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OVERVIEW OF GEOTHERMAL RESOURCE UTILIZATION AND POTENTIAL IN THE EAST AFRICAN RIFT SYSTEM

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ABSTRACT

The Great East African Rift System (EARS) is one of the major tectonic structures of the earth and extends for about 6500 km from the Middle East (Dead Sea-Jordan Valley) in the North to Mozambique in the south. This system consists of three main arms: the Red Sea Rift; the Gulf of Aden Rift; and the East African Rift which develops through Eritrea, Ethiopia, Kenya, Tanzania, Zambia, Malawi and northern Mozambique floored by a thinned continental crust. The EARS is composed of two rift trends; the eastern and western branches. The western branch develops from Uganda throughout Lake Tanganyika, where it joins the Eastern branch, following the border between Rwanda and Zaire. The western branch is, however, much less active in terms of volcanism although both branches are seismically and tectonically active today. The East African Rift is one of the most important zones of the world where the heat energy of the interior of the earth escapes to the surface in the form of volcanic eruptions, earthquakes and the upward transport of heat by hot springs and natural vapour emanations (fumaroles). As a consequence, the EARS appears to possess a remarkable geothermal potential. The eastern branch, that forms the Ethiopian and Kenyan rifts, possesses, by far, the most extensive geothermal resource base in Africa and one of the most extensive in the world. Countries such as Djibouti, Uganda, Eritrea and other countries in southeastern Africa have lesser but still important resource bases. Using today's technologies, Eastern Africa has the potential to generate about 2,500-6,500 MW of energy from geothermal power. East African countries using, or having carried out research on, geothermal resources include: Djibouti, Eritrea, Ethiopia, Kenya, Tanzania, Uganda, and Zambia. Among these, Kenya is the leading country in using geothermal energy for electricity production followed by Ethiopia. Kenya is generating a total of about 130 MWe of electricity using geothermal energy resources. In Ethiopia, a geothermal pilot power plant with a total installed capacity of 7.2 MWe was built. Initially, there was a disruption in power generation due to technical problems. These were studied and are currently being rectified. The plant is now achieving partial generation (3MWe). Countries such as Djibouti, Eritrea, Tanzania and Uganda are at the exploration stage. Other countries such as Rwanda, Malawi and the Malagasy Republic have, to date, not gone beyond the resource potential inventory work.

1. INTRODUCTION

The governments of East African countries are committed to investigate and further develop geothermal energy in order to supplement and diversify energy sources. The commitment arises from:

- Strong growth in electricity demand in the countries;
- Recent effects of drought; and
- Volatile nature of petroleum prices.

The East African countries have similar energy production and consumption characteristics. Most of the rift valley countries in East Africa are dependent on fossil fuels as a primary energy source. They use traditional biomass fuels that represent the largest category of energy produced, ranging from 70 to 90% of total energy production. The high percentage of usage of combustible waste and biomass causes large areas of deforestation and contributes to environmental degradation. All East African countries import petroleum products mainly for transport and electricity production. Renewable energy sources (hydro, geothermal, solar, etc.) represent a small portion of total energy production, averaging 2% for hydropower and solar and geothermal production combined (Table 1).

TABLE 1: Energy consumption in East African Countries from various energy sources

Country	Thermal	Hydro	Geothermal	Wind	Total
Djibouti	85	-	-	-	85
Eritrea	130	-	-	-	130
Ethiopia	113.1	669.9	7	-	783
Kenya	346	584	130	1	1052
Tanzania	202	561	-	-	763
Uganda	-	300	-	-	300
Total	**875**	**2116**	**137**	**1**	**3127**

Hydropower is currently the predominant mode of electricity production in the region (70%), yet recent droughts 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 drought it is important for the region to avoid relying solely on hydroelectricity and to make geothermal energy generation a complementary part of future development. Most of the East African countries with geothermal potential are turning to their own indigenous resources to help them meet their growing energy needs. Geothermal energy presents a clean and more environmentally friendly alternative to more traditional fuels.

Using today's technologies, Eastern Africa has the potential to generate 2,500-6,500 MWe of energy from geothermal power (GEA, 1999) which if developed would represent from ¼ to ¾ of current worldwide production from geothermal sources (8900 MWe total installed capacity). Despite this potential, only Kenya now has active geothermal operations as part of the country's electricity generation infrastructure. The progress of development is affected by (a) lack of finance, and (b) lack of technical capabilities in some aspects of development.

