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# GEOTHERMAL DEVELOPMENT STATUS, ETHIOPIA

Teka Nigussie Gebru

Ethiopian Electric Power (EEP)
Addis Abeba, Ethiopia
teka@grogtp.is

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**ABSTRACT**

Ethiopia, located at the Horn of Africa, between 3.5° and 14°N and 33° and 48°E, is endowed with huge renewable energy resources, namely hydro, wind, solar, geothermal, and biomass. Most of the people yet have no access to electricity and over 90% of the energy consumption is based on biomass, which forces cutting trees for firewood, accelerating impacts such as deforestation, soil erosion and the loss of wildlife. Ethiopia has currently more than 4.3 GW of installed power capacity of renewables sources and only 89 MW of diesel power generation. 3817 MW of the installed capacity are hydroelectric, 324 MW are wind power plants, 7 MW are geothermal plants, and 25 MW from waste to energy plants. The aim of this document is to present the status of geothermal development in Ethiopia, both for electricity and direct use applications.

Ethiopia has the longest section of the East African Rift Valley, which boasts an estimated geothermal potential of **10,000 MW**. Up to date, only one geothermal power plant, i.e., the Aluto Langano power plant with 7.3 MWe, has been developed but it has been out of operation since 2010, because of shortage of skilled manpower to monitor and maintain the plant properly. At present, Aluto Langano expansion project, Tulu Moye and Corbetti projects are on their phase of drilling operations while other prospects are on their early phase of exploration. A feasibility and appraisal study to expand Aluto Langano field to 75 MW by drilling of appraisal and production wells has been conducted in 2010 and 2015, respectively, with the assistance of the Japanese government. Out of the 24 geothermal prospects identified, more than 90% of them are leased to independent power producers (IPPs) for a long-term development.

Geothermal utilization in Ethiopia is also for direct use applications, like hot spa services and tourism industry as well as salt production. Geothermal utilization in Ethiopia goes back to one century, when Emperor Minilik and his spouse princess Taytu were on power for about three decades. Princess Taytu built a hot spa for the royal family at that time, which currently is open to the public with the name 'Fil Wuha' --local term meaning hot spring water. In 2016, a proclamation for geothermal energy development, known as Geothermal Resources Development Proclamation No. 981/2016, was approved, and consecutively in 2018 it was enacted a proclamation that manages Power Purchase Agreements (PPA) with private electricity producers.

## 1. INTRODUCTION

Ethiopia has the longest section of East African Rift Valley, which boasts an estimated geothermal potential of **10,000 MW** (Kebede, 2014). Geothermal exploration in Ethiopia was started in 1969 with a regional geological-volcanological mapping and hydrothermal manifestation inventory in most of the Ethiopian Rift, and revealed high and low enthalpy geothermal resources in the Ethiopian rift valley shown in Figure 1 and Afar depressions (Kebede et al., 2002).

The presence of the Main Ethiopian Rift (MER) in the East African Rift System (EARS) indicates probable heat sources at depth, and transverse faults suggest fractured reservoirs, an ideal situation for the existence of high-temperature geothermal resources. The MER is dominated by a series of diagonal rift basins that has been differentiated into the north, central and south sections. Even though 24 geothermal prospects have been identified so far along the main rift, to date only one geothermal power plant, Aluto Langano power plant, with 7.3 MWe, has been developed by the government. On the other hand, multiple geothermal prospects have been leased to private companies (IPP) to produce power, which could help the government to increase the electricity coverage in the country. Besides electricity generation, direct utilization of geothermal resources, such as for bathing and recreational services, has become popular in some cities like Addis Abeba, Adama, Awassa, and small towns such as Langano and Wendo genet. The

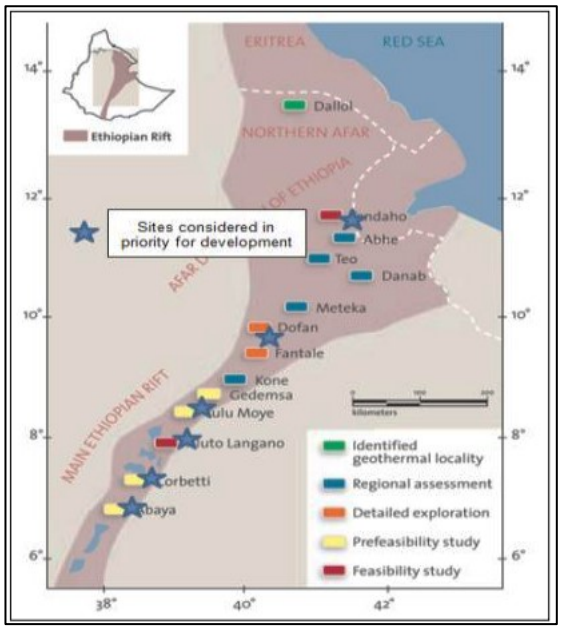


**Figure 1: A map showing the Ethiopian Rift Valley and locations of Geothermal prospects (taken from Kebede, 2014).**

tourist attraction from the abundant geothermal resources is an additional source of income in areas like the Dallol active volcano of Afar region.

