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GEOHERMAL OUTLOOK IN EAST AFRICA AND CONTRIBUTION OF UNU-GTP IN CAPACITY BUILDING

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ABSTRACT

The East Africa Rift System has geothermal energy resource potential of an estimated output of 20 GW. Kenya has been generating electricity since 1981 and Ethiopia started in 1998. Significant progress has been made in the region in recent years in terms of development of geothermal resources towards generation of electricity and direct use application. Currently, Kenya is generating about 676 MWe of electricity and 12 MWt for direct use application from geothermal resources. Ethiopia is following Kenya, with a geothermal pilot power plant of total installed capacity of 7.5 MWe and an intensive geothermal resource exploration and development plan. Exploration for geothermal resources (for electricity production) has also been conducted in other African countries: Burundi, Comoros Islands, Djibouti, Democratic Republic of Congo, Eritrea, Malawi, Mozambique, Rwanda, Sudan, Tanzania, Uganda and Zambia. These countries are at various stages of geothermal exploration ranging from inventory of hot springs to detailed geoscientific investigations; including drilling of exploratory wells.

In the framework of energy, climate change and global and continental development agendas, the governments of most African countries are keen and committed to explore and further develop geothermal energy as one of the alternative renewable energy resources in their respective countries. It is expected that an increase of about 1500 MWe power generation from geothermal resources in the region could result by 2025. While financing is a major challenge for accelerating the geothermal development in the region, lack of adequate local human capital is the main bottleneck for sustainable development of geothermal energy resources in the region.

Many countries from other continents (where major geothermal resources development has taken place) have provided specialized geothermal training for African countries for the last two-three decades; namely from Japan, Italy, New Zealand, Iceland and the USA. From Iceland, notable contribution has been made by the United Nations University Geothermal Training Programme (UNU-GTP), with its 6 months diploma training and the MSc and PhD Programmes. Further, as part of the attempt to address the challenges of inadequate local skilled manpower, UNU-GTP started running shorter courses in Kenya in close cooperation with Geothermal Development Company (GDC) and Kenyan Electricity Generating Company (KenGen). There has, however, been a growing sense that further steps should be taken to internalize geothermal training and capacity building within Africa – and notably East Africa.

In this context, the idea of a specific regional geothermal training centre for Africa emanated a decade ago. This idea has been widely discussed among various parties and organizations including Africa Union Commission (AUC), United Nations Environment (UNEP), UNU-GTP, GDC, KenGen, Icelandic International Development Agency (ICEIDA) and the donor community. This discussion led to an agreement and consensus to establish an African Geothermal Center of Excellence – AGCE” and the Centre to be based in Kenya; with UNU-GTP playing an important role in establishment and operation of it.

1. INTRODUCTION

Affordable, reliable, sustainable and modern energy services are a critical development-enabler for Africa by creating solutions to climate crisis and are essential for implementing the Global 2030 Sustainable Development Goals in general and African Union development Agenda 2063, in particular. Specifically, energy is an enabler and a pathway to address social, environmental and economic challenges through an integrated approach by providing equal energy access and consumption levels, by leap-frogging the dirty fuels of the past with future of clean renewable energy development, and by balancing the demand and supply of energy, notably through programs such as energy efficiency, to enhance economic growth.

About 600 million people in Africa do not have access to electricity, and approximately 730 million people rely on traditional uses of biomass (IEA, 2014). The continent’s energy supplies are not meeting the needs and aspirations of its people. A better system will promote economic diversification, raise productivity, and improve the health and well-being of citizens. While fossil fuels, notably coal, oil and gas, continue to provide a significant quantity of energy, **renewables need to play** a greater role. Africa has plentiful renewable energy resources, from hydropower and the **geothermal power** in the East Africa Rift System, while solar and wind are especially promising, thanks to falling costs and resource abundance.