To put this in an international perspective, approximately 8,900 MWe of geothermal power is generated worldwide. Philippines produce over 1,900 MWe and Indonesia produces about 589 MWe. Kenya and Ethiopia have a total installed geothermal energy capacity of about 137 MWe. Since the early 1980's, Kenya has been increasing their total geothermal power generation from the initial 15 MWe to 130 MWe at Olkaria near Naivasha. Of this total, KenGen generates 115 MWe, ORMAT (an IPP) generates 13 MWe from a pilot binary plant and Oserian Development Company (a flower farm) generates 2 MWe. By 2018, Kenya plans to add a total of at least 1260 MW of geothermal power (S. Simiyu, pers. comm.).

Varying degrees of geothermal exploration and research have been undertaken in Djibouti, Eritrea, Uganda, Tanzania, Zambia and Malawi. The potential to use geothermal energy for grid-connected electrification is greatest in Kenya, Djibouti, Ethiopia, Uganda and Tanzania. In addition, all the countries have the potential to use geothermal energy for grid connected electrification. Government representatives from Ethiopia, Uganda, Tanzania and Eritrea have also expressed interest in using small-scale geothermal plants for rural electrification.

This paper is a summary of literature review collected 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 upcoming projects.

2. THE EAST AFRICAN RIFT REGION

East African countries using, or having carried out research on, geothermal resources include: Djibouti, Eritrea, Ethiopia, Kenya, Malawi, Tanzania, Uganda and Zambia. A brief description of the exploration and utilization of geothermal resources in each country is given below in alphabetical order.

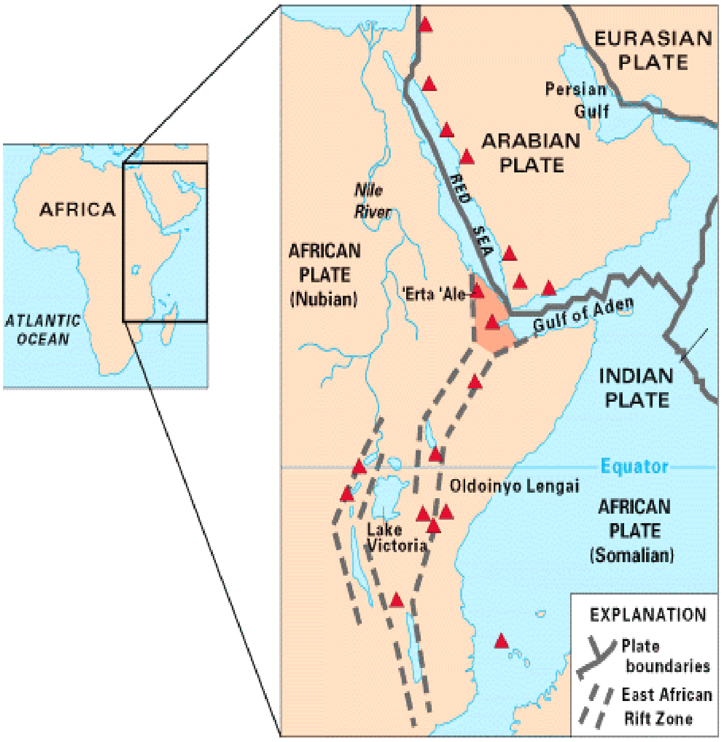

FIGURE 1: The Great East African Rift System

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) and the Red Sea Rift (Figure 1). This structural junction is unique being the focal point of very high heat flux.

According to a recent study by the Geothermal Energy Association (GEA, 1999), the geothermal potential in Djibouti is between 230-860 MWe from a number of prospects including: (i) Lake Assal; (ii) Lake Abhe; (ii) Hanle; (iii) Gaggade: (iv) Arta; (v) Tadjourah; (vi) Obock; (vii) and Dorra (Figure 2).

