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Status of Geothermal Exploration and Development in Ethiopia

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ABSTRACT

Ethiopia is endowed with large geothermal potential. So far 25 prospect areas of high enthalpy geothermal resources have been identified with an estimated electrical potential of over 10,800 MW. These resources are located in the Ethiopian Rift Valley, which is part of the East African Rift System. The country has also extensive low to medium enthalpy geothermal resources.

The current total installed electrical capacity from all sources has reached about 4,500 MW (mainly from hydro), with geothermal only contributing 7.3 MW. The country has planned to develop additional over 12,000 MWe from all renewable energy sources by 2030. Of this plan, 1710 MW is expected to be developed from the high enthalpy geothermal resources. The utilization of the low to medium enthalpy geothermal resources has been so far limited to bathing, in spas and swimming pools. However the exploitation of the resources for direct applications, such as green house heating, drying, aquaculture and industrial uses is foreseen in the near future.

The energy policy goal of the government is to ensure a reliable supply of energy at the right time, at affordable price, in support of agricultural and industrial development. The strategy is to produce all electricity from hydropower, geothermal, wind, solar and other renewable resources, promote energy efficiency and reduce the role of hydrocarbon fuels in transport and industry. The national network of grid transmission and distribution is reserved for the public sector, where as generation and sell to the national grid, as well as the off grid space is open to both the public and the private sector. To create enabling environments for the private sector, a new geothermal law and regulations has been put in to force.

The public sector is currently engaged in surface exploration and deep drilling in selected areas (Aluto Langano and Tendaho prospects). The near future plan is to develop 70 MW from Aluto Langano prospect.

With regards to private sector participations, four private developers have concessions in various geothermal prospects of the country and are completing surface explorations to conduct deep exploration drilling. The contribution of geothermal electricity from independent power producers (IPP's) may reach 1640 MW's by 2030.

1. INTRODUCTION

Ethiopia is located in the horn of Africa between 3.5°N and 14° N and 33°E and 48° E. The country has an area of 1.14 million km^2 and a population of over 100 million, CSA (2016). The government setting has been federal democratic republic with nine regional states.

The Ethiopian economy, which is a non- oil-driven economy, has grown on average rate of 10.2 % for the last 10 consecutive years. The continuous economic growth has influenced the growth of energy demand, including electricity. The electricity demand is over 20 %, since recent years. The economy is agricultural led with major exports of coffee, oil seeds, animal skin and horticultural products.

The sources of energy in Ethiopia can be generally categorized into two major components: (i) traditional (biomass) and (ii) modern (such as electricity and petroleum). From the total energy consumption 87 % is from traditional and derived biomass, 10 % is from petroleum products and coal and only 2% is from electricity, Eshetu (2019). The total installed electrical capacity has reached about 4500 MW. From these, about 4070 MW is from hydro, about 7 MW from geothermal, 350 MW is from other renewables and 90 MW from fossil fuels.

The government policy direction is to generate virtually all of electricity from clean and renewable sources centered on hydropower, geothermal, wind, solar and other renewable energy resources, Eshetu (2019). It aims to facilitate the development of energy resources for economical supply to consumers. It seeks to achieve the accelerated development of indigenous energy resources and the promotion of private investment in the production and supply of energy. Electricity supply, as an element of the development infrastructure is being advanced in two fronts: (a) the building up of the grid based supply system to reach all administrative and market towns, and (b) rural electrification based on independent, privately owned supply systems in areas where the grid has not reached.

An independent power producer (IPP) may engage in power development for selling the generated electricity to the public utility, Ethiopian Electric Power (EEP). However, captive geothermal power generation, i.e. generation for own use in primary economic production or service industries owned by the developer is possible. Engineering, procurement and construction (EPC) turnkey contracts could be negotiated and signed between private companies and the public utility, in which the private sector would have the role of not just as a project developer but also as a critical stakeholder that can bring financing to the table under the right circumstances. Recently, policies on public private partnerships (PPP) options are also put into force.