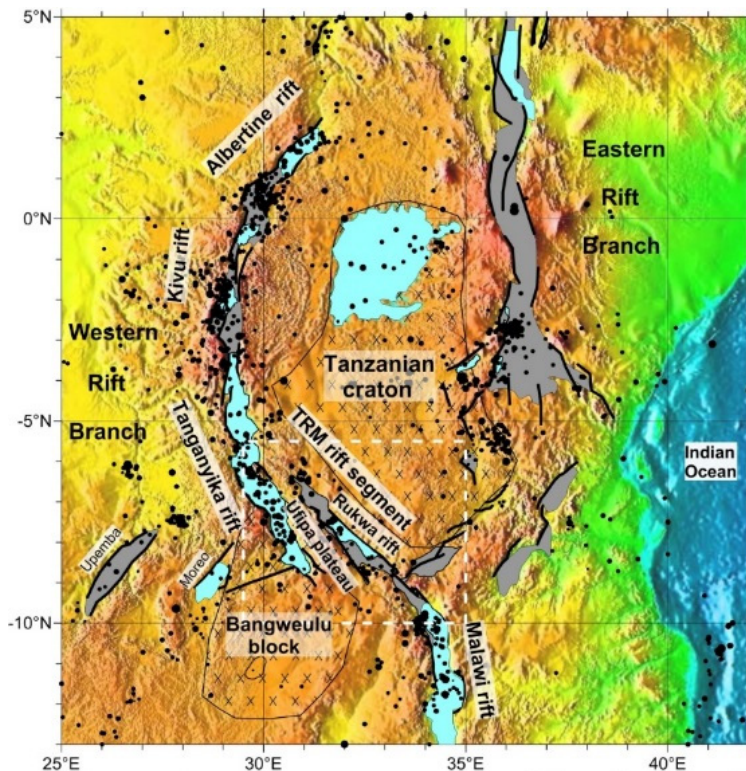


FIGURE 1: The East Africa Rift System with its two branches (after Delvaux, 2016)

The Great East African Rift System (EARS), a 6500 km terrain stretching from northern Syria to central Mozambique in South Eastern Africa is one of the major tectonic structures of the earth where the heat energy of the interior of the earth escapes to the surface. Under such geodynamic conditions, EARS possess a remarkable geothermal potential that is estimated to be about 20 GW. The geologic makeup of EARS region is heterogeneous in its eastern, western, southern and southwestern branches (Figure 1). This has caused wide diversity in the mode of occurrence, characteristics, potential grades and end-use possibilities of its geothermal resources.

The EARS is highly magmatic in its eastern branch, in countries such as Djibouti, Eritrea, Ethiopia, Kenya and Tanzania, while in the countries of the western branch it exhibits little

volcanism (Uganda, NE-DRC, Rwanda and, northern and south-western Tanzania), or none at all (Malawi, Zambia and Mozambique). Thus, there is a wide diversity in the occurrences of potential geothermal systems in the region in terms of their heat sources, reservoir characteristics, resource grades and potential end-uses.

Despite the high geothermal resource potential and its wide distribution in the EARS to be used for power generation and direct use applications, only Kenya and Ethiopia have installed a capacity of about 682 MWe to date. Countries such as Djibouti and Tanzania are in preparation for exploration drilling whereas Uganda, Eritrea, Comoros, DRC, Malawi, and Mozambique are at various stages of exploration from the inventory work to detailed surface exploration of resource potential. Rwanda has also drilled two exploration wells in Karisimbi without intersecting a geothermal reservoir. In Zambia, Kalhari Geenergy, Ltd., drilled temperature gradient holes in Bwengwa river prospect area. With results of temperature > 130°C.

Many African countries have also made some direct uses of their geothermal resources, including Algeria, Egypt, Ethiopia, Kenya, Morocco, Tunisia, and Zambia. Hot springs for direct use applications have also been identified in Burundi, Cape Verde, Madagascar, Malawi, Mozambique, Rwanda, Uganda and Zimbabwe.

In recent years, geothermal energy is being prominently recognized as one of today's renewable energy mix by governments in the region. This arises due to: (i) Strong growth in electricity demand & urgent need to increase access to electricity; (ii) hydro proven unreliable as a base load source due to climatic fluctuations; (iii) Volatile price of petroleum fuels, etc. Geothermal is hundred percent indigenous, environmentally friendly and a technology that has been under-utilized for too long in the continent. It is time to take this technology off the back burner in order to power livelihoods, fuel development and reduce dependence on polluting and unpredictable fossil fuels.

