and 330 MW. Even if the annual increase in demand is quite high (10 to 13% p.a.), the individual systems need only 15 to 40 MW/yr in order to meet the growth.

The petroleum prices quoted for the various countries are different—in the range of 11 to 13 $/barrel (U.S.) for Bunker C, and 13 to 17 $/barrel for diesel oil in 1974. It may be assumed that the total imports of petroleum for electricity generation have amounted to $45 to 50 million in 1974, and that more than 90% of this has been paid by the three countries that are most dependent on oil imports. This gives some idea about the impact of the petroleum crisis which has led to quadrupling of oil prices.

Other energy requirements. Increased supply of cheap electricity would no doubt replace the use of hydrocarbons in the sector of domestic consumption (Table 2). Geothermal energy could play an important role in this. As regards other uses, especially industrial ones, the picture is not so clear due to the lack of data. There are, however, multiple uses of heat in industry presently supplied by hydrocarbons, for which direct use of geothermal heat could be substituted. In the sugar industry, which is a large heat consumer (Table 3), direct geothermal heat could replace the use of bagasse as fuel and release this raw material for cellulose production or other industries.

GEOTHERMAL ENERGY IN CENTRAL AMERICA

Development and Prospects for Electric Power

In the following notes the available knowledge on geothermal prospects in Central America, as well as the development status, will be summed up country by country.

El Salvador. The UNDP-supported Survey of Geothermal Resources in El Salvador, which was executed jointly by the United Nations and the Commisión Ejecutiva Hidroeléctrica del Río Lempa (CEL), the government electricity company, in 1966 to 1971, identified 18 separate geothermal areas, 9 of which appear to be potential high-temperature steam fields. The country has thus a great geothermal potential.

The Ahuachapán field in western El Salvador was selected for development, exploration drilling was carried out, and a feasibility study for a 30-MW power station was made under the survey project. This showed that geothermal power could supply lower-cost energy than either hydropower or thermal power, at the favorable oil prices prevailing at that time (Survey of Geothermal Resources, El Salvador, 1972).

The government decided in 1971 to build a 30-MW geothermal power station which will be put into use in April or May, 1975.

After the onset of the petroleum crisis, the construction program was stepped up, and two other 30-MW units will be commissioned in 1976 and 1977 respectively, bringing the initial development of the Ahuachapán field to 90 MW. The total investment in these plants is estimated to be $40 000 000 (U.S.).

A large hydroelectric plant is being constructed at the same time and will be commissioned in 1977. After that, the country will be independent of oil imports for electricity production.

El Salvador is already exploring a second geothermal field, northwest of Ahuachapán, for future exploitation.

Guatemala. Systematic mapping of geothermal manifestations in Guatemala was taken up in 1971 by Dirección General de Minería e Hidrocarburos (DGMH), which has identified 11 geothermal areas which appear to be potential steam fields (Randmets, private commun., 1974). The Instituto Nacional de Electrificación (INDE), in cooperation with DGMH, has been carrying out detailed investigations of the Moyuta steam field; and another steam field, Zunil, has been studied by Japanese experts.

Guatemala depends on thermal power for 65% of its electricity supply (Table 6) and will be increasingly dependent on imports of oil or electric power during the next years. With this in view, the Guatemalan government is reorganizing and accelerating geothermal developments, with the target of having its first geothermal units operational in 1980 and the following years. No major new hydropower station can be ready until a few years later.

Honduras. No systematic survey of geothermal manifestations has been carried out in Honduras as yet. It is known, however, that a considerable number of thermal springs exist, particularly in the extreme southern and western parts of the country. The development plans for Honduras appear to concentrate on hydropower for the next years since the hydropower resources of the country are very large.

Nicaragua. A survey supported by U.S. AID and carried out by an American company from 1969 to 1971 mapped 10 geothermal areas in Nicaragua and recommended further exploration of two fields, South Momotombo and San Jacinto.

A UNDP-supported exploration project was established in 1972 with the United Nations as executing agency. This project was completed in 1973 after being curtailed as a consequence of the Managua earthquake. It confirmed, however, that both South Momotombo and San Jacinto were commercial prospects that should be drilled, and it discovered very large low-resistivity anomalies west of both fields. (United Nations Development Programme, 1974).

Nicaragua depends on thermal power for about 50% of its generated electricity and this will increase over the next several years. After onset of the petroleum crisis, the Nicaraguan government's power company, Empresa Nacional de Luz y Fuerza (ENALUF), decided to resume its geothermal investigations. Under a new project, financed by commercial bank loans, exploratory drilling for feasibility studies was started in late 1974, under the supervision of an Italian consulting engineering company, at South Momotombo.

If the results are satisfactory, the first geothermal power stations in Nicaragua might be commissioned in 1979 and the next few years. No major new hydropower station could be built before that time, even though Nicaragua is in possession of significant hydropower potential.

