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GEOTHERMAL DEVELOPMENT IN ETHIOPIA

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ABSTRACT

Geothermal exploration activity, that started in the year 1969 in Ethiopia, has revealed the existence of both low- and high-enthalpy geothermal resources in the Ethiopian Rift valley and in the Afar depression, which are both part of the great East African Rift System.

The utilization of the geothermal resources were only restricted for the use of resort and therapeutic purposes until the end of the year 1998, when the testing of the geothermal power plant with a capacity of about 5-7 MWe went on-line at the Aluto-Langano geothermal field. The Ethiopian Institute of Geological Survey (EIGS) handed over this geothermal field to the Ethiopian Electric Power Corporation (EEPCO) for development.

The Aluto-Langano pilot power plant has been operational since July 1998, and the commissioning work by EEPCO was finalized on June 16, 1999. The design power output of the pilot power plant is 8.52 MWe (Gross) and 7.28 MWe (net; Table 1). This pilot power plant is the first geothermal power plant producing electricity in the country.

In the Tendaho geothermal field, a production test and feasibility study is currently in progress. This feasibility study indicates that four productive wells (out of six) of this geothermal field could supply enough steam to operate a pilot power plant of about 5 MWe.

1. INTRODUCTION

1.1 Background

Energy is an important element in Ethiopia's development strategy, because it could be a source of foreign exchange and is a catalyst for industrial progress. Ethiopia has a diversity of energy sources, but relies on imported petroleum and petroleum products. The total installed electric power in Ethiopia exceeds 380 MWe, coal exploration is in progress, gas has been found in the eastern part of the country. To allow the country to emerge from its existing underdeveloped condition. The government's current policy is to develop an adequate amount of cheap energy from new and renewable resources (geothermal energy), to satisfy the electricity demand of large industrial and agricultural projects. Therefore, geothermal power needs to be developed to (i) help replace import of fossil fuel; (ii) provide a major backup to an uncertain availability of hydropower; and (iii) for use in eastern areas of the country where hydropower is unavailable.

Ethiopia is among the few countries in Africa with a significant amount of geothermal resources. These resources are found scattered in Ethiopian Rift valley and in the Afar depression, which are both part of the Great East African Rift System (Figure.1). The Ethiopian rift extends from the Ethiopia-Kenya border to the Red Sea in NNE direction for over 1000km within Ethiopia, and covers an area of 150, 000 Km^2.

The estimated potential of the geothermal resource in the whole Ethiopian Rift is about 700 MWe. Of this, 170MWe is from seven sites in the lakes District, 260 MWe from seven sites in the central Afar, 120 MWe from five sites in the Southern Afar and 150 MWe from five sites in the Danakil depression.

1.2 Summary of geothermal activities in Ethiopia

The history of geothermal exploration in Ethiopia begins in 1969, with a regional geological-volcanological mapping and hydrothermal manifestation inventory in most of the Ethiopian Rift. Thereafter, the united Nations Development Program (UNDP) provide financial and technical assistance to the ethiopian government to conduct a systematic campaign of geothermal exploration all along the main Ethiopian Rift and the Afar Depression. On the basis of several years of exploration activities which included geological, geochemical and geophysical investigation, about eighteen geothermal prospecting areas were selected for further studies (Figure. 1).

Among these prospecting areas, exploration has gradually centered on the Aluto-Langano (Lakes District) and Tendaho geothermal fields (Northern Afar), with additional financial support from the UNDP, together with more consistent financial contributions from the European Economic Community, a geothermal feasibility study was started in the Aluto-Langano area in 1981.

In the Aluto-Langano geothermal field, eight deep exploratory wells were drilled to a maximum depth of 2500m, five of which are potentially productive. Currently, four productive wells of this geothermal field are supplying steam and brine to operate the pilot power plant of 5-7 mWe. In the near future, more production wells will be drilled at Aluto-Langano in order to raise the total capacity of the electric generation to at least 30 MWe.

In the Tendaho geothermal field, three deep and three shallow exploratory wells were drilled to a maximum depth of about 2100m, and have a maximum temperature of 260°C. The drilling operation in the Tendaho geothermal field was financed jointly by the Technical Cooperation of the Italian government and the Ethiopian government. At Tendaho, a production test and feasibility study is currently in hand. The feasibility study indicates that the four productive wells (out of six) could supply enough steam to operate a pilot power plant of about 5 MWe. The total potential potential of the explored area has been estimated to be about 20 MWe.