All East African countries import petroleum products mainly for transport and electricity production. Renewable energy sources (hydro, geothermal, solar, wind etc.) represent a small portion of total energy production, averaging less than 20% for hydropower, solar, wind and geothermal production combined. Hydropower is currently the predominant mode of electricity production in the region (~70%), yet climatic fluctuation pose questions concerning the reliability of these resources. Thermal production (mainly diesel generation) is used in most countries and is the only source of power production in Eritrea and Djibouti. Volatile prices and high import costs make diesel based power production costly. Therefore, to decrease imports and save foreign currency and in the face of the increasingly recurring severe droughts, it is important for the region to avoid relying solely on hydroelectricity and to make geothermal energy generation a complementary part of future development, as generation mix.

This paper is an update and a summary of literature review from various papers presented and/or published in various geothermal workshops and conferences and their proceedings. The paper also covers the main observations, strategies for development and regional geothermal development approach.

2. OUTLOOK OF GEOTHERMAL RESOURCE EXPLORATION AND DEVELOPMENT IN THE EAST AFRICA REGION

2.1 The East Africa Region

The Great East Africa System better known for its picturesque mountains, escarpments and lakes has become the new source of hope to enable Africa to meet its energy needs well into the 21st century. In recent years, the geothermal energy potential in this rift valley (particularly in the Eastern branch of the EARS) has attracted the attention of major public and private investors keen to tap into an energy source that is plentiful, renewable and largely environmentally friendly.

Using today's technologies, Eastern Africa has an estimated potential of more than 20,000 MWe. Despite this potential, only Kenya and Ethiopia have geothermal operations as part of the country's electricity generation infrastructure. The progress of geothermal development in the region is affected by (among others): (i) High upfront cost of exploration including drilling; (ii) Inadequate access to funding and guarantee; (iii) Inadequate policy and legislation as well as institutional and regulatory framework to attract private investment; (iv) Inadequate local human capital and expertise in geothermal science and technology; and (v) Inadequate infrastructure and database in resources.

East African countries that have identified the presence of geothermal energy resource and/or carried out research on, geothermal resources include: Burundi, Comoros Islands, Djibouti, Democratic Republic of Congo (DRC), Eritrea, Ethiopia, Kenya, Rwanda, Malawi, Mozambique, Tanzania, Uganda and Zambia. Brief description of exploration, development and utilization of geothermal resources in some Eastern Africa countries is given below.

Kenya. Geothermal resources in Kenya have been under development since 1950's and the current installed capacity stands at 676.8 MWe against total potential of about 10,000 MWe. All the high

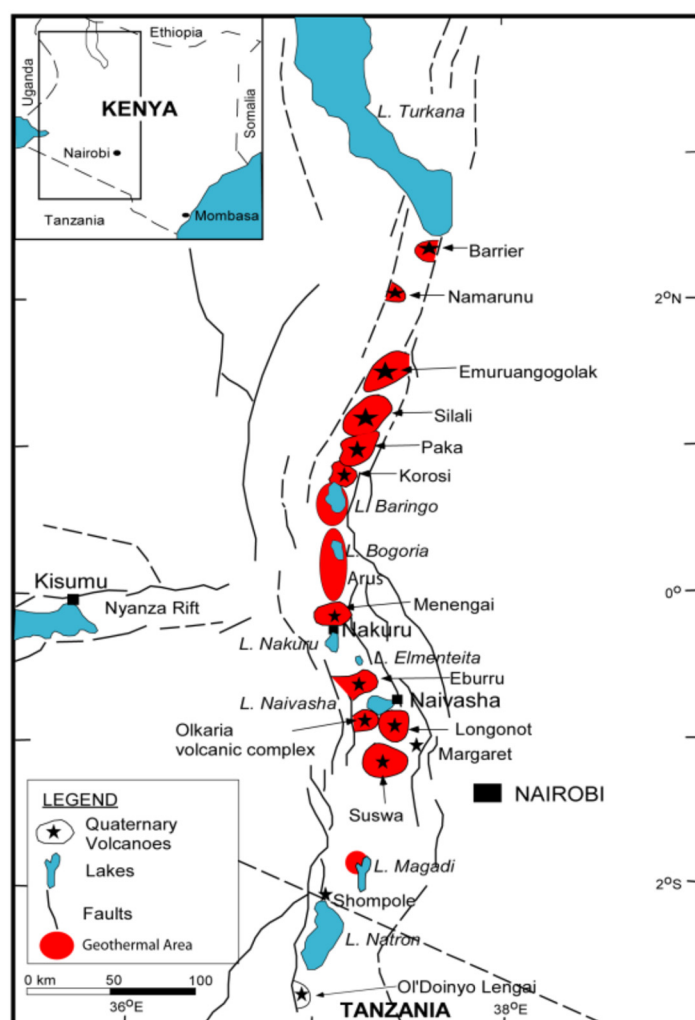


FIGURE 2: Location of geothermal prospects in Kenya

temperature prospects are located within the Kenya rift valley where they are closely associated with Quaternary volcanoes (Figure 2). In the East African Rift region, Kenya is the leader in advancing geothermal resource exploration and development.