## 2. ENERGY DEVELOPMENT IN ETHIOPIA

Ethiopia is endowed with huge renewable energy resources, namely hydro, wind, solar, geothermal, and biomass. However, most of the population have no access to electricity and over 90% of the energy consumption is based on biomass, which means the cutting of trees for firewood, accelerating impacts such as deforestation, soil erosion and the loss of wildlife. The government's Energy policy aims at facilitating the development of renewable 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 part of the development infrastructure is being advanced in two fronts, as clearly stated Kebede (2014): (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. The Ethiopian government currently has fixed a groundwork for the participation of private sector investment in power generation to meet the country's needs both on off grid and on grid scale. This allows investments of private sector in power generation without any capacity limits, with one of the main prerequisites being reaching an off-take agreement (PPA: power purchase agreement) with the national grid operator, i.e. Ethiopian Electric Power (EEP). EEP develops procurement procedures to select contractors and award projects using a competitive bidding process. Currently, few IPPs are involving independently for electricity production in Ethiopia. Tulu Moye Geothermal Operations, Corbetti Geothermal company, the Italian Enel Green Power company and the Saudi ACWA Power company are the companies interested in geothermal who have signed PPA with EEP and already have launched their construction operations on the ground to start producing electricity from geothermal resources. Furthermore, various geothermal, solar, wind and hydropower projects are on the pipeline to be licensed in the near future to private firms for power generation.

Ethiopia has currently more than 4.4 GW of power installed capacity with more than 16 power plants. Table 1 presents the renewable source power plants in operation, excepting the geothermal power plant and a power plant fueled by diesel of 89 MW. All of them were developed by the state. Thus, 3,817 MW of the installed capacity are hydropower, 324 MW are wind, 25 MW are based on waste-to-energy, and 7 MW is geothermal. The share of these energy sources is shown in Figure 2.

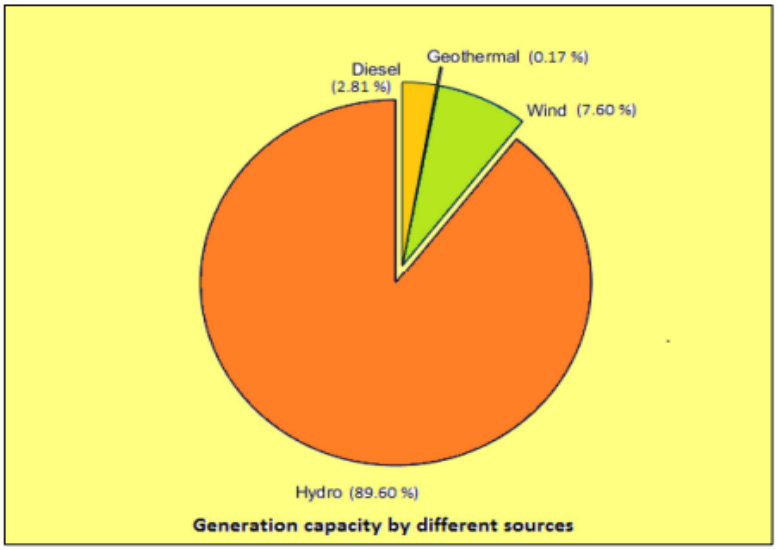


**Figure 2: Different sources Electricity Generation in Ethiopia (Khan & Singh, 2017).**

The government aims to increase the electricity access from 26% (2014) to 60% by 2040. Additionally, the enhancement in the efficiency of existing energy sources is another target (Khan & Singh, 2017). With the plan to reach at least 10% non-hydro renewable energy mix in the grid, a target has been set by the government for contributions from other renewable energy sources. New research on the integration of Variable Renewable Energy Sources (VRES) in the National Electric System of Ethiopia, shows that the country can accommodate up to 3.6 GW of wind capacity and as much as 5.3 GW of solar capacity by 2030 based on the study by (Enel Foundation&Res4africa, 2019).

According to information from EEP, 11% of the population have electricity access through off grid systems. Even though the currently generating electricity is 11,000 GWh, the consumption reaches about 9000 GWh. Its coverage stands at 45% but lowers to 36% in case of rural areas, while per capita income of electricity is approximately 79 kWh. Ethiopia sales electricity to Djibouti and Sudan (up to 100 MW each). There is a plan to increase power exports to Djibouti up to 400 MW due to a growing demand in the region. Ethiopia is also negotiating a PPA to begin power export to Kenya for up to 400 MW. Based on the government's energy plan, Ethiopia has prioritized 300 MW of solar PV projects dispersed across three sites, 820 MW of wind power to be located in four sites, 570 MW of geothermal power to be developed in four sites, and an extra 3879 MW of new hydro plants in eight different sites to be developed by IPPs. In February 2018, Ethiopia enacted a proclamation that will regulate Power Purchase Agreements (PPA) arrangements, in an effort to attract investment and recognizing that the private sector is essential to supporting the country's economic growth and improving the quality of public services, particularly in infrastructure.

