S 11 52

Distr.
LIMITED

E/CN.14/NRD/E/32
20 October 1980

ORIGINAL : ENGLISH

UNITED NATIONS
ECONOMIC AND SOCIAL COUNCIL

ECONOMIC COMMISSION FOR AFRICA

Technical Group of Experts on
(Geothermal Energy)

Addis Ababa, 20-25 October 1980

ISSUE PAPER ON GEOTHERMAL ENERGY IN AFRICA

15 October 1980

SUMMARY

I. Introduction

1. After a long period of lagging interest, geothermal energy has caught the attention of many countries as a viable source of energy not only for power generation but also for multipurpose utilisation such as agricultural, mining, and social projects.

2. At present the USA is the leader in geothermal energy utilisation for power production, with 668 MW on stream and some 1000 MW under construction or planning. Italy the first country to harness geothermal energy for power production (1906) has about 420 MW on stream. New Zealand, Mexico and Japan follow, with individual plants of aggregated capacity of less than 200 MW in each country. If one combines the current plans for utilization of geothermal energy with the already existing installed capacity, it will result that the total installed capacity around the year 2000 will amount to several tens of thousands of megawatts. These estimates would have been further expanded if the Hot Dry Rock technology, currently in an experimental phase, should prove to be economically viable.

As far as Africa is concerned, it has only 220 kw of installed capacity at this stage, which is insignificant when compared to the existing potential of the continent.

3. Geothermal energy is a result of a series of geological and geophysical factors such as heat flow and reservoirs (geothermal gradient and permeability) associated in some cases with convection flow of geothermal fluids along faults in technology affected areas.

The heat flow is of course thousand times lower than solar radiation but still it amounts to about 80 KW per square kilometre in normal areas and to some 1000 kw/km^2 in anomarlous (volcanic) areas.

The reservoir, i.e. the presence of porous and permeable rocks in the earth crust, has its role in the free circulation of fluids when reached by drilling.or.in allowing fluids to circulate and reach the source of heat, usually batholitic or smaller, volcanic masses.

........2/

Any geothermal field, whether of high or low enthalpy, requires the presence of the above mentioned two factors which control the occurence of conductive geothermal fields. Another type of geothermal field results from convection flow of geothermal fluids along the faults, allowing production by a process of therm-syphon, of important quantities water steam or water/steam mixture at the surface as hot springs, fumarolas, geisers, etc..

4. The geothermal energy associated with the natural geothermal gradient, i.e. the relationship between the temperature rise towards the earth's interior and the actual depth through the earth's crust (there is a temperature of some 3°C per 100 m depth), can also be utilized by means of very deep bareholes.

In anomalous areas, most of them volcanic, the geothermal gradient is markedly above average and may be as much as to 8 to 10°C per 100 m consequently, zones where water is trapped in rocks at a very high temperature (of several hundred degree) exist at very easy drilling depths, the borehole causes a very rapid decompression of the water, which issues at the surface.

II. Types of geothermal resources

5. If we look at the presently known types of geothermal resources and attempt to classify them by the number of possible resource components for multipurpose utilization, the following order of significance obtains: (1) wet-steam fields (2) geopressure fields, (3) dry-steam fields, (4) low-temperature fields, and (5) hot dry rock areas. In the first four types, all well known, nature provides us with both the heat and the heat carrier (steam or water); in hot dry rock areas, however, we have only a heat source if, indeed we should find large and economically attractive hot dry rocks areas.

.......3/

....

6. Wet steam fields and geopressure fields are multicomponent geothermal resources and are both frequent in nature. Wet steam fields are shallower and cheaper to develop and as a rule have higher heat flows than geopressure fields. A geopressure field, as it requires far deeper drilling and higher development costs, appears today to require a multipurpose utilization, as a single-purpose utilization would probably be too expensive.

Dry steam fields have so far been developed only for the generation of electricity, though the steam could be used partly for steam and partly for other purposes or totally for other purposes providing a higher return.

