European Commission

SCIENCE BEHIND THE DEBATE

Status of Geothermal Industry in East African countries

Key points

- ✓ Geothermal energy is an indigenous energy source less prone to the instability of the international Oil and Gas (O&G) market, which requires limited operating and maintenance expenditures and could offer a constant generation output independent from weather conditions, a competitive levelized cost of electricity generation (LCOE) and low lifecycle greenhouse gas emissions. However, it is characterized by a long project execution cycle, where important initial investments are necessary and which involves remarkable mining risks (mainly related to the exploration stage).
- ✓ The East African Rift System (EARS) geodynamic context creates high favourable conditions for the existence of geothermal systems at economically and technically drillable depths (less than 4,000 m), with a global potential estimated at about 20,000 MW (mainly located along its Eastern Branch, which extends from Eritrea to Tanzania and crosses Djibouti, Ethiopia and Kenya).
- ✓ At present, only Kenya has exploited a small part of its geothermal resources. Among the main reasons for the delay of geothermal development in East Africa are: the absence of clear and coherent legislative frameworks; the lack of local technical and managerial skills; remoteness of many geothermal areas in relation to O&G regions (where most of the drilling contractors and service providers are based); inadequate financing at the early stages of the projects; competition from other energy sources and; the issue of the remunerative price for the generated electric power in still poor developed national electric markets.
- ✓ International initiatives to help East African countries to overcome these issues include: capacity building to create the necessary legislative framework in each country; creation of public companies in charge of initial exploration activities; grants covering a variable costs fraction of the phases characterized by the highest mining risks and; technical assistance and consultant support to national institutions and geothermal operators.

Introduction

The general objective is to frame the state-of-the-art on the geothermal resource development in East African countries with the focus on geothermal activities aimed at generating electric power by using either flashing or Organic Rankine Cycle (ORC) plants. Thus, direct uses of geothermal energy such spas, cooking, space heating and cooling, greenhouse heating, crop drying, aquaculture and heat for industrial processes are not addressed here,

Geothermal resources, consisting in the heat contained in the Earth crust, are presently exploited for both electric power generation and for direct uses. Favourable geodynamic environments allow founding exploitable geothermal systems at economic and technical feasible depths. Apart for the utilization of low temperature resources (<100°C) only made for direct uses, the generation of electric energy is made from medium (between 100°C and 200°C) and high (>200°) temperature geothermal systems. Almost all the high temperature geothermal systems exploited today are hydrothermal systems from which heat is extracted by means of wells producing fluids contained in a permeable reservoir. According to thermodynamic conditions, the reservoir can be either vapour or liquid dominated depending on the fluid phase controlling the reservoir pressure distribution.

This type of renewable energy is characterized by: low environmental impact and greenhouse emissions when compared to energy generated using fossil fuels; quite constant generation output independent from weather conditions, which makes it particularly suitable for base load electric generation; high initial capital costs; low operating and management expeditures and; remarkable mining risks mainly related to the performance of exploratory drilling phase.

Geothermal power also requires a long project execution cycle, which the IGA (2014) guide divides into eight key phases: 1) Preliminary survey; 2) Exploration; 3) Test drilling; 4) Project review and planning; 5) Field development; 6) Power plant construction; 7) Commissioning and; 8) Operation. The three first phases (which could be broadly called the exploration stage) are seen as the riskiest part of the project development, because either confirm the existence of a geothermal reservoir suitable for power generation or not. According to Gehringer and Loksha (2012), it may take approximately seven years (usually between 5 and 10 years) to develop a typical full-size geothermal project with a 50 MW turbine as the first field development step. Therefore, it could not be regarded as a quick fix for any country's power supply problems, but rather should be part of a long-term electricity generation strategy.