Olkaria geothermal field is so far the largest producing site with current installed capacity of 674.4 MWe from five power plants and wellheads owned by Kenya Electricity Generating Company (KenGen) (533.5 MWe), Oserian (4.3 MWe) and Orpower4 (139 MWe) (Mangi and Omenda, 2016). 12 MWt is being utilized to heat greenhouses and fumigate soils at the Oserian flower farm and Olkaria geothermal spa. Power generation at the Eburru geothermal field stands at 2.4 MWe from a pilot plant. Development of geothermal resources in Kenya has been fast tracked with 335 MWe commissioned in 2014-2016 from conventional power plants and well head units. Production drilling at the Olkaria geothermal project for the additional 560 MWe power plants to be developed under PPP arrangement between KenGen and private sector is ongoing. The Geothermal Development Company (GDC) is currently undertaking production drilling at the Menengai geothermal field for 105

MWe power developments to be commissioned in 2018. Detailed exploration has been undertaken in Suswa, Longonot, Baringo, Korosi, Paka and Silali geothermal prospects and exploration drilling is expected to commence soon in Baringo – Silali geothermal area. The UNEP ARGeo programme provided support in technical assistance of the Silali geothermal project resulting in optimizing the conceptual model of the system and location of target sites for deep exploratory drilling.

Ethiopia. Surface explorations for geothermal resources in Ethiopia has began over four decades ago. The geothermal explorations so far have identified over 22 geothermal prospect areas (Figure 3) suitable for electricity generation, with a total estimated potential of over 10,000 MW. Despite the countries long term geothermal exploration and huge resource potential, the progress of development of geothermal resources in Ethiopia has been slow. Among the 22 prospects, deep exploration drilling has been conducted only in two prospects (Aluto-Langano and Tendaho) and only a 7.2 MW pilot plant has been installed so far at Aluto (e.g., Teklemariam 2005). However, recently the country has developed a renewable energy mix policy that is geared towards the objective of accelerating various renewable resources development, including geothermal energy resources. A new geothermal law for operation of geothermal activities in both the public and private sector has been approved. A proclamation cited as the “*Geothermal Resources Development Proclamation*” has been put into force in 2016. This development significantly increased the interest of both the public and private sector developers where a number of geothermal projects are being implemented at larger scale along the Ethiopian Rift Valley. The public sector has focused on further exploring and developing the two most explored prospects in the country, the Aluto Langano and Tendaho geothermal fields. In these prospects detail surface explorations, test well drillings and feasibility studies are being conducted. The UNEP ARGeo programme provided support in technical assistance of the Tendaho (Dubti-Ayrobera) geothermal project which resulted in optimizing the conceptual model of the system and location of target sites for further exploratory drilling. It is now under preparation for drilling with the support of AfD.