Low temperature fields are used almost exclusively for heating; and hot dry rock areas, if they can be developed successfully, are conceptually designed only to produce steam.

7. When taking into consideration the temperature level of geothermal sources, one may distinguish three types of geothermal systems:

- low enthalpy systems (below 150°C)
- medium enthalpy systems (from 70° to 150°C)
- high enthalpy systems (higher than 150°C)

The above classification is conventional and is difficult to be used due to frequent interrelation between the systems found in nature.

- Low enthalpy geothermal exploitation may consist in producing hot water from deep reservoirs through a well (artesian or pumping) or just by simple utilization of hotsprings.
- Medium enthalpy geothermal exploitation may rely on hotsprings, shallow wells in anomalous areas or on deep wells drilled for oil exploration and encountering hot water reservoirs.
- High enthalpy exploitation is based on either dry steam or steam hot-water mixture.

........4/

III. Geothermal Resources Development

8. The multipurpose use of geothermal resources is found to become the predominant type of geothermal resource utilization. This is because, compared to single-purpose development, multipurpose use offers the following advantages: (1) it is more economical and may offer additional social benefits(such as heated swimming pools, therapeutic uses, space heating, etc); (2) it usually allows higher efficiency in energy use; (3) it often allows the utilization of associated resources (such as water for agriculture, minerals, and gases).

9. The location and resource characteristics are important for geothermal resources in general and overriding in the case of multipurpose utilization.

Hot water, the main component of most types of geothermal resources, cannot be transported economically over distances exceeding 50 km; thus, the use of hot water as a heat source requires nearly utilization, and the same applies to steam, which requires a nearby geothermal power station. Electricity can be transmitted over long distances; and valuable minerals extracted from geothermal water could also be transported over long distances, but in each case the first processing has to be done near the field.

10. Given these resources restraints, the economic needs and the economic opportunities of the area around the geothermal field are decisive for a multipurpose utilization.

Thus, if there are nearby agriculture or forestry products for processing which require heat, if the geothermal field is in an area where heating of houses and hospitals, industrial buildings, schools, and so on, is required, if there are industries nearby which can utilize the various components of the geothermal resources, then a manifold multipurpose utilization of the geothermal resources is not only feasible but will also be economically attractive in practically all cases.

11. From the energy and industrial points of view, the main utilization of geothermal energy up to this time has been for conversion into electrical power. This latter, infact, can be easily transmitted over long distances, converted into all other forms of energy, distributed in large or small quantities and so on. Geothermal power stations are not complicated in comparison with traditional steam power stations and they are easier to operate. The use of geothermal steam to generate electricity is well known. Its main attractions are the base load characteristic of geothermal electricity generation the high reliability of such generation and, of course, its low cost due to the low cost of the steam and the low capital cost of a geothermal power station.

12. The use of steam and hot water for non electric utilization is even more profitable at today's level of oil and coal costs. It is obvious therefore that where the geothermal field can provide such low-cost steam or hot water, industries in the future will use it even in a small field, if they exist in the area; and they will be attracted to large fields just as industries moved to hydropower sites at the beginning of the modern era of electricity.

13. Geothermal hot water can also be used for refrigeration and air conditioning at very much lower cost than any other alternative method.

14. In semi arid or arid areas, the large volumes of water produced by geothermal resources could make important contributions to food and fiber production in a variety of ways.

15. A geothermal field indeed is the only resource which could provide for greenhouse farming for around the year production the necessary water supply, heat supply and CO_2 supply. In certain cases some of the fertilizer also may be derived from geothermal resources. Geothermal fields produce enough water even for larger-scale farming, and in areas which lack fresh water geothermal desalination can provide desalinated water at reasonable cost.

......6/

IV. Role of geothermal energy in Africa

16. The development of geothermal energy in Africa has become particularly attractive due to the incertainty of future oil supplies coupled with the regular increases in the price of the available oil supplies and their effects on the balance of payments of some African countries. Since geothermal plants operate on an indigeneous energy resource, foreign exchange costs are minimal. The absence of any fuel cost for a geothermal power plant means that practically the operating costs are fixed in nature.