**Table 1: Main power plants under operation connected to the national electric grid in Ethiopia (Khan & Singh, 2017).**

| Power plant name | Installed capacity (MW) | Start operations year | Type |
|---|---|---|---|
| Aba Samual | 6.6 | 1932 | Hydro |
| Koka Awash I | 43 | 1960 | Hydro |
| Koka Awash II+III | 64 | 1966 | Hydro |
| Fincha | 134 | 1973 | Hydro |
| Fincha Amerti Neshe | 95 | 2011 | Hydro |
| Gilgel Gibe I | 184 | 2004 | Hydro |
| Gilgel Gibe II | 420 | 2010 | Hydro |
| Gilgel Gibe III | 1870 | 2016 | Hydro |
| Melka Wakena | 153 | 1989 | Hydro |
| Tana Beles | 460 | 2010 | Hydro |
| Tekeze | 300 | 2010 | Hydro |
| Tis Abay I+II | 84.4 | 1953/2001 | Hydro |
| Genale Dawa III | 254 | 2019 | Hydro |
| ADAMA I+II | 204 | 2012/2015 | Wind |
| Ashegoda | 120 | 2013 | Wind |
| Reppi | 25 | 2018 | Waste |
| **Total capacity** | **4417 MW** | | |

## 3. ENERGY MARKET LEGISLATION & REGULATION

Energy Policy of Ethiopia encourages mix up of all the renewables in the future time. Hydro generation share will have decreased from 89.5% in 2018 to 73% in 2030 while solar and wind variable energy will increase from 7.6% in 2018 to 18.8% in 2030. Geothermal share also increased from 0.2% in 2018 to 5% in 2030. The government has a plan to achieve Universal Electric Access by 2025, and launched the National Energy Plan (NEP) in 2017 to achieve 65% grid connection and 35% off grid solution by utilizing all the available sources of renewables. The future electricity mix, considering two scenarios, low and high, are presented in Table 2.

**Table 2: Forecast of future electricity capacity in MW, considering low and high scenarios (Source: Mengistie, 2019).**

| Energy type | Low Scenario | | High Scenario | |
|---|---|---|---|---|
| | **2025** | **2030** | **2025** | **2030** |
| Hydropower | 14,103 | 14,570 | 14,103 | 15,603 |
| Biofuel | 496 | 496 | 496 | 495 |
| Wind | 544 | 544 | 1,244 | 1,244 |
| Solar | 1,950 | 1,950 | 2,750 | 2,750 |
| Geothermal | 850 | 1050 | 850 | 1,050 |
| Waste | 25 | 25 | 25 | 25 |
| **Total** | **17,968** | **18,635** | **19,468** | **21,168** |

Ministry of Water, Irrigation and Energy (MoWIE) is the top regulatory body to undertake planning, development and management of resources, preparation and implementation of guidelines, strategies, polices, programs, and sectorial laws and regulations of water, irrigation, and energy. The energy sector is established as one directorate/state minister under MoWIE. The energy sector has three pillars namely, Ethiopian Electric Power (EEP), Ethiopian Electric Utility (EEU) and Ethiopian Energy Authority (EEA). The overview organization of the ministry and its subsidiaries is shown in Figure 3.