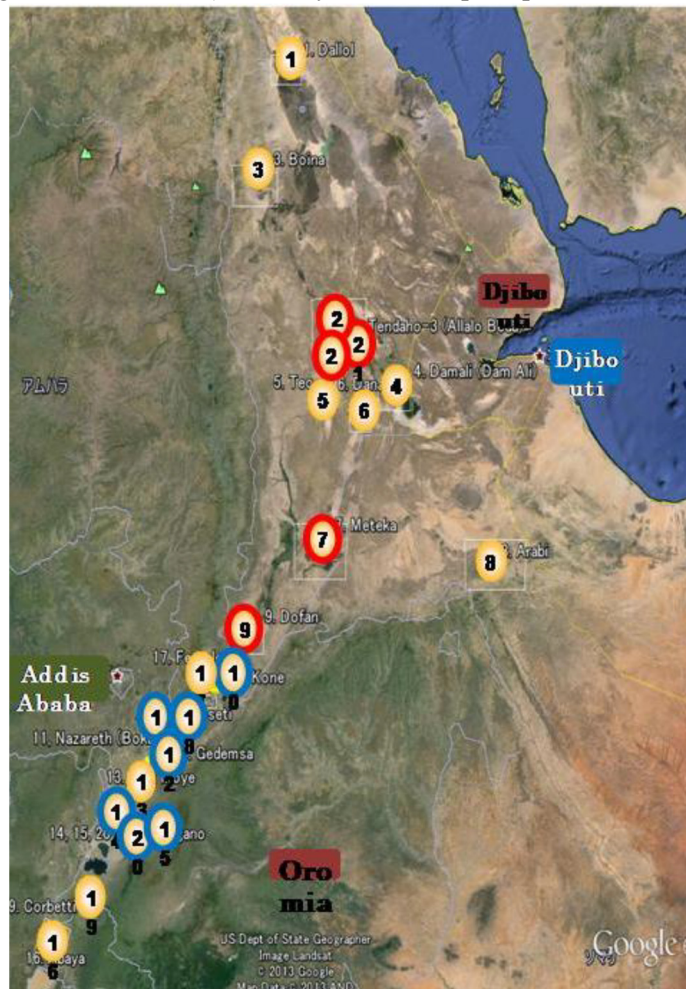


FIGURE 3: Location of geothermal prospects in Ethiopia

Various private sectors have concessions in about seven prospects and are being actively engaged in exploration, including in green fields that include: Tulu-Moye, Abaya, Dofan, Butajira, etc. The most advanced exploration activity is being carried out by the private company, Corbetti Geothermal Plc., in the Corbetti geothermal prospect. A power purchase agreement for Corbetti geothermal development has been signed with the government where the agreement considers development of the Corbetti prospect to 500 MWe with estimated investment cost of 2 billion US\$ (Kebede 2016). Currently mobilization works are being conducted by the company to commence test well drilling. The country’s geothermal development plan considers the development of 675 MW geothermal power in the medium term and 5000 MW by 2037 (Kebede, 2016).

Djibouti

Djibouti lies at the junction of three active, major coastal spreading centres: (a) the Eastern Africa Rift zone; (b) The Gulf of Aden Rift; and (c) the Red Sea Rift (Figure 4). This structural junction is unique being the focal point of very high heat flux. A number of prospects in Djibouti includes: (i) Lake Assal;

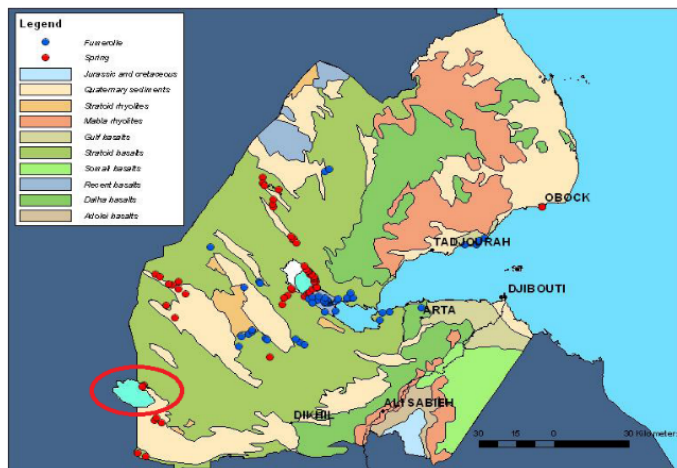


FIGURE 4: Geothermal prospects in Djibouti

(ii) Lake Abbe; (ii) Hanle; (iii) Gaggade; (iv) Arta; (v) Tadjourah; (vi) Obock; (vii) and Dorra (Figure 3).

ODDEG (Office Djiboutien de Developpement de l'Energie Geothermique) is the newly established specialized agency responsible for exploration and development of geothermal resources in Djibouti. In the last one decade, the country took initiatives to reduce fossil fuel dependence for power generation by promoting development of its own geothermal potential through the technical assistance of various regional and international support programmes. These

include: exploration studies in the Lake Abhe with the technical support from ISOR, Hanle-Garabayiss with technical support from JICA and Sakalol prospect jointly carried out by ODDEG with CERD. The country also raised around 31 Million USD for exploration drilling in the Asal-Fiale geothermal field with the financial support of the World Bank, AfDB, OFID, AFD (Abdillahi et al., 2016). In Assal, a feasibility study of 50 MW geothermal power plant is being carried out with a possible extension to 150 MW. The government is also building the institutional and infrastructural capacities in order to have a sustainable geothermal development in the country.