17. Compared to its closest rival as an indigeneous renewable source of energy, hydropower, the capital as well as operating costs are similar whereas the cost of geothermal exploration may be high, geothermal exploitation lends itself particularly to the installation of power generating units in comparatively small sizes. Thus the development of geothermal resources in any area would be based on a continuing programme resulting in the regular installation of small power plants whose size may be increased in step with the increase in consumer demand for electricity. Technically geothermal power installations are not complicated and extremely simple to operate. In deprived areas, electrification can be done very easily by the development of geothermal resources.

18. Geothermal resources can also be used on a multipurpose basis such as space heating air conditioning, greenhouse operation soil heating, irrigation, therapeutics, etc.

V. Present status of geothermal resources development in Africa

19. The best zones in Africa are in East Africa where there are many still active volcanoes and hot springs, all linked with the tectonics of the Rift Valley, between the Red Sea and Lake Malawi through the territories of Djibouti, Ethiopia, Kenya, Uganda and the Great Lakes Region.

20. There are promising sites in West and North Africa such as the Mount Cameroon and Adamaou regions in the United Republic of Cameroon, the Lake Faguibine in Mali, the Tibesti region in Tchad, some of the zone between the Volta basin and the Senegal basin and a zone stretching from the Canary Islands to the Libyan Arab Jamahiriya through Morocco, Algeria and Tunisia. Madagascar is also a promising area.

21. During 1970 a geothermal exploration projet commenced in Ethiopia under the United Nations Technical Assistance programme. As a result of this survey areas of special geothermal promise were identified in the Lakes District, the Awash Valley and the Danakil Depression Lake district area has been given top priority. Drilling for geothermal power still begin by the end of December 1980 in the vicinity of Aluto Mountain near Lake Langano. The drilling is expected to determine whether it will be feasible increase the generating capacity of Ethiopian Electric Light and Power Authority by up to 30 megawatts by using the geothermal resources. Since the Lakes District is comparatively close to Addis Ababa there will be no difficulty in absorbing the output from such a geothermal power station in the Addis electricity network. Concurrently, with the carrying out of detailed geophysical and geochemical investigations in the Lakes District an economic feasibility study will be undertaken to assess the possible economic impact of developing geothermal energy in the other two regions.

22. Kenya has vast potential of geothermal resources. A large part of the Kenyan Rift Valley is characterized by intense geothermal activity. This is in form of geysers, fumaroles, warm and hot springs. The area of active surface geothermal manifestations extends from Lake Logipi, just south of Lake Turkana in the north, to Lake Magadi in the south. The exploitable geothermal potential would be by rough estimates more than sufficient to supply the country with all its power needs.

Increased attention has been given to the exploration and subsequent exploitation of geothermal resources since the imitation of the United Nations co-operation with Kenya in the geothermal exploration (1970-1975).

........8/

Detailed geological, geophysical, geochemical and drill hole studies were made of the geothermal potential of areas near Lake Naivasha and Lake Bogoria while a considerable amount of preliminary data was obtained from other geothermal prospects within the Rift Valley.

Based on the results of this work the first geothermal power plant capable of producing 15 MW of power is being constructed at Olkaria, an area south Lake Naivasha. The output of this geothermal power plant is to be progressively increased following the completion of the first construction phase until the maximum output capacity of approximatively 170 MW is achieved. This contribution of geothermal energy towards the total energy needs of Kenya promises to be significant.

23. Since 1970 the BRGM (Bureau de Recherches Geologiques et Minieres) has undertaken geothermal prospecting in the Republic of Djibouti. The initial aims of this geothermal prospecting was to provide electricity for a power plant of 4 MW supplying the town of Djibouti. In the first instance the prospecting concerned three rift areas in the South of the Republic of Djibouti namely, the rifts of Gobaad, Hanleh and Asal. Over the past three years it has been intensified in the Asal zone, which has the most tectano-volcanic activity and where the geochemical indications concerning the springs were the most promising. Moreover, the fact it is nearer to Djibouti than the other areas would permit the construction of an electric power line over a shorter distance (it is easily accessible from the sea). The proximity of a brine deposit at Lake Asal (unexploited) might allow further development at a later date. Finally its central geographical position and its distance from the political frontiers confirm the interest of this region. The reconnaissance bareholes were drilled in spring 1975.