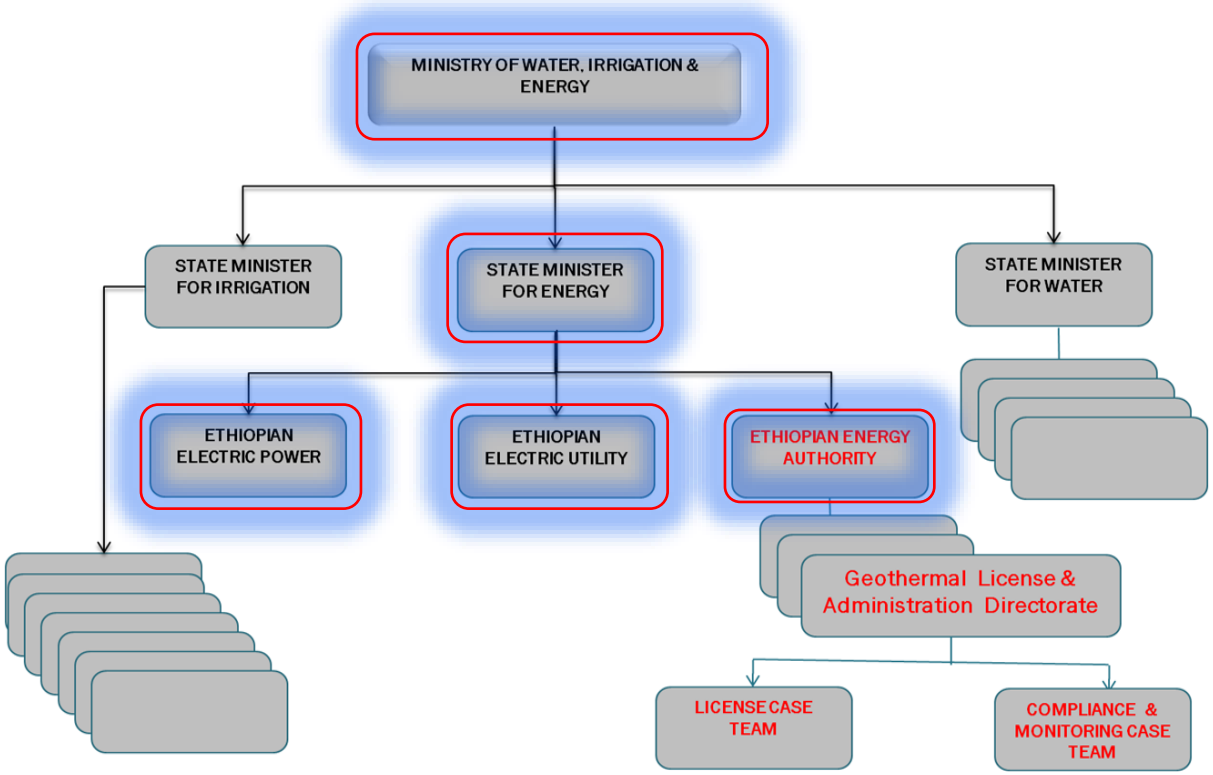


**Figure 3: Structural framework of Ministry of Water, Irrigation and Energy**.

The first proclamation on energy was passed by the parliament in 2013 and is known as energy proclamation No.810/2013. It introduces a legal framework for generation of electricity by both the state and Independent Power Producers (IPPs). The proclamation also incorporates the Power Purchase Agreements (PPAs) to be signed between IPPs and the off takers, i.e., the state-owned firms like EEP and EEU. The energy proclamation obliges the transmission and distribution network owners (EEP and EEU) to give access to other license holders with payment of a prescribed fee. The enactment of such third-party access rule can be a guarantee to IPPs that the transmission network owner will provide connection to all generation facilities without unduly favoring generation facilities owned and operated by the state. According to the proclamation and regulations, the state-owned firm EEA is the regulatory body and issues the license based on the procedures stated in the regulations.

Following the approval of the energy proclamation, subsequent legislations like Energy Proclamation Amendment No. 1085/2018, Energy Regulation No. 447/2019 and Public Private Partnership (PPP) Proclamation No. 1076/2018, were also into effect. The approval of the Ethiopian Energy Authority should be obtained once an IPP agrees to invest in Ethiopia and reaches an agreement on the respective PPA with the EEP. This agreement is to be done between two primary parties, i.e., the Power Producer/Generator/Project Company (the seller), and the Power Purchaser/off-taker, which is EEP. The PPA identifies and allocates various risks, defines the parties rights and obligations, as well as defines cash flow structure of the project. Apart from PPA, an implementation agreement (IA) should be signed between the IPPs, EEP and other governmental offices such as MoWIE, Ministry of Finance and other similar ministries. Finally, the IPP starts operations, once the the PPA and IA have been signed, as well as further permits are granted, such as the principal registration certificate, land permits and investment permits.

### 3.1 Ethiopian Electric Power (EEP)

As mentioned before, EEP is one of the firm under the umbrella of MoWIE engaged in construction, generation, operation, and development of electric projects from hydro, geothermal, wind, sunshine and waste, and the construction of power transmission lines. It is the state monopoly in generating electric power for the national power grid, until at least some IPPs commence generating electricity. Making Power Purchase Agreement (PPA) negotiations with IPPs is also other duty of EEP. EEP is currently owning, administrating, operating and maintaining 14 hydropower, three wind power, one geothermal, one waste energy and six power diesel plants throughout the country. Projects including the new big projects for hydroelectric dams and other hydro, wind and solar, and future geothermal projects are still carried out by EEP.

### 3.2 Ethiopian Electric Utility (EEU)

EEU is the sister company of EEP, whose mandate is to sell and purchase bulk electric power on transmission lines up to 66 kilovolts level, to undertake construction and upgrading of off-grid electricity transmission lines and substation up to 66 kilovolts, administer, operate and maintain off-grid electricity generation, transmission lines, substations and distribution up to 66 kilovolts, undertake feasibility studies, design and survey off-grid electricity generation, and construction of transmission lines and substation up to 66 kilovolts and finally to submit proposal for electricity tariffs and implement them upon approval. Depending on the type of the work, it is common the company contract external companies and consultants.

### 3.3 Ethiopian Energy Authority (EEA)

EEA is the other sister company of both EEP and EEU. Its activity is reviewing national grid related tariff submitted by a licensee and submit its recommendation to the government for approval, approving PPAs and network service agreements, collecting analyzing, organizing and disseminating information relating to energy efficiency and conservation, regulating energy by managing electric and geothermal generation licenses, issue and renew or extension, issue and renew certificate of competency, supervising the operations of licensees and holders of certificates of competency, promoting energy efficiency and conservation at national and sectorial levels, promoting and coordinating energy efficiency and conservation research, development and demonstration and technology transfer activities.

## 4. GEOTHERMAL LEGISLATION AND REGULATION

Until 2016, there was no legislation and regulation dealing specifically with geothermal projects to be carried out by both the government and IPPs. Geothermal projects were treated by the proclamation set for energy development at broader term in 2013. This resulted in delaying geothermal development projects, especially by IPPs. In 2016, a specific proclamation for geothermal projects, known as Geothermal Resources Development Proclamation No. 981/2016 was approved, and consecutively in 2018, it was enacted the proclamation that manages Power Purchase Agreements. As mentioned in previous section, EEA is the responsible governmental organ that regulates and monitors all energy related developmental permits, including geothermal.