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East African Rift System (EARS)

East Africa is characterized by the presence of the East African Rift System (EARS) with: the Eastern branch extending from Eritrea to Tanzania and crossing Djibouti, Ethiopia and Kenya; the Western branch extending from Uganda to Mozambique and crossing Burundi, Rwanda, Zambia, Tanzania and Malawi (Figure 1). While this geodynamic context creates high favourable conditions for the existence of geothermal resources at economically and technically drillable depths, at present only Kenya has developed its geothermal resources with an installed electric power of 865 MW, representing about 30% of total installed power, against estimated resources amounting to some 7,000 MW.

Currently, it appears to be evident that the countries crossed by the Eastern Branch of EARS have a definitely higher geothermal potential, mainly concentrated in the Afar depression and the Ethiopian and Kenyan Rift Valleys. Even if not huge on an absolute scale, the resources inferred in Eritrea, Djibouti and the Comoros (the latter not actually pertaining to the Eastern Branch of EARS), if developed, would contribute to a large fraction of their present and future

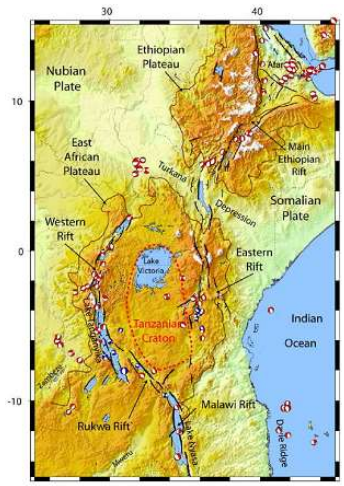

Figure 1. The East African Rift System (Source: Omenda, 2018b)

electric network base load. In the case of the countries crossed by the Western Branch, they have a lower geothermal potential, mostly related to medium, rarely high, temperature fault controlled geothermal systems, whose utilisation for electric power generation would require ORC power plants. As a consequence, about 95% of EARS estimated potential amounting to some 22,400 MW belongs to geothermal areas located along the Eastern Branch.

The role of geothermal energy in the energy mix of the East African countries depends on the present status of the energy market of each country, on the potential of indigenous energy sources, including geothermal energy, and strategic choices taken by each government. There are several reasons for the delay of geothermal resources development experienced so far by these countries, such as:

- Lack of clear and coherent legislative frameworks, regulating the activities of both public and private investors in several countries.
- Lack of local technical and managerial skills, able to conveniently support the exploration and exploitation of geothermal resources.
- The remoteness of many East Africa geothermal areas from developed O&G regions, where most of the drilling contractors and service providers are based, and then the absence of infrastructures and logistic facilities supporting the drilling activities characterising well developed O&G regions.
- Inadequate financing of the early stages of geothermal projects; commercial banks reluctance to participate in the exploration phase and the need for more risk reduction opportunities, which facilitate the investment by both public and private operators.
- Competition from other energy sources, such as hydropower in Ethiopia and several other countries, which creates a challenging environment for geothermal projects in the region.
- The issue of remunerative price for the generated electric power in still poor developed national electric markets.

Historically, reconnaissance and preliminary surface studies on geothermal prospects in East Africa where performed by public institutions or companies supported by international donors and consultants. Often, this approach has been characterized by a discontinuous performance of exploration phases separated by long periods of inactivity, sometime accompanied by the switch of operations from one institution to another one, with loss of skilled personnel and know-how. More recently most of the countries have developed regulatory environments in which both public and private operators, as well as private-public initiatives are allowed to develop the geothermal resources.

The way forward

Regarding the forecasted role of geothermal energy in the generation of electricity in sub-Saharan countries (Figure 2) shows the electricity supply by type, source and scenario in sub-Saharan Africa, excluding South Africa (IEA, 2019a). The situation in 2018 is compared to two different scenarios (Stated Policies & Africa Case) foreseen for year 2040. The IEA's Stated Policies Scenario is based on current and announced policies, while the Africa Case scenario is a new scenario built by IEA around Africa's own vision for its future. It incorporates the policies needed to develop the continent's energy sector in a way that allows economies to grow strongly, sustainably and inclusively.