2.0 THE ALUTO-LANGANO GEOTHERMAL PILOT POWER STATION

The drilling of eight exploratory wells and a feasibility study at Aluto-Langano was completed in 1985-86. The feasibility study indicated that the potential of the field is as high as 30 MWe for 30 years, and develops merit the field in three phases starting with a 3.5 MWe back pressure pilot power plant. Figure 2 depicts one of the discharging wells (LA-6) in the Aluto-Langano geothermal field.

The Ethiopian Institute of Geological Surveys (EIGS) handed over the Aluto-Langano geothermal field to the Ethiopian Electric Power Corporation (EEPCO) for development. The 1986 feasibility report was reviewed by gENZL (Geothermal Energy New Zealand Limited) in 1995. They have recommended starting development of the field by installing a 5 MWe condensing turbine power plant. During the tender evaluation process, the capacity and type of power plant was changed. The turn-key contract for the supply and construction of the pilot power plant was awarded to Ormat Industries of Israel on August 9, 1996.

The Aluto-Langano geothermal power plant is the binary type, which consists of two types thermodynamic cooling cycles. These include: (i) Geothermal combined cycle unit (GCCU) and (ii) Ormat energy converter (OEC). The pilot power plant is supplied with steam and brine from the four production wells (LA-3, 4, 6 and 8) of around 2000-2500m depth. There is one reinjection well (LA-7) which is an original field exploration well. The working fluid in the binary units is pentane. Ambient air is the cooling media for the condenser in both units. There is a closed system for the geothermal fluid from the production wells to the reinjection well with no steam or brine discharges to the air and no cooling tower plumes, thus minimizing the environmental impact of the plant.

The design power output of the pilot plant is 8.52 MWe (Gross) and 7.28 MWe (net). The plant is connected to the national grid, and has been operational since July 1998. The commissioning work was finalized on June 16, 1999.

3.0 CURRENT GEOTHERMAL ACTIVITIES IN ETHIOPIA

The status of on-going geothermal activities in the ethiopian institute of geological survey is: (i) monitoring (geochemical and reservoir engineering) of the aluto-Langano and tendaho geothermal fields; (ii) Detailed geological mapping and geophysical studies of the Lakes District area (e.g. Tulu Moye, Gedemsa, Abaya etc.); (iii) Sampling of water samples, for isotope, chemical and gas analysis from surface geothermal manifestations around Main Ethiopian Rift, Southern Afar and Northern Afar regions.

To acquire experience and knowledge in using isotope techniques for geothermal exploration and exploitation, the Ethiopian Institute of Geological surveys (EIGS) started a technical Cooperation (TC) agreement, through the Ethiopian Science and Technology Commission (ESTC), with the International Atomic Energy Agency (IAEA) in the year 1993. since then, to develop experience and knowledge through training of local personnel, expert advice, and the provision of equipment. Furthermore, water samples from the whole Ethiopian Rift Valley and its escarpments are being analyzed at the isotope hydrology laboratory of the IAEA, Vienna, Austria. This has helped improve the infrastructure and built local capability to study geothermal resources using stable and radioactive isotopes.

4.0 FUTURE PLAN OF GEOTHERMAL EXPLORATION AND DEVELOPMENT IN ETHIOPIA

In Ethiopia, there are limitations of local financing due to the high investment requirement to carry out pre-investment phases (reconnaissance and pre-feasibility studies) and the capital investment phases (geothermal exploration drilling, field development and plant construction) to develop geothermal resources. However, with such high potential to generate power (i.e. double its annual consumption), Ethiopia suffers from Occasional power shortages.

Ethiopia could generate about 700 MWe in excess of its annual requirement (which is about 380 MWe) through the use of geothermal energy. Thus, not only is there the potential to develop geothermal for local consumption, but it is also possible to generate energy for export. One constraint indicated above, is the lack of finance. In this connection, the government is looking in to different options, one of which is consideration of viable means that could develop the resource while reviewing the overall energy policy of the country. Another would be inviting private investors to participate in the sector. Or, as was the case in the development of hydroelectric power, loans and grants from international financial institutions could be another possibility.