Geothermal licenses are issued by a sub department called Geothermal Resource Development and Licensing Directorate (GRDLD) under the umbrella of EEA. GRDLD by itself is further divided into two teams: License and Administration Case Team (LACT) and Compliance and Monitoring Case Team (CMCT). The main activity of the first team is issuing Grade I and Grade II geothermal licenses to IPPs that fulfill the requirements in accordance with Geothermal Laws, as well as issuing certificate of professional competency for geothermal consultancy services, technical works and drilling permits. The main functions of CMCT are follow up and administer reconnaissance, exploration and well-field development and use licenses, facilitate mineral samples exports, verify and provide supporting letters for custom duties and tax free, work permits and visa requests in accordance with the Geothermal Laws, and finally approve or issue permits as appropriate to drilling plans and programs, well design plans and drilling permits applications.

Another legislation, Geothermal Resource Regulation No. 453/2019 that handles geothermal development licensing procedure, was signed by MoWIE in 2019. According to the regulation, geothermal is classified as Grade I (Electricity Generation) and Grade II (Direct Use), and includes three categories of licenses: reconnaissance survey license, exploration study license and well-field development and use license. The license period for reconnaissance tasks is set to be 24 months without extension, in a maximum area of 2,000 $km^2$. The period for exploration work licenses is 5 years with possibility of two extensions of one year each with a maximum surface of 200 $km^2$, while the period for well-field development license is fixed up to 25 years and the maximum area is set at 50 $km^2$. All these features are shown in Table 4.

Following the approval of geothermal energy legislation and regulation, multiple private sectors were motivated to invest in the geothermal. Currently, two IPPs (Tulu Moye and Corbetti Geothermal Companies) are conducting drilling and implementation activities in the prospects of Tulu Moye and Corbetti, respectively, and other IPPs like Reykjavik Geothermal, OrPower12, Inc, and Cluff Geothermal, are engaged in geothermal exploration activities in the country.

## 4. GEOTHERMAL ENERGY UTILIZATION

Geothermal energy in Ethiopia is used both for power generation and some direct applications, mainly bathing and tourism services.

### 5.1 Bathing services

Historically, geothermal utilization in Ethiopia began in 1886, when Empress Tayitu, the wife of king Menelik II, built a bathhouse for herself and members of the royal court near the Filwoha, an Amharic term which means “boiled water” (Nigussie, 2017). The facilities at these hot springs are still open, but now for all public. As the Empress spent more time there, she also built a small home nearby and established a church. Eventually, the small home became the National Palace, while the church became the Holy Trinity Cathedral.

**Table 4: Summary of Geothermal Legal framework for licenses of Grade I, according to the geothermal regulation No. 453/2019.**

| Type of Licenses Grade I | License Period | Details |
|---|---|---|
| Reconnaissance License | • 24 Months,<br>• No Renewal | • Non-exclusive,<br>• Non-competitive<br>• Up to 2,000 sq.km |
| Exploration License | ▪Valid for an initial period specified in the license, Provided, however, such period not exceeds five (5) years,<br>▪Can be renewed twice for a period not exceeding one year each | • Exclusive,<br>• Up to 200 sq.km |
| Well-field Development and Use License | ▪Valid for an initial period specified in the license, Provided, however, such period not exceeds twenty five (25) years,<br>▪Government may continue the development of the resource as it finds feasible | • Exclusive,<br>• Up to 50 sq.km |

As Ethiopia is endowed with many natural hot springs and lakes, people enjoy these facilities, among which are Sodere, Langano lake, and Wendo Genet (Figure 4). These facilities receive hundreds of visitors every day.


**Fig. 4. Sodere (up left), Lake Langano (up right) and Wendo Genet (bottom) hot springs.**

### 5.2 Touristic attractions and salt production

The presence of active volcanoes and mineralized hot spring in the Afar region, northeast part of Ethiopia, is a huge touristic attraction which provide income for the surrounding communities, as well as for the country. Erta Ale volcano, in Denakil depression and Dallol mineralized hot spring waters, are among the main ones visited by national and foreign tourists (Fig. 5).

**Fig. 5: Left: Dallol mineralized hot springs with temperatures >40°C and acidic springs. Right: Erta Ale volcano with continuous lava flows.**

On the other hand, due to presence of salt minerals in the hot spring, both local people and some companies are involved in salt production and distribution of salt to the rest of the country. Most Ethiopians, especially those residing in rural areas, utilizes this salt, and so it can be said that the most locally produced indigenous material in Ethiopia is salt.

### 5.3 Electric Generation

**Figure 6: Aluto Geothermal Binary Power Plant, commissioned in 1998.**

Due to its unique feature among renewable sources, of not being influenced by climate variation, and its availability in huge scale, geothermal proved to be a reliable source of electric power in Ethiopia. After completion of 8 vertical wells, in 1998 it was commissioned a 7.3 MWe binary power plant (Figure 6) that consists of two units: a Geothermal Combined Cycle Unit (GCCU) and an Ormat Energy Converter (OEC) installed at the Aluto geothermal field. It was installed as a pilot plant to test the geothermal resources and to identify any resources or issues that could affect the power plant, as well as to provide power to the interconnected grid system.

