STATUS AND STRATEGIC FRAMEWORK IN GEOTHERMAL DEVELOPMENT IN ETHIOPIA

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ABSTRACT

The significance of Geothermal Power within Ethiopia has long been recognized. Under a programme that began in 1969, geo-scientific studies have been conducted in a number of Ethiopian fields and over sixteen areas have been identified in the Ethiopian Rift Valley to have Geothermal Resources suitable for electricity generation. From these areas it is recognized that a total of about 5000 MWe geothermal energy could be developed. So far deep drilling has been undertaken in Aluto Langano (1982 to 1985) and Tendaho (1993 to 1998) and detailed surface exploration has been nearly completed in four other areas. A 7 .3 MWe net capacity pilot plant has been installed at Aluto, currently generating about 5MWe. Feasibility study for the expansion of the Aluto Langano Geothermal power has been recently completed with the Japanese Overseas Development Assisstance. The study indicated expansion of the Aluto Geothermal power to additional 35MWe is feasible.

Accordingly, as an initial step to develop the 35MWe, it is planned to drill four deep appraisal wells in 2011 with the Japanese technical assistance and the World Bank loan. The government encourages private sector investment in Geothermal exploration and development. Attractive feed in tariffs and incentive packages are in the process of being implemented.

Within the Ethiopia's long range power plan, geothermal is now recognized as offering an important (potential) input to the Ethiopian grid as it is base-load and climate independent. Irrespective of future hydro developments, geothermal's contribution to energy security at times of drought is considered critical. The generation development plan consists mainly of hydro projects. However generation from Wind and Geothermal power plants are foreseen to compliment the hydro. By 2015 it is planned to generate 75 MWe geothermal power from Aluto Langano and by 2018 it is anticipated to generate a total of 450 MWe from five other geothermal areas in the Rift. The order of priority for geothermal development in these areas is: Aluto Langano, Tendaho, Corbetti, Abaya, Dofan-Fantale and Tulu Moye

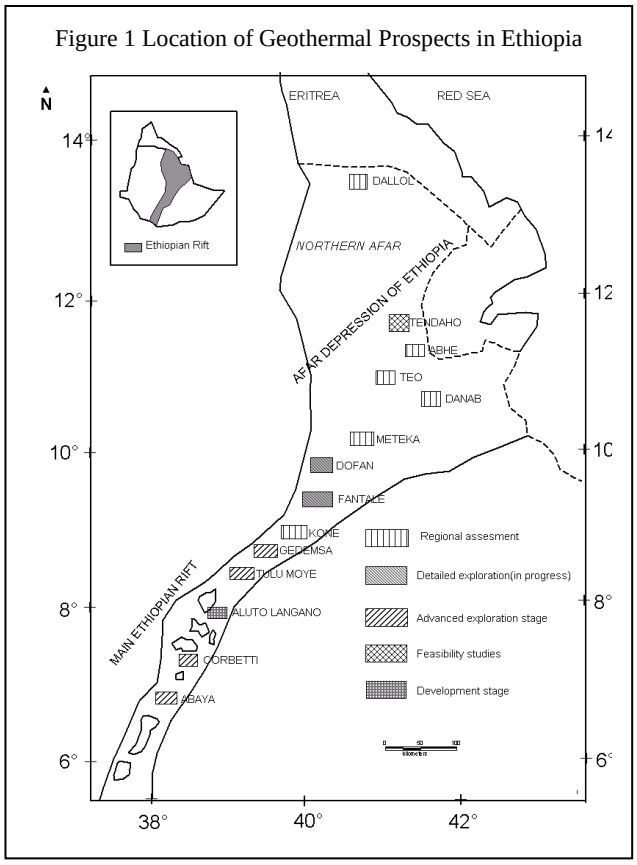
INTRODUCTION

Ethiopia started long-term geothermal exploration in 1969. Over the years, an inventory of the possible resource areas within the Ethiopian sector of the East African Rift system, as reflected in surface hydrothermal manifestations has been built up. The inventory work in the highland regions of the country is not complete but the rift system has been well covered. Of the about 120 localities within the rift system that are believed to have independent heating and circulation systems, about two dozen are judged to have potential for high enthalpy resource development, including for electricity generation. A much larger number are capable of being developed for non-electricity generation applications such as in horticulture, animal breeding, aquaculture, agro-industry, health and recreation, mineral water bottling, mineral extraction, space cooling and heating, etc. (UNDP, 1973).