At present, in response to the power shortage of the country, the government has allocated limited amounts of money for the exploration and development of the geothermal energy in Ethiopia. These future plans include:

1)Monitoring (geochemical and reservoir engineering) of the Aluto-Langano and Tendaho geothermal fields.

2) Detailed geoscientific studies in the Lakes District areas (Tulu Moye, Gedemsa, Abaya etc.)

3) Drilling of more production wells at Aluto-Langano in order to raise the total capacity of the electrical output, to at least 30 mWe, for a period of thirty years.

4) Generation of electricity from 2.5 to 3 mWe using the existing exploratory wells, in the Tendaho geothermal field.

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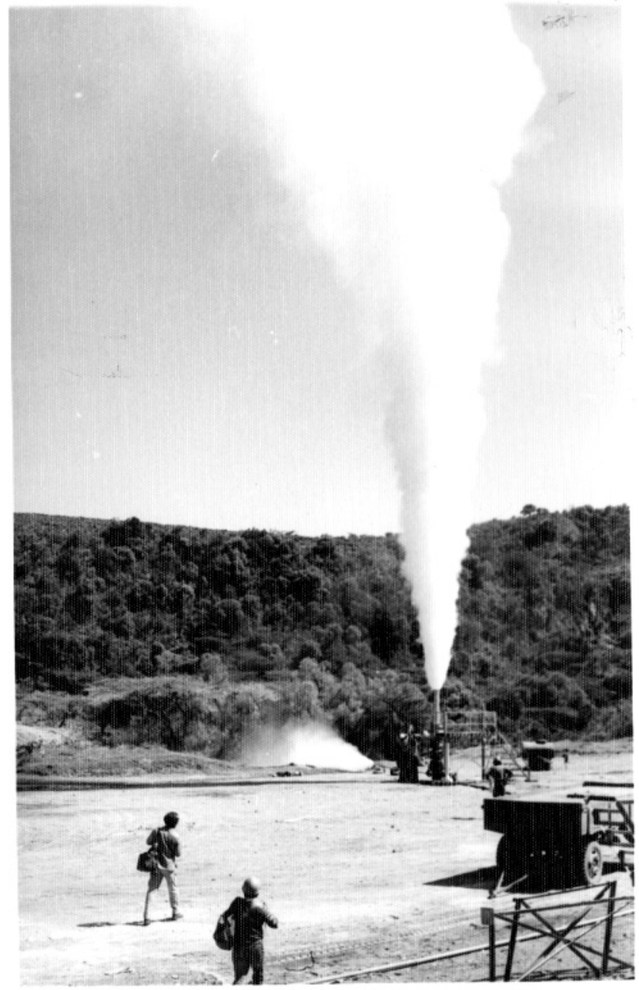

Figure 2. One of the discharging wells (LA-6) in the Aluto-Langano geothermal field, Ethiopia.