Construction of the power plant began on January,1997. Ormat supplied and installed both units (the GCCU and OEC), each rated at about 4 MWe gross. The GCCU is composed of a conventional steam turbine and an organic turbine, each driving opposing ends of a single generator. The plant has faced several challenges and interruptions, and finally in 2010 the plant stops operations. The main reason is the lack of proper monitoring of the production wells and lack of planned and proper maintenance and operations, particularly of the electromechanical parts of the plant.

At present, several IPPs have shown a high interest to invest in geothermal power generation, and some of them already launched their implementation following PPA negotiations with the government, which considers geothermal development as a high priority.

## 5. GEOTHERMAL PROJECTS

In Ethiopia there are currently three geothermal projects in development, at the drilling stage. They are the Aluto project, carried out by the state firm EEP, and the Tulu Moye and Corbetti projects, each one carried out by private companies. There are also several other prospects in early phases of development. As mentioned before, the only geothermal power plant, Aluto Langano, is out of operation since 2010.

Besides, one wellhead power plant is programmed to be constructed by EEP in the near future, in the same geothermal field of Aluto, with financing granted by the Japanese government. Table 5 summarizes the main geothermal projects in the country, and their current status.

**Table 5: Current geothermal projects in Ethiopia.**

| Geothermal project and field | Field Developer | Current status |
|---|---|---|
| Aluto-Langano | EEP | Drilling operation, with 6 wells already drilled, the deepest at 2500 m. Hydrothermal reservoir of vapor dominant type. |
| Tendaho-Alalobad | EEP | Drilling Preparation-Suspended |
| Tendaho-Dubti | EEP | Drilling Preparation-Suspended |
| Tulu Moye | TMGO PLC | Drilling Operation |
| Corbetti | Corbetti Geothermal PLC | Drilling Preparation |
| Abaya | Reykjavik Geothermal Company | Exploration License |
| Boku | Or Power 12 Inc | PPA Negotiation |
| Boseti | M&M Trans Africa PLC | Exploration License |
| Butajira | Cluff Geothermal Ltd / Hot Spur Geothermal | Exploration License |
| Duguna-Fango | Or Power 12 Inc | PPA Negotiation |
| Dofan | Or Power 12 Inc | PPA Negotiation |
| Fentale | Cluff Geothermal Ltd | PPA negotiation |
| Kone | M & M Trans Africa PLC | Exploration License |
| Meteka | Red Rose Meteka Ltd | Exploration License |
| Wendo Genet | Or Power 12 Inc | Exploration License |

### 7.1 Aluto Langano Geothermal Project

The Aluto-Langano Geothermal field is one of the high temperature prospects located in the main Ethiopian rift valley, close to the lakes district, at 7.788° East and 38.795° North, about 180 km far south of the capital city, Addis Ababa, in the Oromia regional state (Figure 7). This field has been prioritized with commercial interest since 1969 by conducting several geoscientific investigations that confirmed temperature higher than 200°C at a depth of 1000 m. Some downhole temperature logs of some wells are reported to be up to 300°C. A total of 10 deep exploratory wells have been drilled at Aluto geothermal field to a maximum depth of 2500 m. Eight of those wells (LA-1 to LA-8) are vertical, drilled between 1983 and 1986, and two of them, LA-9D and LA-10D, are the first directional wells in Ethiopia, drilled to a depth of 1920 and 1950 m, respectively, and completed in 2016. The exploration and development work has been financed by different governments and donor organizations, such as the governments of Italy, New Zealand, Iceland (through ICEIDA), Japan (through JICA), United Nations Development Program (UNDP), World Bank (WB) and the Nordic Development Fund (NDF).