Since the late 1970's, geo scientific surveys mostly comprising geology, geochemistry, and geophysics, were carried out at, from south to north, the Abaya, Corbetti, Aluto-Langano, Tulu Moye and Tendaho prospects (Teklemariam and Beyene, 2005). In addition, a reconnaissance survey of ten sites in the Central and southern Afar has been carried out, some of these being followed up by more detailed surface investigation. The prospects and fields discussed here are shown in Figure 1.

Due to various factors that determined where the first geothermal power plant would best be located, detailed exploration work was decided to commence in the Lakes area of the rift system during the 1970's. The ICS was already being extended into this region of load growth. The best prospect areas from the technical point of view were located in the Afar which had then been poorly endowed with essential infrastructure and local load demand to support power development. The present circumstances however favor resource development also in the Afar region.

Figure 1 Location of Geothermal Prospects in Ethiopia



Exploration work peaked during the early to mid 1980's when exploration drilling was carried out at Alutu. Eight exploratory wells were drilled with five of these proving productive. During 1993-98, exploration drilling was also carried out at Tendaho. Three deep and three shallow wells were drilled and geothermal fluids were encountered in the 200-600m-depth range.

Resource utilization was delayed until 1999. The 7.3 MWe net capacity pilot plant installed at Aluto has faced operational difficulties that are essentially due to the lack of the appropriate field and plant management and operation skills. The plant was then put back in to operation after problem identification and rehabilitation of the plant was carried out at the Aluto-Langano geothermal field.

During the three decades that geothermal resource exploration work was carried out in Ethiopia, a good information base and a good degree of exploration capacity, in human, institutional and infrastructure terms, has accumulated, ensuring that selected prospects can be advanced to the resource development phase much more rapidly than before.

The exploration work to date has been carried out by the Geological Survey of Ethiopia (GSE) but has benefited from a number of technical cooperation programs. The most consistent over the long term had been support by UNDP, which also helped in creating other technical capacities of the GSE. The European Development Fund financed the overseas cost of the exploration-drilling project that resulted in the discovery of the Alutu resource. The development cooperation program of the Italian Ministry of Foreign Affairs provided the funding for the offshore costs of the surface and drilling exploration of the Tendaho prospect. The reconnaissance survey of the Afar was sponsored by the Petroleum Exploration Promotion project financed by IDA during the 1980's. The IAEA is assisting the GSE in the isotope geochemical study of hydrothermal fluids and in the process is providing training and experience in the application of the technique in geothermal investigations. IAEA also provided technical advice and equipment. The German Geological Survey (BGR) assisted in Geophysical investigations (MT) of the Tendaho deep geothermal Reservoir during 2006-07. The specialized geothermal science and technology training programs in Japan, Italy, New Zealand, Iceland and Kenya (in cooperation with United Nations University- Geothermal Training Programm of Iceland and Kenyan Generating Power Company) contributed in human resource training and development.

WORK DONE IN GEOTHERMAL EXPLORATION AND DEVELOPMENT

The explored prosects are at various stages of exploration and include: (i) More advanced prospects where exploration drilling has been conducted (Aluto Langano and Tendaho), (ii) Prospects where surface exploration is relatively at higher level (Corbetti, Abaya, Dofan, Fantale and Tulumoye), and (iii) Prosects where surface exploration is at lower level and warrant further exploration in the future (Kone, Meteka, Teo, Danab and L. Abe).

The More Advanced Prospects

Only two prospect areas have been subjected to exploration drilling to date.

The Aluto-Langano Geothermal Field

Detailed geological, geochemical and geophysical surveys were carried out in the Langano area during the late 1970's and early 1980's. Results showed the existence of an underground fluid at high temperature with evidence of long time residence in zones occupied by high temperature rocks (ELC, 1986). The objective then was to locate an economically exploitable geothermal reservoir.