Costa Rica. A mission of United Nations experts to Costa Rica in 1963 identified two geothermal steam fields, Las Pailas and Las Hornillas de Miravalles, in the northern part of the country besides geothermal manifestations in other areas. This was not followed up by detailed exploration at the time.

Costa Rica has concentrated on exploiting its hydropower resources which are very large, and it is in many ways ahead of the other countries in the area as regards electrification (Tables 4 to 6).

The government electricity company, Instituto Costarricense de Electricidad (ICE), is now organizing geothermal exploration, spurred by the petroleum crisis and a critical situation for the hydroplants due to serious drought in 1972 and 1973.

Major new hydroelectric plants will come on line in Costa Rica within the next five years.

Panama. There are geothermal resources in western Panama near the Costa Rican border. The Government has recently initiated preliminary reconnaissance of these resources with a view to development for electric power.

Competitiveness of Geothermal Power

The capital costs of geothermal power have increased substantially during the last two years, partly as a direct and indirect consequence of the energy crisis. Even so, the cost of new geothermal plants on wet steam fields should not exceed $450 to $500/kW installed, including exploration, drilling, water disposal, the generating plant, cooling tower, transformers, and switching gear. With 10% interest, depreciation in 25 years, and 85% annual load factor, this corresponds to an energy cost of 8 to 9 U.S. mills/kWh.

The capital costs of hydroprojects under study in the area vary between $470 to $790/kW installed. At 10% interest, depreciation in 50 years, and 60% annual load factor, the corresponding energy costs would be 11 to U.S. mills/kWh.

The capital cost of a 50- to 60-MW steam-turbine thermal plant is of the order of $350/kW installed. With 10% interest, depreciation in 25 years, annual load factor of 50%, and fuel oil price of $11/bbl, the energy cost would be about 28 U.S. mills/kWh; whereof the cost of the fuel would be about 17 mills/kWh. The competitive position of geothermal power is thus very strong in comparison with alternate sources of energy.

Joint UNDP/CEPAL/SIECA Mission in 1974

The United Nations Development Programme (UNDP), in cooperation with the Economic Commission for Latin America (CEPAL) and the Secretariat for Economic Integration of Central America (SIECA), sent a mission of technicians to the region in the beginning of 1974, a few months after the onset of the petroleum crisis. The purpose of the mission was to study the impact of the crisis on the economics of the Central American countries and to prepare a plan of action as regards countermeasures.

Contrary to what was the case in some other countries, the supply of sufficient petroleum products was not a problem in Central America. The main problem was the effect of the price increases on the balance of payments, which was estimated to increase the deficit from about 33 million dollars in 1973 to about 400 million dollars in 1974.

The mission prepared a plan of action recommending various measures aimed at (1) rationalization of the petroleum supply and consumption, and (2) substitution of hydrocarbons in the domestic, industrial, agricultural, and transport sectors by electricity derived from indigenous sources, by a system of interconnections between the various national

Table 7. Forecast of total electricity demand and supply (GWh) in Central America (Joint UNDP/CEPAL/SIECA Mission, 1974).

Year	Total demand	Hydro-supply	Geothermal supply	Thermal supply
1974	4 325	3 148	—	1 177
1975	4 912	3 188	210	1 514
1976	5 520	3 272	540	1 708
1977	6 194	4 032	930	1 232
1978	6 848	5 166	1 130	552
1979	7 578	5 166	1 630	782
1980	8 384	5 416	2 130	838
1981	9 205	7 277	2 630	−702
1982	10 135	9 442	3 440	−2 747
1983	11 181	9 660	4 150	−2 629
1984	12 305	10 960	4 860	−3 515

Note: The negative sign under thermal supply means surplus of hydro and geothermal power over total demand.

power systems, and by accelerated development of hydropower and particularily of geothermal power (Misión Conjunta UNDP/CEPAL/SIECA, 1974).

Table 7, which is taken from the mission's report, gives a forecast of the total electricity demand and supply in Central America for the decade 1974 to 1984, assuming that the development schedules at the time will be adhered to. According to this there should be a surplus of hydro and geothermal power in the area from 1981 on. By 1980 geothermal power would be supplying 25% of the total, increasing to 39% in 1984. Central America should therefore become independent of petroleum imports for electric power generation after 1980.

NONPOWER USES OF GEOTHERMAL ENERGY

The predominant interest in utilizing geothermal energy for electric power has somewhat obscured the many and varied potential nonpower applications, where the heat can be used directly and with great economic advantage (Einarsson, 1970, 1973).

Geothermal energy can generally be used in applications where a temperature level of 150°C or lower is called for. There are multitudes of such requirements in various industries, especially the food industries and various agro-industrial processing, where fuel-fired boilers are generally used for supplying the heat.