A new geothermal law for operation of geothermal activities for both the public and private sector has been approved. The proclamation cited as the “Geothermal Resources Development Proclamation” has been put in to force in 2016. The objectives of this proclamation are to: (i) ensure that the country’s geothermal resources are developed in an orderly, sustainable and environmentally responsible manner; (ii) support the generation and delivery of electricity from geothermal energy for local consumption and export; (iii) promote the use of low enthalpy geothermal resources for direct uses including space heating and cooling, industrial and agricultural processes, refrigeration, green housing, aquaculture and balneology; (iv) ensure security of tenure for all investors in respect of geothermal resources development operations; and (v) encourage a sustainable, carbon-neutral economy in Ethiopia, Federal Negarit Gazette (2016) .

The geothermal exploration work by the public sector to date has been carried out by the Geological Survey of Ethiopia (GSE), and has benefited from a number of technical cooperation programs. The most recent technical assistances and funding are from Icelandic International Development Agency, United Nations Environment, French Development Agency, the World Bank and Japan International Cooperation Agency. EEP is the sole public developer of energy including from geothermal. Since recent years IPP’s are also involved in geothermal research and development. The Ministry of water, irrigation and energy gives general directions on energy policy and regulatory issues. A geothermal licensing and administration directorate under the Ministry gives geothermal licenses and administers it.

This paper mainly highlights: the status of geothermal resources exploration, its utilization and future geothermal development plans in Ethiopia.

2. GEOTHERMAL RESOURCES EXPLORATION

2.1 Geology background

The East African Rift system cuts Ethiopia from north east to south west forming a topographic depression, known as the Ethiopian Rift system (Figure 1). The Ethiopian Rift system is divided in to: the Main Ethiopian Rift (MER) and the Afar depression. The MER extends in a NNE-SSW trend and is dominated by occurrences of silicic volcanoes with underlying remnant magmas as heat sources. On the other hand, volcanism in the Afar depression has been related, mainly to a NW-SE trending fissured structural systems with some eruptive centers. The composition of the lavas produced in Afar ranges from basalt dominated to siliceous types. The lower elevations of the Rift floor are mainly filled with young sediments of Quaternary age. These includes: conglomerate, sand, clay and lake sediments.

2.2 Exploration background

Ethiopia has started geothermal exploration in 1969, within the Ethiopian sector of the East African Rift system. The initial exploration has been reconnaissance, covering the whole rift system. Under this survey, about 120 localities within the rift system were believed to have geothermal systems and from these, about two dozen were judged to have potential for high enthalpy resource development. A much larger number have been considered as low to medium enthalpy resources, suitable for direct utilizations, UNDP (1973). The geothermal sites are geographically distributed from the south western part of the Ethiopian Rift up to the north eastern part. Currently, the number of identified high temperature prospect areas has reached 25 (Figure 2).

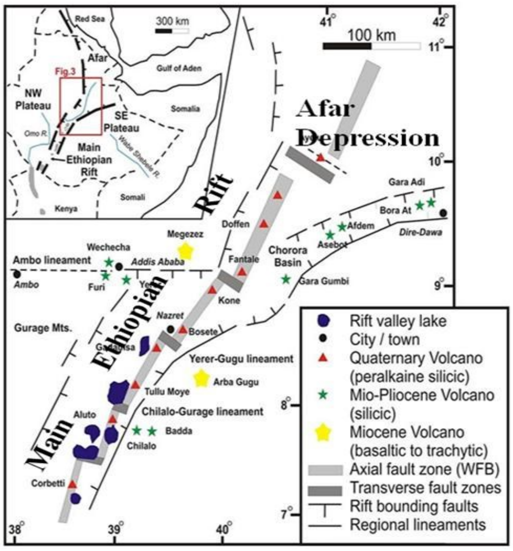

Figure 1: Geological set up of geothermal prospects in Ethiopia

Since the late 1970's, geo scientific surveys mostly comprising geology, geochemistry, and geophysics, were carried out at the southern-central part of the Ethiopian Rift and Tendaho prospect in Afar to the north. In addition, a semi detailed surface exploration of ten sites in the central and southern Afar has been carried out in 1986, GSE and ElC (1986).