24. In Uganda, at least 20 geothermal areas with numerous hot springs discharging water at 30 to 100°C, occur in the western rift and in tertiary to recent volcanics of eastern Uganda flanking the Kenya rift.

.....9/

The locations of the various geothermal anomalies in Uganda are far from the main hydro-electric schemes. Thus, harnessing the geothermal systems for local production of electricity would contribute greatly to the rapid electrification of rural areas.

25. A first attempt was made at assessing the geothermal potential of southern Nigeria sedimentary basin from a study of subsurface temperatures from over 1000 oil well log records. The geothermal gradient varies from 1°F/100 feet at the centre of the Niger Delta gravity minimum to 3°F/100 feet in the Cretaceous rocks, to the north, which are affected by the Santonian folding and magmatic episode in the Benue through. The low geothermal gradient in the Niger Delta suggests very little potential for geothermal resources development in this area, whereas the steeper gradients to the north define an area with better prospects.

26. In Algeria, many thermal indications are located in the northern eastern part of the country. This area is considered the most favorable for a high enthalpy geothermal development programme. Nevertheless, implantation of small scale units for producing electricity from hot springs (100°C) may be considered well before development of high-enthalpy zones.

A prospection programme have been carried out in Algeria more than 10 years ago and has been recently reactivated (geophysical survey).

The University of Annaba is presently engaged in R & D activities and leads a medium enthalpy project.

27. In Tunisia, several areas are known to have medium and low enthalpy geothermal resources, particularly the North Western part of the country, the Zaghouan-Cap Bou area and Gabes region. The presence of high enthalpy fields is not excluded.

Research and development programmes are carried out by the "Office National des Mines) by a small geothermal group of scientists. Geological mapping of geothermally potential areas, hydrogeochemical sampling and analyses, as well as studies of deep well logs are currently carried out by the same office and sites are selected for low and medium enthalpy projects.

........10/

Research is carried out by the University of Tunis in the field of geology geochemistry and geophysics.

28. In Morocco, several areas of major interest for low and medium enthalpy were identified as follows: the Rif/Atlas region and the great basins of the West, Kuneitra (Gharb) and southern plains.

Reconnaissance surveys for geothermal potential have been carried out in the 1960-1970's.

29. For financial reasons, assessment of geothermal potential in Madagascar is limited in scope at the time being. Although a large number of warm springs is known to be spread throughout the eastern part of the country, no area has been yet delineated as a high priority zone for detailed exploration. However, a reconnaissance survey of all warm springs has been planned, to provide geochemical information for selection of priority areas for detailed information. The Malagasy Government is assisted in performing this survey by UNDP in purchasing of equipment and contracting of consultancy services.

Work began on the project in 1979 and will be completed by end of 1980. On completion of the survey, a technical team will review the results and make recommendations for further work.

30. Although Africa has extensive geothermal resources, so far as is known, only a single small power plant is presently using the earth's natural heat: It is located at Kuabukwa in the Shaba province of the Republic of Zaire. This geothermal plant has an installed capacity of 220 kw.

.........11/

VI. Major obstacles to the geothermal energy utilization in Africa

31. The overriding factors determining the pace of geothermal development are as follows:

- cost of energy from alternative sources
- geological conditions (risk on investment) and need for extensive geological and geophysical exploration;
- the haphazard factor of boreholes
- the very high cost of drilling
- availability of capital for investment

32. The personnel of agencies responsible for natural resource development in Africa is usually aware of a geothermal potential when it exists, but these agencies normally do not have budgets sufficient to implement the level of exploration required.