In 2018 geothermal power accounted for 2% of electricity generation and is expected to represent in 2040 4% of electricity generation by both IEA's scenarios. Thus, geothermal is expected to double its contribution share in

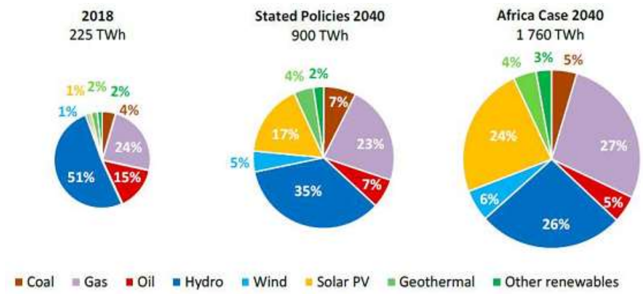

Figure 2. Electricity supply by type, source and scenario in sub-Saharan Africa (excluding South Africa), 2018 and 2040 (Source: IEA, 2019a)

2040, but still representing a small fraction of electricity generation, in particular if compared to the important increment of Solar PV, which will compensate for the reduction of hydropower contribution. These scenarios both suggest that even if most of the investments on renewable energies will be drained by Solar PV, geothermal will anyway experience a large increment of generated energy and then of installed power.

In order to help East African countries to overcome the identified barriers to the development of geothermal resources utilization, international organizations and financial institutions are actively collaborating with national governments to create the necessary legislative framework in each country, to facilitate the capacity building with the creation of excellence centres and the organization of dedicated courses and conferences.

On the other hand, financial and international institutions, such as WB, AU, EU, IRENA, NDF, AFD, AfDB, JICA, USAID, etc., are providing both grants and low interest loans to help public and private

operators in the various steps of geothermal resource development, from the exploration surveys to the construction of power plants.

In addition, the following technical approaches, derived from experiences and lessons learned, are believed to reduce risks and improve the bankability of geothermal projects (IRENA, 2018):

- Sound exploration for high-quality geological data.

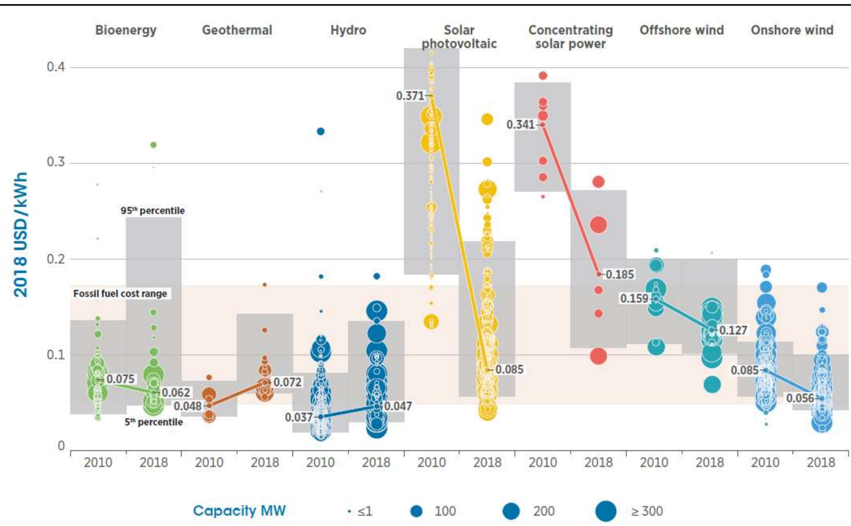

Figure 3. Global LCOE evolution of utility-scale renewable power generation technologies in the 2010–2018 period. Real weighted average cost of capital is 7.5% for OECD countries and China and 10% for the rest of the World. (IRENA, 2019)

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- Linking technical and commercial analyses to the development of realistic prefeasibility studies prior to making major investments.
- Generating early revenue through wellhead generators: it appears that installing wellhead power plants is advantageous when an early electric generation can be obtained during a long-term field development in quite large fields, and when the wellhead power plants can be relocated on another field or field sector when the final power plant starts its operations.
- Supplement project revenues through direct use applications and sale of other by-products such as heat, lithium, CO_2, silica, etc.