Exploration work by deep test well drilling has started during the early to mid 1980's, when exploration drilling was carried out at Aluto Langano, in the southern part of the Rift. Eight exploratory wells were drilled with four of these proving productive. A power plant of 7.3 MW has been installed in 1998 using the productive wells.

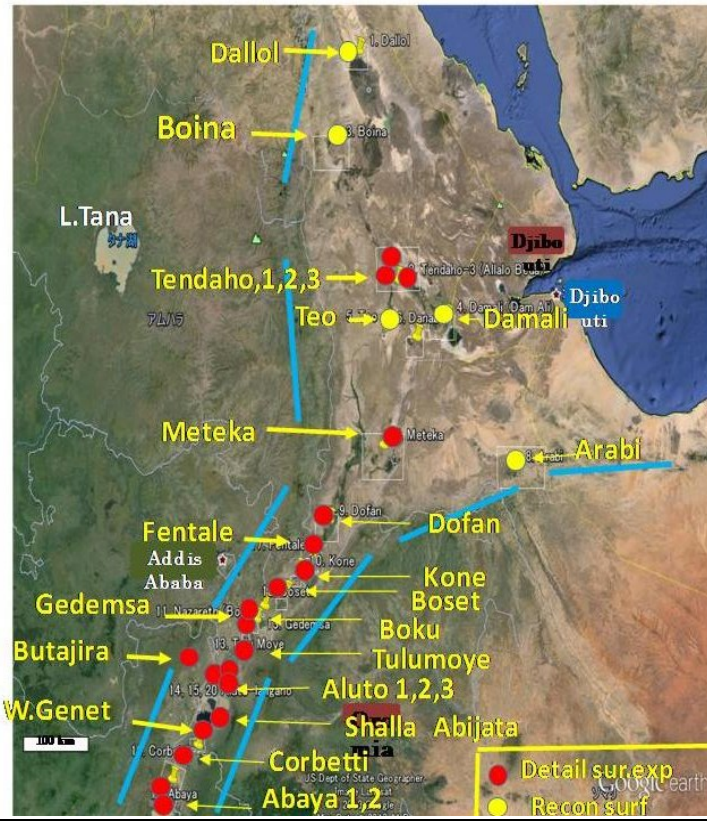

Figure 2: Location map of geothermal prospects in Ethiopia

Further explorations in the late 90's have tested the Tendaho prospect in Afar by drilling of three deep (average 2000 m depth) and three shallow (500 m depth) wells. From the six wells drilled, the three deep wells have encountered high temperature (as high as 270° C) but poor permeability, while the three shallow wells have been productive with temperature of over 250 ° C.

2.3. Recent geothermal exploration and development

Recent exploration and development activities in the country are being carried out by both the public and the private sector.

2.3.1 Activities being carried out by the public sector

Master plan study

A geothermal master plan study has been completed in 2015. The project has conducted geo scientific, social and economic surveys in 22 prospects, for potential estimation and prioritization of the resources for development. The results of the study have showed that the total geothermal electrical potential of the 22 prospects is estimated upto 10,800 MW. Ranking of the prospects for development has also been made on the bases of geothermal knowledge, potential, economics, and site specific factors, GSE and JICA (2015).

Surface explorations

From the 25 prospect areas, so far, 19 prospects have been explored in detail by surface exploration with the participation of the private and public sector (Figure 2). Under the public sector recent surface investigations (mainly geology, geochemistry, geophysics (MT/TEM, gravity and micro seismic) have been carried out at Aluto Langano , at Tendaho (Ayrobera and Allalobeda), Shalla-Abiata, Butajira and Meteka prospects. At Aluto Langano, the results have indicated that there is an additional upflow center east of the previously drilled productive wells, in an area locally known as Bobesa. A conceptual model has been developed for this new area, which have indicated a potential of 35 MWe, in addition to the previously estimated 35 MW to the prospect, ElC (2016). In the other prospects, conceptual models have been also developed and priority target areas for test well drillings have been indicated.