33. Significant technical assistance is being provided to African countries, from both multilateral and bilateral sources, in the form of grants for preinvestment feasibility studies which include the provision of experienced technical staff, equipment required for exploration and fellowships for overseas training.

34. The difficult cases for utilization of geothermal resources in Africa are the areas which are thinly populated or unpopulated, where the usual infrastructure does not exist and where the market for the variety of resource components is difficult to find. The cases become even more difficult if the geothermal resources are located deep inside the country in areas of difficult access of mountains or jungle territory.

VII. Consideration on possibilities of mineral extraction related to utilization of geothermal energy in Africa

35. The utilization of geothermal fluids for energy purposes may prove to be more profitable when using these fluids as a source of obtaining byproducts such as lithium, rubidium, cesium, boron strontium and so on.

36. High concentrations of lithium, rubidium cesium and boron have been found in thermal carbon dioxide waters of mountains folded regions, in thermal water of the regions of recent volcanism, and in hot brines of artesian basins. High concentrations of strontium are characteristic only of artesian basines.

37. Rare elements are accumulated mainly in chloride sodium and chloride calcium ground waters. Low values of the Na:Li and K:Ca ratios are typical of rare-metal waters. These ratios may be an exploration index of thermal water.

38. The problem of industrial extraction of rare elements from thermal water should be developped in the direction of (1) preparing a raw material base, that is, in finding thermal water and in calculating water resources and (2) working out technological methods of extracting rare elements from thermal water in different geochemical classes.

VIII. Economic reliability and technological developments of geothermal energy

39. The economies of geothermal energy in general is difficult to be discussed without a reference to a specific case. Consequently the problem should be taken up in relation with activities presently carried out in Africa, which again, unfortunately are either not completed or as in the only case of Kuabukwa Geothermal Power Station, data is not available.

In general, the parameters met in geothermal systems are so numerous that a general rule is difficult to be drawn up. The temperature in increases in depths and the costs will increase consequently. Of course, there are corrective systems and high enthalpy products may be found at/or close to the surface in which case costs are significantly diminished. The other variable is the flow rate which depends on permeability or fracturing of the rocks and hence influences the energetic power of the wells. Problems of exploration and exploitation, composition of the water (minerals and gas content), associated with corrosion are another variables which make the economical assessment more difficult.

Therefore, in order to have an idea of the geothermal energy economics, it should be emphasized that when good geothermal fields are found, independently of the enthalpy value, they are of very high economic interest and the energy they produce is competitive with fossil fuels, oil in particular. As an example, high enthalpy plants existing elsewhere, produce electricity at the production cost of 0.02 to 0.10 US$ cents per kwh, whereas medium enthalpy plants produce electricity at a cost of 0.15 to 0.25 cents per kwh, competitive with diesel plants of similar size.
When compared to oil, geothermal energy investments varies between 250 and 2000 US$ per ton of oil, provided the system is productive for an average of 20 years.

It should be noted that exploration for geothermal sources takes a big share of the cost. Within this , a large differential exists between the cost of drilling a large diameter exploration hole and the cost of a pre-drilling geoscientific investigations. The current cost of full size exploratory well in a developed country (about 23 cm. diameter) is about 450-550 US$ per meter, or about one million US$ per hole drilled to a depth of 2000m.

A typical 50 mw power plant in a fluid-dominated geothermal system requires an average of 12 producing wells (7 to 8 wells in a dry-steam field).

39. At the current rate of sucess in geothermal exploration (about 10 per cent), which is higher than the rate of success in petroleum exploration, about 10 million US.. are being spent on exploration drilling for the discovery of one geothermal reservoir. The cost of prebuilding geoscientific investigations may be estimated at some 12 to 15 per cent of the expenditure on drilling.

40. Technological developments have kept pace along with the growth in sophistication of exploratory activities. The most relevant developments have taken place in geochemical and geophysical techniques; remote sensing data and structural geology interpretation have also made significant progress. Drilling equipment has been consequently adapted and except for few modifications and utilization of high quality anti-corosive parts, remained practically similar to that used for petroleum exploration and is keeping the same rate of progress in sophistication. Developments in exploitation technology are more significant and vary from case to case pending the factors listed above.