Two wells (LA3 and LA6) drilled on the Aluto volcano produced 36 and 45 T.P.H. geothermal fluid at greater than 300^{O}C along a fault zone oriented in the NNE-SSW direction. Two wells drilled as offsets to the west (LA4) and east (LA8) of this zone respectively produced 100 and 50 T.P.H. fluid with a lower temperature. LA5, drilled in the far SE of the earlier two wells was abandoned at 1,867m depth due to a fishing problem but however later showed a rise in temperature over an extended period of time. LA7 was drilled in the SW but could discharge only under stimulation, being subject to cold-water inflow at shallow depth. The earliest wells drilled in the prospect were drilled outside the present limits of the reservoir area, to the south (LA1) and west (LA2) of the area drilled later.

A 7.3 MWe pilot geothermal plant was installed in 1999 utilizing the production from the above exploration wells. The plant has not been fully operational due to reasons that have to do with the lack of operational experience. But now the plant is partially rehabilitated and put back into an operation of about 5 MWe.

The Tendaho Geothermal Field

Geothermal exploration was carried out in the Tendaho area with economic and technical support from Italy between 1979 and 1980. Between 1993 and 1998, three deep (about 2,100m) and three shallow exploratory wells (about 500m) were drilled and yielded a temperature of over 250ºC. The Italian and Ethiopian governments jointly financed the drilling operation in the geothermal field. A preliminary production test and techno-economic study indicated that the shallow productive wells could supply enough steam to operate a pilot power plant of about 5 MWe, and the potential of the deep reservoir is estimated about 20 MWe.

Based on this and further studies, the Ministry of Mines and Energy is currently working on Tendaho for progressing it towards development. The recent upgrade of a trunk highway through the Tendaho area will help facilitate such exploration and development. In addition, the Ethiopian government plans to extend the country's main 230KV transmission line to Semera, which is within ten km of the drilled wells at Dubti.

Prospects where Surface Exploration is Relatively at Higher Level

Over the years, a number of prospects have been subjected to surface investigation: geology, geochemistry and geophysics and the shallow subsurface has been investigated by drilling at a few of the prospects. They are mostly located in the MER, especially in its most recent zones of tectonic and magmatic activity, the different sectors of the discontinuous WFB. The more important areas are Abaya, Corbetti, Tulu Moye, Dofan and Fantale.

The Abaya Geothermal Prospect Area

Abaya is located on the northwest shore of Lake Abaya, about 400 km south by road from Addis Ababa. The Abaya prospect exhibits a widespread thermal activity mainly characterized by hot springs, fumaroles and altered ground. Spring temperatures are as high as 96 °C with a high flow rate. Integrated geo scientific studies (geology, geochemistry, and geophysics) have identified the existence of a potential geothermal reservoir with temperature in excess of 260°C (Ayele et al., 2002). Further geophysical studies including drilling of shallow temperature gradient wells are recommended here.

The 132 KV transmission line to Arba Minch to the south starts at the Wolayta Soddo substation located about 40 km distance to the NNW of the prospect. This raises the prospect for development of the resource once it is adequately explored, including by drilling.

The Corbetti Geothermal Prospect Area

The Corbetti geothermal prospect area (Figure 1) is located about 250 km south of Addis Ababa. Corbetti is a silicic volcano system within a 12 km wide caldera that contains widespread thermal activity such as fumaroles and steam vents. Detailed geological, geochemical and geophysical investigations conducted in the Corbetti area indicate the presence of potential geothermal reservoirs with temperatures exceeding 250°C. Six temperature gradient wells have been drilled to depths ranging from 93-178m (Kebede, 1986). A maximum temperature of 94°C was recorded. Detailed shallow temperature distribution surveys and geochemical surveys have conducted in 2009-2010. The data so far collected shows the probable existence of a deep reservoir with temperatures exceeding 250 °C.

A 132 KV power transmission line passes within 15 kms of the prospect and is the main trunk line to Southern Ethiopia, to towns along the two branches of the highway to Kenya.

The Tulu Moye Geothermal Prospect Area

The area is characterized by volcanism dating from Recent (0.8 –0.08 Ma) to historical times. Volcanism involved the extrusion of per alkaline felsic lava associated with young tensional and transverse tectonic features dating from (0.1 –1.2 Ma) with abundant silicic per alkaline volcanic products (Di Paola, 1976) in the Tulu Moye-Gedemsa prospect area. This suggests the existence of a deep seated magma chamber with a long residence time. The area is highly affected by hydrothermal activity with the main hydrothermal manifestation being weak fumaroles, active steaming (60-80°C) and altered ground. The drawback of the hydrothermal manifestations is related to the relatively high altitude of the prospect area and the considerable depth to the ground water table. During 1998-2000, integrated geological, geochemical and geophysical studies including shallow temperature gradient surveys (150-200m) , confirmed the existence of potential geothermal reservoirs with a temperature of about 200°C (Ayele et al., 2002) and delineated target areas for further deep exploration wells.