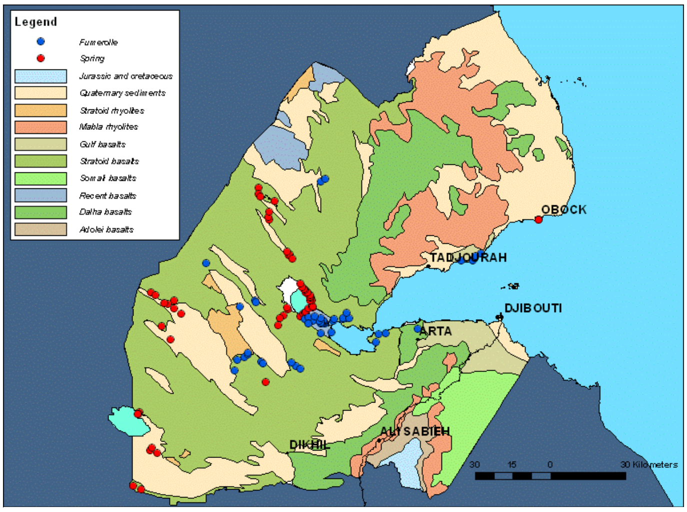

FIGURE 2: Location of geothermal prospects in Djibouti

Much effort has been spent in Djibouti since the 1970's, in view of the country being deficient of indigenous energy resources. Djibouti's current energy production is by fossil fuels (Table 1). The first concerted effort to assess and explore Djibouti's geothermal resources took place in the Assal area from 1970 to 1983 and was funded by the French government. About six exploratory wells were drilled in the Assal geothermal fields. While a high-temperature system with high temperatures has been successfully located, problems related to high salinity of the discovered fluids, which is due to the close proximity of the field to the Gulf of Aden, has delayed resource development and exploitation. In 2000, Geothermal Development Associates (GDA), of USA completed a feasibility study for the development of a 30 MWe geothermal power plant in the Lake Assal region.

The government of Djibouti has a plan to drill additional wells and build a geothermal pilot power plant in the Assal geothermal field. This geothermal pilot plant could also be used as a tool to train local staff for larger geothermal plants in the future (Chideh, 2006).

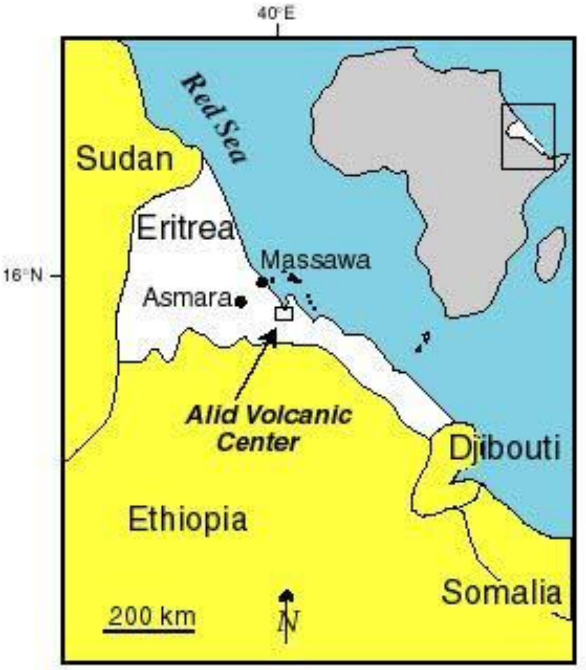

FIGURE 3: Location of Alid volcanic centre in Eritrea

Eritrea

In 1973 the United Nations Development Programme (UNDP), identified a potentially significant exploitable geothermal resource in Eritrea. In 1995 with help of the United States Geological Survey (USGS), Eritrea identified the Alid geothermal prospect area for a follow up of detailed investigations. This area is located about 120 km south of Massawa (Figure 3).

The eastern lowlands of the country are of potential geothermal interest. First priority was given to the Alid volcanic centre for exploration as it has numerous manifestations in the form of hot springs and fumaroles. Detailed geoscientific investigations revealed a reservoir temperature of about 250°C (Abraha, 2005). It is possible that there could be other sites suitable for the discovery of a high-temperature resource.

Ethiopia

Ethiopia started a long-term geothermal exploration undertaking in 1969. Over the years, a good inventory of the possible resource areas has been built up and a number of the more important sites have been explored in the Ethiopian Rift Valley. Of these areas, about sixteen are judged to have potential for high-temperature steam suitable for electricity generation (Figure 4). A much larger number are capable of being developed for direct utilization of geothermal heat in agriculture, agro-industry etc. (Teklemariam and Beyene, 2005, Teklemariam, 2006).

Exploration work peaked during the early to mid-1980’s when exploration drilling was carried out at the Aluto-Langano geothermal field (Lakes District). Eight deep exploratory wells were drilled to a maximum depth of about 2,500 m, and four were found to be productive with a maximum geothermal reservoir temperature of about 350ºC.