Deep drilling and testing

At Aluto Langano prospect, the drilling of two appraisal wells for reservoir modeling and subsequent selection of production wells has been carried out in 2013 and 2014. The wells, LA-9D and LA-10D, each have been completed to depths of 1920 m and 1951 m respectively. Both wells are productive with bottom hole temperatures of over 300º C. Testing of the wells has indicated that the two wells together may sustain about 5 MW electricity. Installation of a well head turbine on the two wells is under consideration for early power generation.

Reservoir simulation has been conducted using data from the newly drilled wells at Aluto, including data from previous wells, to estimate the potential of the area around, for initial phase of conventional power plant installation. The results of 5 cases (25 MW, 35 MW, 45 MW, 55 MW and 65 MW) in generation capacity of forecasting simulation were considered and analyzed. Based on these results, it is preferred to develop first a 35 MW unit power plant.

2.3.2 Activities carried out by the private sector

Currently four private companies have concessions in various prospects. Most of them have completed surface exploration and have selected target areas of drilling. Two of the companies have an ultimate plan of developing about 1040 MW from two prospects, Lemma (2014). Next steps in exploration activities of the private sector would be the drilling of test wells.

3. GEOTHERMAL UTILIZATION

The utilization of geothermal resources for electric power in Ethiopia is so far limited to the only pilot plant of 7.3 MW that has been installed at Aluto Langano in 1998. The plant has been functioning intermittently, due to technical problems. It has been using steam from two of its highest temperature wells to run a steam turbine and two of its lower temperature wells were being used to heat a working fluid, known as iso pentane to run another turbine. The plant is currently under maintenance.

Direct use applications in Ethiopia are limited to bathing and swimming. A number of resorts, hotels and parks have been utilizing hot water and steam for bathing, in swimming pools and for balneological purposes. The energy used for these direct utilizations has not been yet determined.

4. DISCUSSION

Ethiopia is endowed with large geothermal potential, but currently the dominant source of electricity generation is hydro. The overdependence on hydropower makes energy supply unstable, resulting in heavy strains on the supply of the energy during periods of draught and thus additionally a more stable geothermal power is considered essential as base load. Compared to cost of large hydro electric generation, geothermal generation is considered more expensive in Ethiopia and focus has been given to large hydro projects, because of a least cost development strategy. However compared to solar, wind and small hydro generations, geothermal is cost competitive and has an additional advantage of availability. Geothermal is even much cheaper, compared to fossil fuels, which are being imported at high cost in foreign currency.

The least cost development strategy of the country in the past, which has compared geothermal to large hydro, had given little attention to its development. As a result, the wells drilled in geothermal, number of geothermal professionals so far involved and the level of investment in the geothermal sector has been indicated to be insignificant (Appendix, Table 3 to 5).

From past experience, the unfavorable periods of severe droughts have been creating shortfalls in hydroelectric generations in the country. The base load nature of geothermal electricity makes it suitable to avert the shortfalls and complement hydro generation. As a result geothermal development in Ethiopia is being given more attention recently than before.

Currently geothermal is: (i) integrated in the national energy development master plan, (ii) participation of international financial institutions, bilateral donors and development agencies, to assist geothermal development projects has grown and (iii) the public sector is implementing various geothermal projects and the private sector is being encouraged to participate in geothermal development projects,. Therefore, Ethiopia is expected to connect thousands of MWs of geothermal power in to the grid in the long term.

4. FUTURE DEVELOPMENT AND INSTALLATIONS

On the bases of the country's energy development plan, production of electricity in Ethiopia has to reach 16,942 MW by 2030. This includes generation from hydro, geothermal, wind, solar and waste to energy (Appendix, Table 1). The total planned geothermal electricity by 2030 is 1710 MW (Appendix, Table 2). This geothermal development goal is expected to be achieved with investments from both the public and the private sector.