Tanzania. Geothermal exploration in Tanzania was started between 1976-79. The occurrence and distribution of geothermal resources (Figure 5) include (Kabaka et al., 2016):

- (i) In the north (Lakes Natron, Manyara, Eyasi and Mara);
- (ii) Central: Arusha, Dodoma, Singida and Shinyaya);
- (iii) Coastal sedimentary basins Rufiji (Luhoi and Utete); and
- (iv) In the south - Mbeya (Ngozi, Songwe, Kiego etc.).

Among these, the projects that are being implemented at various stages include:

- (i) Detailed integrated geoscientific studies -Ngozi and Songwe;. This study was supported by the UN Environment ARGeo programme in collaboration with MFA-ICEIDA, GDC and ISOR. The results of this study is submitted to the AUC-KfW Geothermal Risk Mitigation Facility to secure partial grants for drilling.
- (ii) Detailed surface exploration studies: Luhoi and Mbaka (supported by MFA-ICEIDA.
- (iii) Reconnaissance study - Kisasi and Meru (Kabaka et al., 2016).

Among the notable new developments, Tanzania has set up a Tanzanian Geothermal Development Company that is responsible for exploration and development of geothermal resources in Tanzania. At present, TGDC is in preparation to drill slim holes and TG wells in Ngozi and Songwe geothermal prospects respectively. TGDC is also working on developing a clear and coherent geothermal policy, laws and regulations.

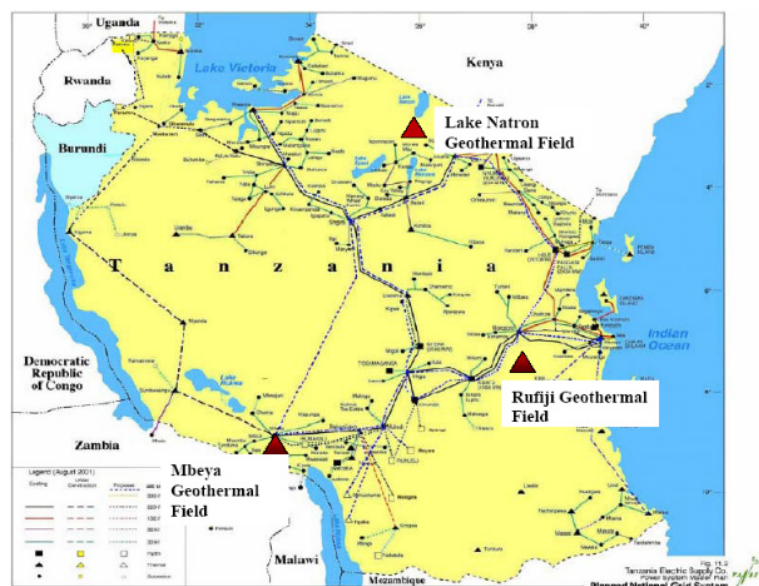


FIGURE 5. Geothermal prospect areas in Tanzania (Kabaka et.al. 2016)

Uganda. Exploration for geothermal energy in Uganda has been in progress since 1993. The studies have focused on four main geothermal areas, namely: Katwe-Kikorongo, Buranga, Kibiro and Panyimur (Figure 6). These are all located in the western branch of the EARS along the border of the Democratic Republic of Congo (DRC). Three areas are in semi-detailed to detailed stages of surface exploration (Kato 2016). The overall objective of the study is to develop geothermal energy to complement hydro and other sources of power to meet the energy demand of rural areas in sound environment.

Detailed integrated geoscientific studies in the Kibiro geothermal prospect area undertaken with the support of the UN Environment ARGeo Programme in 2016 resulted in developing a conceptual model of the geothermal system in Kibiro. The results of these studies recommended drilling of shallow water wells (200-300 m) to explore the possibility of shallow aquifer. The Climate Technology Center of Network (CTCN) in collaboration with the ARGeo programme also supported a review of the geothermal legal and regulatory framework in Uganda.