This prospect area is located close to the koka and Awash II and III hydro-electric power stations, the associated 230 and 132 KV substations and transmission lines.

The Dofan Geothermal Prospect Area

Geological, geochemical, and geophysical investigations in the Dofan geothermal prospect (Figure 1) show that the area is characterized by a complex volcanic edifice that erupted a considerable volume of pantelleritic lava from numerous eruptive centers between 0.5-0.2 Ma (Cherinet and Gebreegziabhier, 1983). The presence of several hydrothermal manifestations (fumaroles and hot springs) within the graben, together with an impervious cap, needs to be regarded with high priority for further detail exploration and development (Teclu, A, 2002/2003).

The area is located about 40 km from the high voltage substation at the Awash town.

The Fantale Geothermal Prospect Area

The Fantale geothermal prospect is characterized by a recent summit caldera collapse, felsic lava extrusions in the caldera floor and widespread fumarolic activity, suggesting thereby the existence of a shallow magma chamber. Active tensional tectonics form fissures up to 2m wide near the volcanic complex. Ground water discharge to the system is assured by the proximity of the area to the western escarpment. The results of an integrated interpretation of previous data suggest that the area is potentially prospective for future detailed geothermal resource investigations. Therefore, due to the presence of an impervious cap rock, the western part of the prospect particularly deserves to be investigated during a more detailed geothermal exploration program. In this view, the Geological Survey of Ethiopia has carried out detailed geological, geochemical and geophysical investigations in order to delineate and select target areas for deep exploration wells.

Prospects where Surface Exploration is at Lower Level

The strategic exploration and development plan deals with a total of six geothermal project areas which had been selected on the basis of proximity to areas of economic activity and the national power grid. However, past work has shown that there are several other attractive prospects that are suited for pursuing in the long run.

During the 1980's, reconnaissance geological, geochemical and geophysical investigations have been conducted at Kone, Meteka, Teo, Danab and L. Abe areas that are found in a zone extending between the southern and northern Afar geological provinces (Elc, 1986). Meteka and Teo hold promise for the discovery of economically exploitable geothermal resources at high temperature and warrant detailed surface investigation, followed by exploration drilling. The Lake Abe area warrants further investigation in a wider exploration context that encompasses areas in the eastern part of Tendaho graben and the Lake Abe prospect in Djibouti. These resource areas were not investigated in detail so far, as their large distances from electricity load centers and the national grid accord them lower priority. With advancing economic activity in southern and central Afar as well as in the eastern part of the country, these prospect areas should prove useful for power supply both within the region and to the national grid in the longer-term.

The prospects that have been dealt with under reconnaissance stage are located to the north of 12°N latitude and comprise terrain that is at the most advanced stage of rift evolution in the eastern Africa region and holds a much greater potential for geothermal resources than any other region of equivalent size. This region should be considered as a prime target area for future exploration and development. With the improving availability of the economic development infrastructure in the region, the power-supply system in the load growth areas of northern Ethiopia would benefit from geothermal power generating facilities located in this part of the country.

From these long-term points of view, reconnaissance and preliminary surface evaluation works should commence in the not too distant future in the regions of southern and central Afar, north of 12°N latitude, in order to raise the available level of knowledge regarding the resource areas and to provide the necessary information that is required for long-term planning.