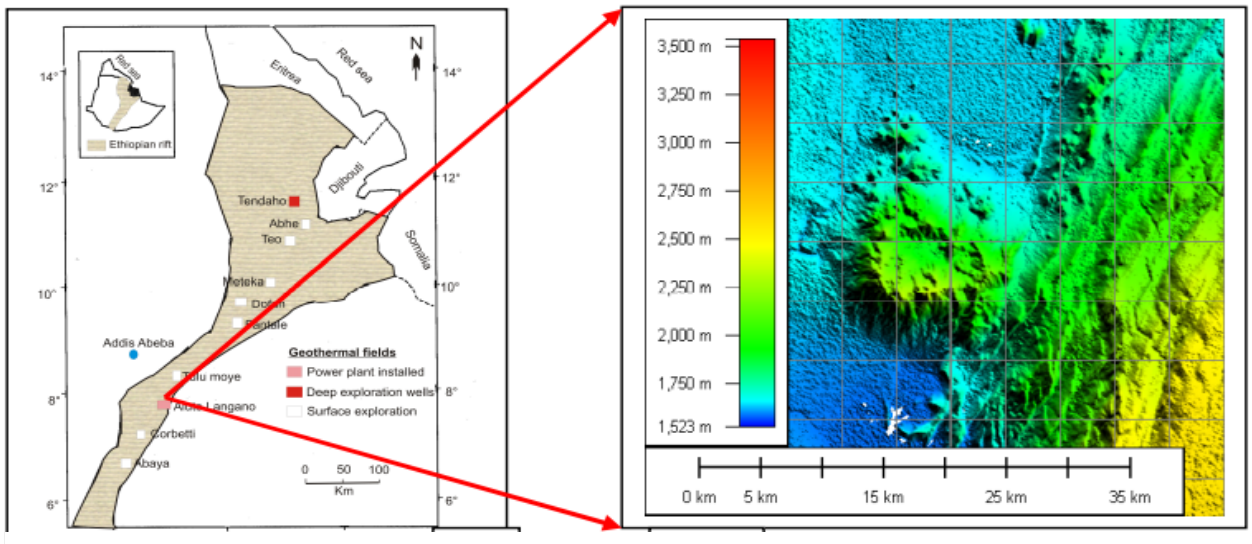


**Figure 7: Location of Aluto Langano and other geothermal fields (Ministry of Mines and Energy, 2008).**

A feasibility and appraisal study to expand the field to 75 MW by drilling more appraisal and production wells was conducted in 2010 and 2015, respectively, with the assistance of the Japanese government. After the wells proved the field contains a promising

geothermal resource at depth, a first phase of drilling eight production wells was developed. Currently the Kenyan firm **KenGen** along with Chinese firm **Kerui Petroleum** jointly has won the bid and signed a contract with EEP in early 2019 to perform drilling operations. The developmental work at Aluto is divided into three phases namely, Aluto I, Aluto II, and Aluto III, which cover an area of 100 km$^2$. So far, six deep wells have been drilled and well testing activities are underway.

Furthermore, EEP is preparing to install a wellhead power plant of 5 MWe that will use steam produced by a couple of directional wells. The finance to build the power plant is a grant from the Japan government via JICA, and the selected firm to build this small power plant is the Japanese **Toyota Tsusho Corporation**. The contract agreement worth's 1842 million Japanese yen and was signed in late 2019 in Tokyo. Besides, a Japanese consulting firm will oversee the construction and installation aspects of the power plant on behalf of EEP.

### 7.2 Tendaho Geothermal Field

Tendaho geothermal field shown in Figure 8, is 600 kms far from the capital Addis Ababa to the North East. It has been also explored by drilling three deep wells and three shallow wells in 1990s. Initial estimates indicate a total of 100 MW that could be developed from a geothermal reservoir at depth (Ministry of Mines and Energy, 2008). The maximum measured temperature in the wells is 300°C. The shallow wells are proven to be productive and the deep wells encountered high temperature, but the permeability has not been sufficient at the drilled levels to sustain commercial production. So far, no power plant is installed at this place. Recently, Tendaho geothermal field was divided into three prospects namely, Alalobad, Aerobera and Dubti. Two of them, Alalobad and Dubti, are still run by the state owned company EEP, and the Aerobera prospect was taken over by JICA (Japan International Cooperation Agency) for research purposes. Surface exploration activities including geological, geophysical and geochemical surveys, concluded in 2016 with the Icelandic fund ICEIDA in all three prospects. The exploration activities were made by the Italian consultant firm called Electroconsult, with funds from the World Bank and GRMF AfD. EEP called for a bid to drill four wells at the Alalobad prospect and eight at the Dubti prospect in 2019, but no company was able to meet the EEP cost estimate. So, the project is currently suspended.


**Figure 8: Location map of Tendaho Geothermal Field and some resistivity anomalies (right) (Ministry of Mines and Energy, 2008).**

### 7.3 Tulu Moye Geothermal Project

Even though various geothermal prospects have been leased to IPPs to produce power, only two prospects are being drilled. They are Tulu Moye and Corbetti.

Tulu Moye geothermal project (Figure 9), is situated 100 km southeast of Addis Ababa, in the Oromia Regional State of Ethiopia, with Lake Koka to the north and Lake Ziway to the south. The site is believed to be close to the eastern margin of the main Ethiopian Rift, where tectonic and volcanic activities are concentrated. The expected reservoir temperature of the drilled wells is to be more than 250°C. The project is being developed by Tulu Moye Geothermal Plc (TMGO), the pioneer independent power producer in Ethiopia, which is composed of two global French and Icelandic firms known as Meridiam Infrastructure Africa Fund (51% ownership) and Reykjavik