Others. Countries such as Burundi, Comoros, DRC, Eritrea, Malawi, Mozambique and Zambia are at different stages of exploration that ranges from inventory of hot springs (Burundi) to detailed integrated geoscientific studies (Comoros). A private developer, Kalhari Geo-Energy has done detailed geoscientific studies in Bwengwe River geothermal prospect in Zambia that includes drilling of temperature gradient holes with a temperature of 130°C (Vivian-Neal et al., 2016)

Rwanda has carried out various geothermal exploration activities that ranges from detailed geoscientific studies in Gisenyi and Kinigi as well as drilling of temperature gradient wells in Bugarama geothermal prospects. Detail exploration including drilling of two deep exploratory wells in Karisimbi geothermal prospect was carried out without intersecting a geothermal reservoir. The above exploration studies were mainly supported by the government of Rwanda with contribution from JICA and EU (Rutagarama 2016).

3. VARIOUS SUPPORT PROGRAMMES IN THE REGION

There are various regional and international programmes, which provide support to the region to mitigate the risk associated with resource exploration, catalyse investment and accelerate the development of geothermal resources. These include (among others):

- (i) *UN Environment Africa Rift Geothermal Development Facility programme (ARGeo):* Technical assistance, capacity building, regional networking and information systems;
- (ii) *AUC-KfW Geothermal Risk Mitigation Facility:* Partial grant for exploratory drilling and

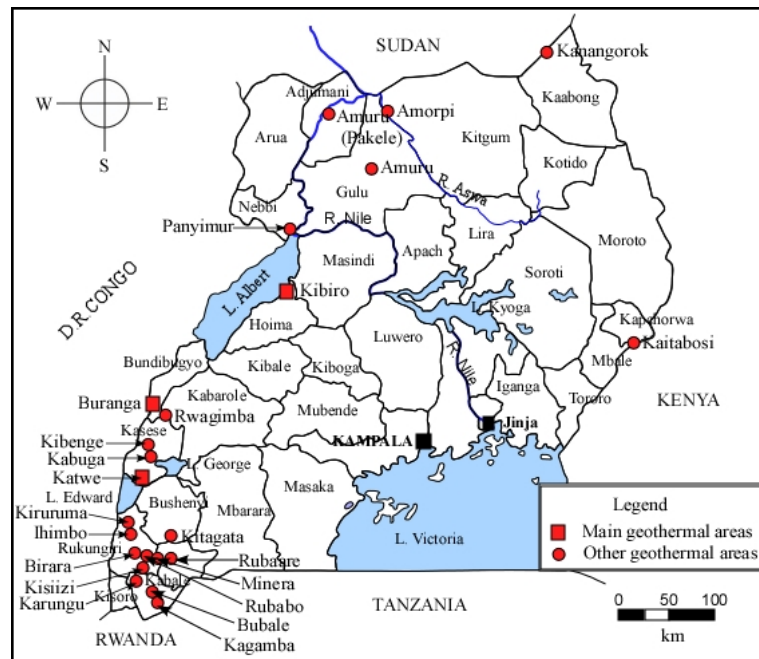


FIGURE 6: Location of geothermal prospect areas in Uganda (Bahati, 2011)

- surface studies;
- (iii) *MFA- Iceland International Development Agency*: Technical assistance and capacity building;
 - (iv) *NDF – Nordic Development Fund*: Technical assistance and capacity building;
 - (v) *EAGER/DFID* – Technical assistance;
 - (vi) *BGR*: Technical assistance and capacity building;
 - (vii) *New Zealand geothermal facility*: Technical assistance and capacity building;
 - (viii) *US Power Africa/EAGP*: Technical assistance and capacity building;
 - (ix) *JICA* – Technical assistance and capacity building;
 - (x) *Italian Agency for Development Cooperation*: Technical assistance and loan for infrastructure development and drilling; and
 - (xi) *UNU-GTP*: Capacity building.

Further investment and development banks that support geothermal projects in the region include (among others): African Development Bank – Afd, EIB, China Exim Bank, World Bank, OPIC, KfW and IFC.

4. MAIN CHALLENGES AND BARRIERS TO GEOTHERMAL DEVELOPMENT

Main challenges and barriers to develop the geothermal resource in the region both for power generation and direct uses include:

- (i) High upfront costs;
- (ii) Inadequate grant support for exploration drilling;
- (iii) Reluctance of development finance institutions and agencies to support exploration of low to medium geothermal systems;
- (iv) Hesitance of commercial banks to participate in exploration phase; and
- (v) Inadequate trained human capacity.