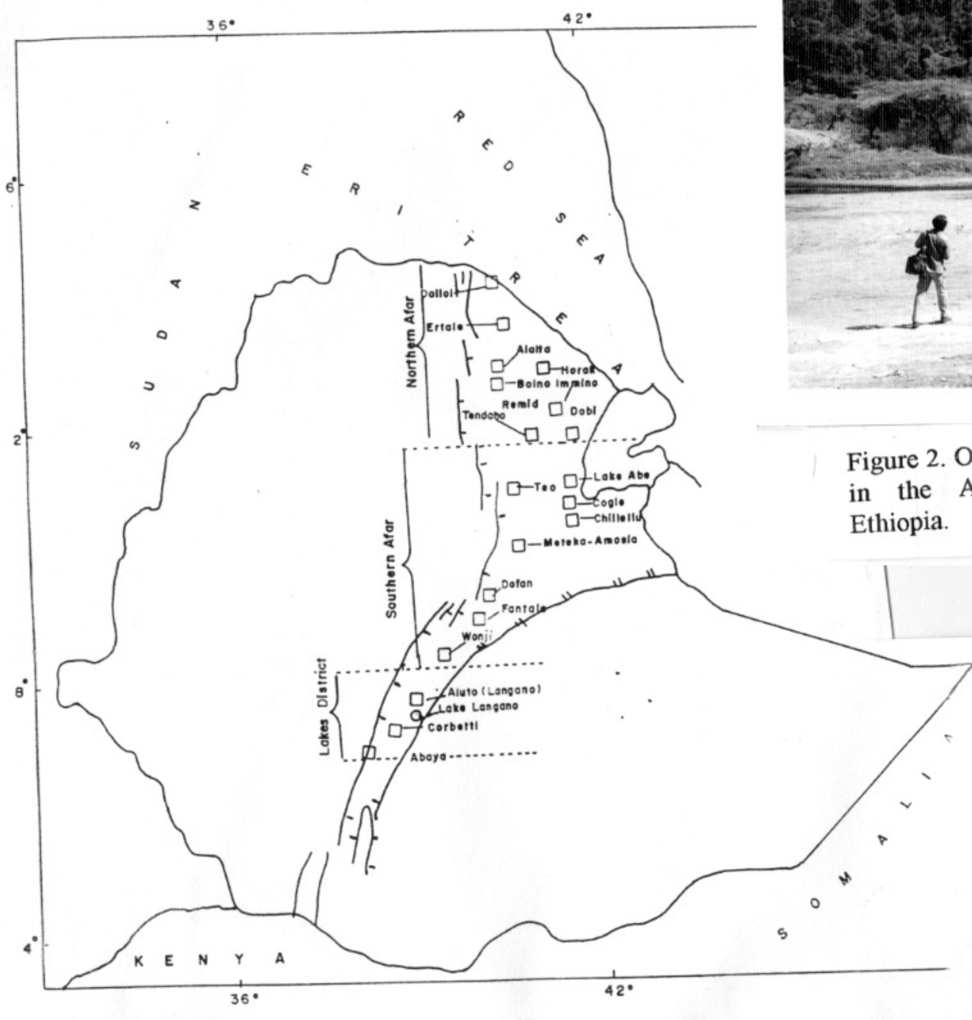

Figure 1. Location map showing geothermal prospecting areas in the Ethiopian Rift Valley and Afar depression. ☐=Geothermal prospecting areas.

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil fuels Diesel		Hydro	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Capacity MWe	Capacity MWe	Gross Prod. GWh/yr
In operation in January 2000	7.3	30.05	40.3	48.7	377.75	1622.4
Under construction in January	-	-	-	-	-	-
Funds Committed, but not yet under construction in January 2000	-	-	-	-	237.25	-
Total projected use by 2005					615	2455

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 1999

1) N = Not operating (temporary) R= Retired
2) 1F = Single flash; 2F=Double Flash; 3F= Triple flash; D= Dry steam; B=Binary (Rankine cycle); H= Hybride; O=other (please specify which)
3) Data for 1999 if available, otherwise for 1998. Please specify which.

Locality	Power Plant Name	Year Commissioned	No. Of Units	Status [1)]	Type of Unit [2)]	Unit Rating MWe	Total Installed Capacity NWe	Annual Energy Produced 1999 [3)]	Total under Constr. Or planned MWe
Aluto-Langano	Aluto-Langano pilot power plant	1999	2	Under operation	Binary type	~3.5	7.28		30
Total									

TABLE 3. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1995 TO DECEMBER 31, 1999

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric power	Direct use	Combined	Other (specify)	
Exploration [1]	(all)	6	2	-	-	8.23
Production	> 150 °C	-	-	-	-	
	150-100 °C	-	-	-	-	
	<100 °C					
Injection						
Total		6	2			

TABLE 4. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with a University degrees)

(1) Government
(2) Public utilities
(3) Universities
(4) Paid Foreign Consultant
(5) Contributed through Foreign Aid programs
(6) Private industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	24				10	
1996	24			1	10	
1997	14			4	-	
1998	14			1	-	
1999	13			1	-	
Total	24			6	20	

TABLE 5. TOTAL INVESTMENTS IN GEOTHERMAL IN (1999) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization		Funding type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1985-1989	800,000*					
1990-1994	9,600,000*					
1995-1999	2,000,000*	16,313**	-	-		100

** Obtained from EEPCO data file
* Source of fund is from government + foreign aid