In any case, geothermal energy shall be competitive in relation to other energy sources, either other renewables or fossil fuels. According to IRENA (2019), most of the plants allows a LCOE lower than about 0.08 USD/kWh, which is competitive with electricity generated with fossil fuels (Figure 3). Cheaper renewable energy sources like Solar and Wind not affected by the mining risks of geothermal energy may likely be preferred by many international and national investors.

The countries that at present show the best geothermal perspectives, mainly located along the Eastern Branch of the EARS, are::

- **Eritrea**: a single explored site, with reported potential of 70-100 MW. Further activities aimed at completing the surface exploration and target exploratory drillings seem worth to be performed, as the installation of a 50 MW geothermal plant in Eritrea would already cover most of its present national base load.
- **Djibouti**: surface and drilling exploration dates back to late '70s, with several prospects recently explored within the Asal rift area at Gale le Koma and Fialé caldera. In Djibouti too the installation of a geothermal power plant of some 50 MW would cover most if its electric network base load, consistently reducing the use of imported oil.
- **Ethiopia**: the country has a large inferred potential in the order of 10,000 MW, but only a 7.5 MW power plant was installed at Aluto caldera, now not in operations. The situation has recently changed thanks to a new geothermal proclamation and regulations issued in 2016 and 2019, respectively. Geothermal development in Ethiopia will face the competition with cheaper renewables, such as the huge hydropower resources presently developed by EEP and the large estimated solar and wind resources.
- **Kenya**: it is the leading country as far as the geothermal development in East Africa is concerned. Kenyan experience is taken as a successful example of geothermal industry, characterized by the development of the great Olkaria geothermal field by a public electric utility (KenGen), with both KenGen and GDC providing consultancies and services to neighbouring countries. Kenya has been also chosen as the location of the Africa geothermal Centre of Excellence operated by GDC in collaboration with KenGen.
- **Tanzania**:it has deployed several efforts in last years both with the creation in 2011 of TGDC, the state-owned company with the main mission to develop the national geothermal sector, as well as on the exploration of the most promising prospects. The potential has been recently conservatively estimated in 500 MW. When compared to the planned electric power development in Tanzania, it is clear that geothermal energy will play a minor role in the future energy mix, unless additional exploration activities will identify new promising prospects.
- **Comoros**: surface exploration of the Karthala prospect in Grande Mayotte allowed to identify a geothermal potential of up to 40 MW, largely exceeding present and future base load of the country. Exploration wells have been targeted and a project is underway with the aim to drill 3 exploration wells.

In conclusion, thanks to the efforts of both national governments and international stakeholders, the geothermal energy in Eastern Branch countries of EARS seems to be at a turning point in particular in Ethiopia and Djibouti, with Kenya going on in an accelerated way along an already established successful path. Geothermal exploration in the Comoros has also good perspectives with geothermal potential to be confirmed, but largely exceeding the present base load of the country..

The geological settings and the exploration activities performed so far suggest that the countries crossed by the Western Branch of EARS have a lower geothermal potential, mostly related to medium, rarely high, temperature fault controlled geothermal systems whose utilisation for electric power generation would require ORC power plants.

Experiences recently gained with the exploration of fault-controlled systems in the Western Branch and related new achieved understanding, have implications for both taylored geological exploration approaches and the identification and prioritization of prospects in the Western Branch countries, which will likely allow to identify new promising prospects.

Full references in

Battistelli et al. (2020).The African Networks of Excellence on Water Sciences Phase II (ACE WATER 2). Status of Geothermal Industry in East African countries. JRC Technical Report (2020).

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