The Aluto Langano and Alalobad geothermal fields are some of the priority areas in the current public-sector projects and preparations are being conducted for drilling of deep wells to be followed by construction of power plants. Under the framework of Geothermal Sector Development Project of the World Bank, the two geothermal prospect areas are to be drilled with a total finance of 218.5 million USD, funded by the World Bank (major financer), Government of Iceland and Government of Ethiopia. Concessionary loans for the power plant are expected from the Government of Japan. At Aluto Langano geothermal field, it has been planned to drill up to 22 geothermal wells with potential to develop 70 MWe in two phases. Procurement of two drilling rigs with provision of drilling operation has been carried out and drilling is ecpected to commence in early 2020. At Alalobad area of Tendaho prospect, 4 deep test wells will be drilled to explore the site and identify its resource potential. A feasibility study will be conducted to define the future developments at Alalobad, EEP (2017).

Corbetti and Tulu Moye prospects are on the way forward for development by IPP's, with drilling activities to commence soon. A total geothermal electrical power generation of 1040 MWs is expected to be developed from the two prospects in the long term. Other private sector investors are operating at Shashemene, Dofan, Boku, Dugna Fano and Fentale prospects and are at present negotiating PPA's to commence geothermal development (Eshetu, 2019).

Regarding direct utilization, apart from the use in swimming pools, there a number of potential applications suitable for Ethiopia's climate conditions, including in: paper and pulp factories, sugar refining, drying and curing of cement, drying of agricultural products, heating of green houses and fish farming. The Geological Survey of Ethiopia has a plan to study the technical feasibility of some of these applications in pilot areas to promote direct uses by the public and the private sector.

APPENDIX (Table 1 to 5)

	Geothermal		Fossil Fuels		Hydro		Other renewables (specify)*		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	7.3	58	89	460	4,077	16,245	349	1,007	4,522.3	17,770
Under construction in December 2019	70	520	-	-	10,390	30207	220	770	10,680	31497
Funds committed, but not yet under construction in December 2019	1640	8549	-	-	-	-	100	210	1740	8759
Estimated total projected use by 2020	7.3	58	89	460	4,077	16,245	569	2,164	4742.3	18, 927

*Other renewable include: wind solar and waste to energy

Table 1: Present and planned production of electricity in Ethiopia by 2030

No	Locality	Power plant name	Year commissioned	No. of units	Status1)	Type of unit	Total Installed Capacity MWe)	Total Running Capacity MWe)	Annual Energy Produced 2019 GWh/yr	Total under Constr. or Planned MWe
1	Aluto Langano	Aluto Langano	1998	2	Not operating	Binary	7.3	4	20	70
2	Corbetti	-	-	-	-	-	-	-	-	520
3	Tulu Moye	-	-	-	-	-	-	-	-	520
4	Shashemene	-	-	-	-	-	-	-	-	100
5	Dofan	-	-	-	-	-	-	-	-	100
6	Boku	-	-	-	-	-	-	-	-	100
7	Dugna Fano (Abaya 2)	-	-	-	-	-	-	-	-	150
8	Fentale	-	-	-	-	-	-	-	-	150
	Total									1710

No 1 is under construction, No 2 and 3 are at financial closure, No 3 to 7 are under PPA negotiations.

Table 2: Present and planned production of geothermal electricity in Ethiopia by 2030

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration)						
Production	>150º C	2	-	-	-	1.92 & 1.95
	150-100º C	-	-	-	-	-
	<100º C	-	-	-	-	-
Injection						
Total		2				1.92 & 1.95

Table 3: Wells drilled for electrical use in Ethiopia from Jan 1, 2016 to Dec 31, 2019

Year	Professional person-years of effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	20	10	-	-	20	
2016	-	10	-	-	20	17
2017	5	11	-	5	10	21
2018	15	11	-	8	10	25
2019	40	11	-	9	10	17

1) Government, 2) Public utilities, 3) Universities, 4) paid foreign consultants, 5) contributed through foreign aid program, 6) private industry

Table 4: Allocation of professional persons with a degree to geothermal in Ethiopia.

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	60	-	-	16.5	-	100
2000-2004	1	-	-	-	-	100
2005-2009	8	-	-	-	-	100
2010-2014	5	25	-	-	-	100
2015-2019	36	218.5	-	-	10	90

Table 5 : Total investments in geothermal in Ethiopia, 1995 - 2019

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