Among the most used modern methods in geothermal exploration, related to technological developments, may be listed the accounting of the dilution or re-equilibration effects of the hot water by cold water and measurement of reservoir temperature at the surface as an addition to the classical geochemical methods.

Within the geophysical methods, beside the classical electrical reistivity and thermal gradient/heat flow methods, progress has been registered by the direct current and electromagnetic methods (with magneto-telluric). The advent of light-weight portable microprocessors, has resulted in the very recent development of real MT data acquisition equipment. Presently, three entities have the capability of converting the natural electro magnetic signal data into vertical resistivity cross-sections. Micro earth quake seitueology is being used as an auxiliary technique in geothermal exploration particularly today with high improvement of the aparatus sensitivity.

In addition to traditionally useful exploration methods such as gravity and magnetics for auxiliary data, self-potential surveys or soil geochemistry, experiments are currently made of the Curie Point phenomenon - the fact that rocks lose their magnetic characterisitics at 578°C - by mapping the depth to the Curie Point temperature. This is being done through a sophisticated wave length analysis of large scale aeromagnetic maps.

Areas where the Curie Point temperature is shallower than others, are likely to be characterized by a steeper temperature gradient.

41. It should be emphasized that success in geothermal exploration, depends on a careful selection of a group of exploration techniques, specifically adapted to local geological conditions and based on the exploratory experience gained elsewhere but in similar areas.

Whereas the technological development progresses, an increase in exploratory rate of success will continue to depend upon an increase in experience, careful planning of the exploration programme and capability to assimilate new technological developments.

IX. Suggestions and conclusions

42. Given the enormous geothermal potential of the continent, its development should be considered as a matter of priority. In order to achieve such objective, the first step to be undertaken is the Resources assessment. This may consist in a) inventory of all hot springs, hot grounds, fumaroles, mofettes, temperature and other physical and chemical measurements; b) study of existing deep well data, temperature and other physical logging, geological sections; c) geological studies in order to define reservoir occurences, tectonic lines, magmatic manifestations; d) volcanological and geophysical studies in order to locate heat sources and heat anomaly areas.

43. Following the resources assessment, an Inventory of geothermal resources should be undertaken. It will result in synthesising data collected on maps and reports in order to establish at any point of the area or country concerned, potential geothermal energy source available at depth, with some precision on cost of production. Such inventory can be performed in sedimentary basis and areas of simple geology, but is more difficult in tectomically affected areas with active volcanism.

44. Resources assessment and inventory of geothermal resources should be followed by reconnaissance activities. All these make part of the Basic Research activities and surveys and should be considered as compulsory for the beginning of development of geothermal resources in any country.

45. In those countries which already undertook the first step, prefactibility studies may be considered; they should include geological, geochemical and geophysical surveys. Whithin this activities, countries such as Somalia, Egypt, Algeria, Morocco, Cameroon may be considered.

46. Technico-economic feasibility studies could be considered in those countries which already know their potential in geothermal energy. Such studies may also consider training of local staff and develop local expertize.

47. Economical viability of geothermal energy utilization may be proved by building demonstration plants, preferably of small-scale type and by organizing study tours for African technicians, engineers and researchers, in those countries which already achieved this stage.

48. Transfer of technology should be given highest consideration and may develop fast provided that the staff involved in geothermal activities has good technical background. In this context, programmes for training of manpower at national level should be considered.

49. Scientific and technological research for industrial application of geothermal resources as a source of generating electricity, for heating, cooking processes, extraction of minerals production of water and steam for agricultural purposes or social needs, may be initiated.

51. The order to expedite the harnessing of geothermal energy intensification of geothermal exploration in those African countries which are already engaged in it, should be considered.

52. Finally, to assist African countries in exploration, development and utilization of their geothermal resources, establishment of a regional coordinative instituion may be also considered.