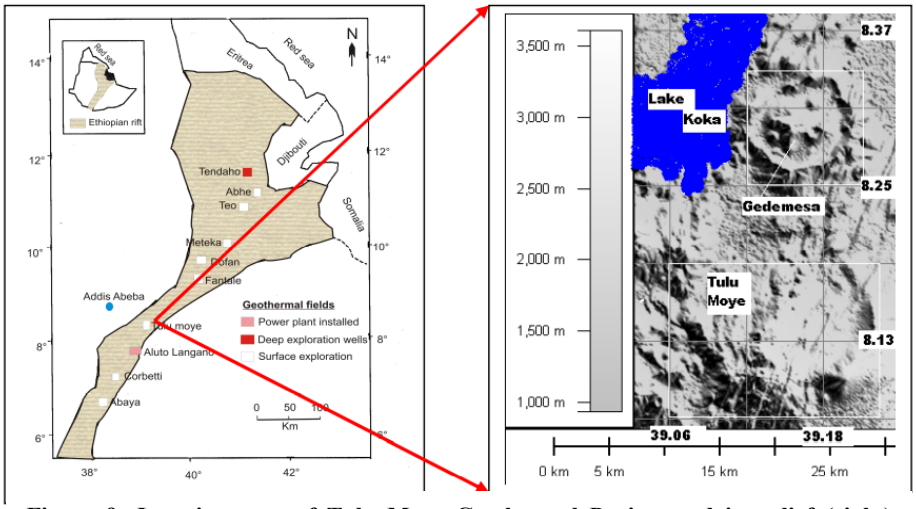


**Figure 9: Location map of Tulu Moye Geothermal Project and its relief (right) (Ministry of Mines and Energy, 2008).**

Geothermal (RG) (49% ownership), respectively. Since 2010, RG has been working in Ethiopia and secured licences of another two projects, Corbetti and Abaya, to develop geothermal power. The Icelandic firms Mannvit and Verkís (M-V) jointly in collaboration with Landsvirkjun Power, ÍSOR and MGM, oversee overall project management activities on the behalf of the owner. The development is programmed in two phases: one of 50 MWe and other of 100 MWe, but the final goal is to reach 500 MWe within the next 10 years. The total cost of the project is estimated at US$250 million, and financing comes from different sources of fund like GRMF, US-TDA, AfDB, and Clean Technology Fund (CTF), besides the equity part of shareholders. It is relatively the busiest project in terms of drilling activities compared to other prospects owned by other IPPs in the country. The drilling operation is contracted to KenGen to drill an initial 12 exploratory, production, and injection wells, following the completion of civil works. An Implementation Agreement (IA) between TMGO and the government as well as a Power Purchase Agreement (PPA), based on a tariff of $6.95 cents per kWh during 25 years, has been signed between TMGO and EEP since December 2017.

### 7.4 Corbetti Geothermal Project

Corbetti Geothermal prospect is located 6.990°E and 38.245°N, approximately 250 km southwest of Addis Ababa, in between the towns of Shashamene and Hawassa in the Oromia Regional state of Ethiopia. The place is situated in the southwards of Ethiopian Rift valley (Figure 10) and the expected temperature of the reservoir is more than 300°C. Eight shallow exploration wells were completed in 1987 with depths ranging from 93-178 m (Endashaw, 1988). The project, programmed at 150 MWe, will be developed in two phases over a five-year period with a total investment worth around 4 billion USD by a private developer called Corbetti Geothermal Company.

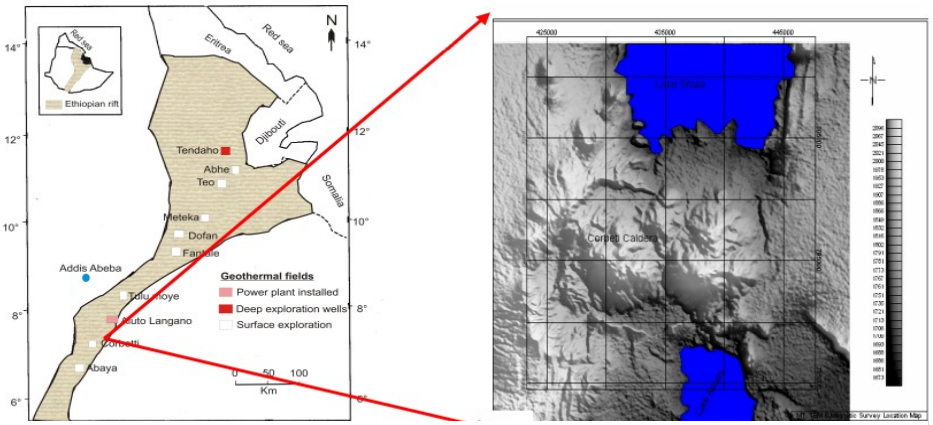


**Figure 10: Location map of Corbetti Geothermal project and its relief (right) (Ministry of Mines and Energy, 2008).**

The first phase will be drilling four to six exploitation wells. Steam from these wells will be collected to operate a 50 MWe power plant that is expected to become operational in 2023. This phase will be financially supported by US Power Africa, UK government via InfraCoAfrica, and the Geothermal Risk Mitigation Facility (GRMF) that is a sub-regional organization that finances and facilitates the development of geothermal energy in East Africa. The second phase of the project will consist of an additional 100 MWe power plant and facilities. Upon completion, Corbetti Geothermal power plant will be a privately developed, owned, and operated geothermal IPPs in Ethiopia. It will allow the Ethiopian government to meet 18% of its geothermal production target by 2025. Surface exploration activity was reassumed in 2013, with collaboration of the state-owned Geological Survey of Ethiopia (GSE).

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