CURRENT GEOTHERMAL ACTIVITIES AND FUTURE STRATEGIES

Current Activities

Currently the following geothermal activities are being conducted in Ethiopia:

- A three year project entitled Strategic Geothermal Resource Assessment in the Ethiopian Rift Valley has started in 2009. The target areas of assessment are Tendaho, Aluto Langano, Corbetti and Abaya. Geo scientific studies including: (i) geological, (ii) geochemical, (iii) geophysical (MT, TEM, Gravity and Magnetics) and (iv) Reservoir Engineering studies are being conducted in these areas. The objectives of the project are to locate and identify areas (sites) for deep drilling by acquiring data that can supplement the already available ones, and upgrade and synthesize all existing information in order to establish a geothermal exploration conceptual model for future feasibility studies. The surface geo scientific studies at Tendaho are being assisted by the German Geological Survey.
- In order to expand the Aluto Geothermal Resource to its full potential, a study on the power development at the Aluto Langano geothermal field in Ethiopia (Phase I) has been conducted by GSE and Japanese consultants as part of "FY2009 Studies for Economic Partnership Projects in Developing Countries " promoted by the "Ministry of Economy, Trade and Industry of Japan (METI)" and that was entrusted to West Japan Engineering Consultants Inc. (West JEC) through Ernst & Young Shin Nihon LLC and the Japan External Trade Organization (JETRO) (Ernst & Young LLC et.al, 2010). The objective of the study was to assess the capacity of the geothermal resource to generate electricity and to determine the technical and eco-financial feasibility of the project. This was done by integration all the existing information and of the execution of MT geophysical survey. The study outlined subsequent two phases for the Expansion and power development. In Phase II the drilling and testing of appraisal

wells will be conducted and preparation to conduct this phase are on going and in the third phase drilling of additional wells and construction of a 35 MW plant is planned.

Future Strategies

Rationale for Strategy

During the past several decades, Ethiopia faced repeated cases of impending or actual power shortages. Reliance on hydro-power has exposed the Ethiopian power sector to the vagaries of periodic drought as it limited the power that could be generated. Consequently, it is planned to diversify the power generation mix. Specifically, this will be done through utilizing indigenous energy resources that are economically competitive, reliable and have a low environmental impact. According to worldwide experience, geothermal resources meet these criteria. Indeed, geothermal is known to be a cheaper energy source. Besides, in Ethiopia it is more intensively studied compared to other renewable resources.

Currently, the desire to increase geothermal development and utilisation in Ethiopia is on account of the:

- Critical role of energy in socio-economic development of the country
- Energy demand growth
- Rural Electrification focus
- Increasing world oil price
- Vulnerability to drought of the hydro power (currently, the main energy supply)
- Availability of a Clean Development Mechanism (CDM)
- Readily available local qualified geoscientists and engineers and equipment (Deep drilling Rigs etc..), for geothermal exploration and development and
- Existence of identified potential geothermal prospect areas

Strategic Plan for Geothermal Development

Six areas which are at advanced stage of exploration are selected as a prime target of near future Geothermal Development of the country. From these areas it is recognized that a total of about 450 MW geothermal energy could be developed in the next 8 years. It is known that the development of geothermal resources is generally more expensive than for a similar capacity hydro electric scheme on a $/kW installed basis. Within Ethiopia however, the level of exploration drilling that has been completed at Aluto and Tendaho, and the potential availability of existing drilling equipment should assist in reducing the cost of the next phases of development

The main criteria for prioritization of various prospect areas for undertaking further exploration and development are: (i) State of advancement of exploration level (Technical); (ii) The relative strategic location (proximity to the existing National grid as an economical factor), and; (iii) Population density of the areas (GSE and EEPCO, July 2008).

Based on these main criteria, the following geothermal prospect areas have been selected (in order of priority) for further exploration and development: (i) Aluto-Langano, (ii) Tendaho (iii) Corbetti, (iv) Abaya, (V) Dofan and Fantale and (vi) Tulumoye

The strategies in each geothermal prospect area are developed in terms of:

- Additional work required to fill knowledge gaps;
- Estimated time to complete the work;
- Estimated potential (MWe) of the field; and
- Required input to implement the project (Human resource, Finance, equipment).

The projected electrical potential of these areas is tabulated in Table 1.

Table 1: Projected output of six selected geothermal prospects in Ethiopia

No.	Prospect Area	Estimated out put (MWe)	Estimated time to develop (Years)
1.	Aluto-Langano Geothermal Field	≈ 75-100	3-5
2.	Tendaho Geothemal field	≈ 100	4-5
3.	Corbetti Geothermal Prospect area	≈ 75-100	5-6
4.	Abaya Geothermal Prospect Area	≈ 100	5-6
5.	Dofan and Fentale Geothermal Prospect area	≈ 60	5-6
6.	Tulu Moye Geothermal Prosepect Area	≈ 40	5-6
	Total	450	

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