5. UNU-GTP SUPPORT IN CAPACITY BUILDING FOR AFRICA

Recognizing the keenness and commitment of the governments of East Africa region to develop geothermal resources to meet the energy demands and in turn the need to develop geothermal expertise for sustainable geothermal development in the region, UNU-GTP is putting more emphasis than ever before in enhancing and strengthening the capacities of the region, and geothermal research aimed at furthering geothermal development in the region. About 39% of the total trainees of UNU-GTP during 1979-2016 have come from 17 African countries. Further, 30 MSc students (out of 51) have come from Africa (Georgsson and Haraldsson, 2016). This indicates a significant contribution of UNU-GTP in enhancing the capacities of the region and in turn accelerating the geothermal development in the region such as in Kenya.

6. THE AFRICA GEOTHERMAL CENTER OF EXCELLENCE FOR SUSTAINABLE GEOTHERMAL DEVELOPMENT

The increased interest and commitment of the governments of East African countries in geothermal resource development (aiming at about 1550 MWe by 2025) requires a critical mass of geothermal scientists, engineers, drillers, managers and financiers in the region. In this context, the idea of a specific regional geothermal training centre for Africa emanated and was widely discussed among various member states, organizations and agencies. These include Africa Union Commission (AUC), United Nations Environment (UNEP), UNU-GTP, GDC, KenGen, Icelandic International Development Agency (ICEIDA) and the donor community. The long-term aim is the sustainable development of

geothermal energy resources for power generation and direct use application that will contribute to the socio economic development of the continent.

The validated feasibility study of the Africa Geothermal Center of Excellence (financed by the MFA-ICEIDA) and the results of skill gap analysis of the region (conducted by UN Environment) presented at the stakeholders workshop held in August 2015 led the stakeholders to reach a consensus to set up an “African Geothermal Center of Excellence”. The key consensus points included:

- (i) *Regional relevance*: Align the Center with the regional needs and requirements;
- (ii) *Regional ownership*: The Center will be owned and led and have all African players on board;
- (iii) *Build on existing initiatives*: Utilize the existing facilities and initiatives without re-inventing the wheel.

In this context, the stakeholders agreed:

- (i) The Center to be hosted by the Government of Kenya, and use the existing training facilities of GDC and KenGen;
- (ii) The Steering Committee to be established comprising: AUC (Chair), UNEP (provide technical backstopping), two representatives from countries on rotational basis (e.g. Djibouti, Rwanda), GDC, KENGEN, Kenya Ministry of Energy and Petroleum, and UNU-GTP; and
- (iii) AUC, UNEP and other development partners to continue facilitating the institutional support to the realization of the AGCE.

At present, the Interim Project Coordination Unit of the centre (IPCU-AGCE) is being hosted at the UN Environment in order to facilitate geothermal training programme as per needs and expectations of member states while facilitating the establishment and legalization of a full-fledged centre. Various levels of geothermal training modules have been developed already. Further, cost recovery of the GDC and KenGen training facilities are being defined in order to start the training activity under the auspices of IPCU-AGCE. UNU-GTP, as a member of the SC of centre is providing its technical guidance and support to the Unit.

7. LOOKING TO THE FUTURE

- Need for the development of geothermal resource in the region as one of the alternatives for clean and renewable energy to achieve the global (SDG 2030) and continental (AU 2063) development agendas as well as Paris agreement 2015.
- Increased national and regional level policy commitments.
- Increased and spurred private sector investment specifically in high enthalpy geothermal systems.
- Existence of various innovative financing schemes: Climate financing (e.g. GCF, CIF, SREP, etc.) and risk guarantee funds (GRMF, SCAF, REPP etc.).
- Need for a critical mass of geothermal scientists, engineers, drillers, etc.
- Need for better understanding of the low to medium temperature geothermal resources located in the western branch of the EARS and identifying the commercial viability of the resource.
- Need to diversify the use of geothermal resources for both power generation and direct use application that contributes to the achievement of SDG 7 which is the main enabler to achieve the rest of SDGs.

8. SUMMARY

- Large geothermal resource potential exists in the East Africa region both for power generation and direct use application
- Further support is still required in various areas to accelerate geothermal resource development in the region. These include (among others):

- Human capacity development;
- Technical assistance;
- Increased grant support for exploration phase;
- Risk guarantee mechanisms to catalyse investment;
- Innovative environmental solutions that include business and finance models and technology for low to medium temperature geothermal systems.

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