The joint UNDP/CEPAL/SIECA mission recommended that such opportunities be studied. The problems involved are primarily associated with economics of the transport and distribution of the heat. The cost of the heat delivered to the customer depends on the transportation distance, the temperature of the heat carrier (water), and the size of the market (Einarsson, 1975).

A large industrial user of heat such as a sugar factory or a pulp and paper factory may suffice in order to form an economic basis for transporting the heat over tens of kilometers. In the case of smaller users, they would have to be concentrated in industrial parks or groups of sufficient size, or in the vicinity of a large user.

The Central American countries may have tremendous unused potential in this respect. The following opportunities could be pointed out as examples.

There is currently a shortage of pulp and paper in the world. FAO is reported to have estimated that some 50 000 000 m^3 of pulpwood will be needed to meet the expected pulp and paper deficit in the world in 1978. Processing this quantity would require 25 million barrels of oil equivalent. Central America has an ideal climate for fast-growing species of trees, and the geothermal fields could supply the heat for processing. Geothermal heat has been used successfully for years in a large-scale pulp and paper factory in New Zealand (Smith, 1970).

Another field is the sugar industry. Sugar cane is one of the most important crops in Central America. The production of 1 ton of sugar requires about 9 tons of sugar cane. For processing this, about 0.50 metric tons or 3.5 barrels of petroleum are used. The present practice is to use bagasse as fuel for supplying the heat. If geothermal energy were used for heating, the bagasse could be released as raw material for cellulose or other valuable products.

A number of other applications in the food industries could be mentioned, for instance, refrigeration.

CONCLUDING REMARKS

The technical assistance rendered by the United Nations in order to develop the geothermal resources of Central America has turned out to be quite fruitful, as can be seen by the foregoing. The petroleum crisis has given this work extraordinary significance and accelerated the activities; but it is the opinion of the author that comparable developments would have taken place anyway, albeit at a slower and more manageable pace.

Possible Obstacles

There may still be a few lions on the road ahead. The shortage of experienced personnel in geothermal exploration has been a limiting factor in the past, but it is likely to be even more severe in the present and near future. The United Nations, thanks to friendly cooperation of member states, has been able to recruit experts on a world-wide basis and to make them available to the developing countries. Now many of these experts are tied up in their home countries, due to expanded geothermal development everywhere because of the energy crisis. However, recruitment of competent experts for medium- or short-term service is still considered possible.

An important phase of the technical assistance has been the training of national professionals, both on the job under the United Nations projects and under fellowships abroad. In this way a number of experts have been left behind who can continue the work with a minimum of outside assistance. This is an essential requirement for any country which embarks on exploitation of geothermal energy.

There are a great number of service companies which are offering their services on a commercial basis. Many of them specialized in relatively narrow fields. However, there are very few, if any, service companies that have previous experience in handling a complete geothermal exploration and development project, and that have sufficiently varied geothermal expertise on their own staff.

The work involved in preparing a feasibility study for a geothermal power project is entirely different from that for a hydroproject or a thermal project. While the latter can be handled efficiently by a multitude of consulting engineering firms, this is not yet the case with the geothermal projects because of the exploration aspects, which in fact extend, as regards production drilling, into the investment phase of the project. It is hoped, however, that in the not

too distant future, consulting or service companies will develop that can handle this work also. In the meantime, the United Nations, in view of their wide and varied experience in geothermal development and international recruitment, can perform very important assistance to the developing nations.

In the case of Central America, intensive geothermal developments are planned for the next years in five countries as reported before. Keeping in mind that each megawatt of geothermal power can save imports of fuel oil worth 120 000 dollars (U.S.) per year at present prices, the urgency of carrying out the plans in the shortest time possible is obvious. Here the availability of competent manpower is likely to be the controlling factor.

Regional Approach Desirable

Taking advantage of the fact that the countries in question are located in a small geographical area with relatively good communications, a regional approach to this problem might be quite efficient.

A regional office organized by the United Nations, headed by a coordinator and staffed with a pool of international experts, could provide the expert services needed by the various national projects participating in planning, supervision, interpretation of data, and so on.

The United Nations, depending on the wishes of the governments, could provide full managerial services for national projects which would then be directed by a UN project manager in the country, as in the case of previous technical assistance projects. The project activities would be subcontracted to the greatest possible extent to service companies, and the subcontracts would be awarded and supervised by the United Nations.

Main emphasis would be put on training of national professionals, and full advantage would be taken of the training facilities existing in the area, for instance in El Salvador, on the job, and possibly by exchange of professionals between the participating countries.

Such an arrangement is likely to offer the following benefits:

1. It would save manpower and make more efficient use of the limited international expertise available.
2. It would make the extensive experience of the United Nations in geothermal development available to the countries and would provide efficient management.
3. It would take full advantage of the capability of the service companies under subcontracts, and give them an opportunity of gathering experience.
4. It would create competent national staff for managing the exploitation of the geothermal resources and developing new fields.

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