During the early 1990’s exploration drilling was also carried out at Tendaho (Northern Afar). Three deep (2,100 m) and three shallow wells (500 m) confirmed the existence of a high temperature (270ºC) reservoir. Currently, discharge tests and geochemical monitoring work is in progress.

The Aluto-Langano geothermal field was handed over to the Ethiopian Electric Power Company (EEPCO) for development in the year 1996 but utilization was delayed until 1998. The first 7.2 MWe pilot power plant was built under a turnkey contract by an Israeli company ORMAT. Initially, there was a disruption in power generation due to technical problems. These were studied and are currently being rectified. The plant is now achieving partial generation (3 MWe).

Other geothermal prospect areas in the Ethiopian Rift Valley are at various stages of exploration that vary from reconnaissance to detailed geoscientific studies including drilling of temperature gradient (TG) wells. These include:

(i) Tulu-Moye and Corbetti : Detailed geoscientific including drilling of TG wells
(ii) Abaya, Dofan and Fantale: Detailed geoscientific studies
(iii) Kone, Meteka, Teo, Danab, and L.Abhe: Reconnaissance investigations.

During the three decades that the geothermal resources exploration work was carried out in Ethiopia, a good information base and degree of exploration capacity has been developed. This is especially true in the human capacity and basic infrastructure development that will be critical in ensuring that future selected resources sites are advanced to the development phase much more rapidly than before.

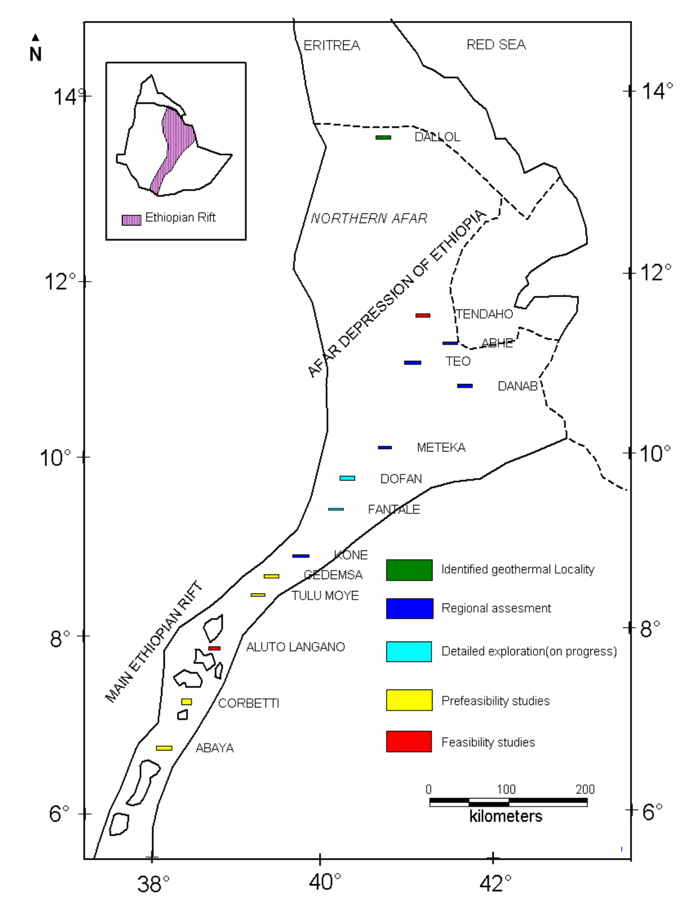

FIGURE 4: Location of geothermal prospect areas in Ethiopia

Kenya

In the East African Rift region, Kenya was the first African country to tap geothermal energy for electric power generation. This has partly been due to its limited hydro resources and the success that it had in the staged geothermal development since 1982. Kenya's first electricity generating plant has been operating for 24 years and has proven to be reliable and economical with a 98% availability and 100% load factor. This has encouraged Kenya to speed up its geothermal power development program. It now has an installed capacity of about 130 MWe. This has been achieved over a period of 50 years since exploration started in the 1950's. To date, a total of 105 wells have been drilled for exploration, production, monitoring and injection with depths varying from between 1,000 and 2,600 m. The recent long term least-cost power development program foresees an addition of generating capacity from geothermal by 1,260 MW by the year 2018. It is notable that in Kenya other than electricity production, geothermal water and carbon dioxide from geothermal fluids are used in an extensive complex of green houses for growing roses. Rose exports from that farm total US$300 million per year (Mwangi, 2005; S. Simiyu pers. comm.).

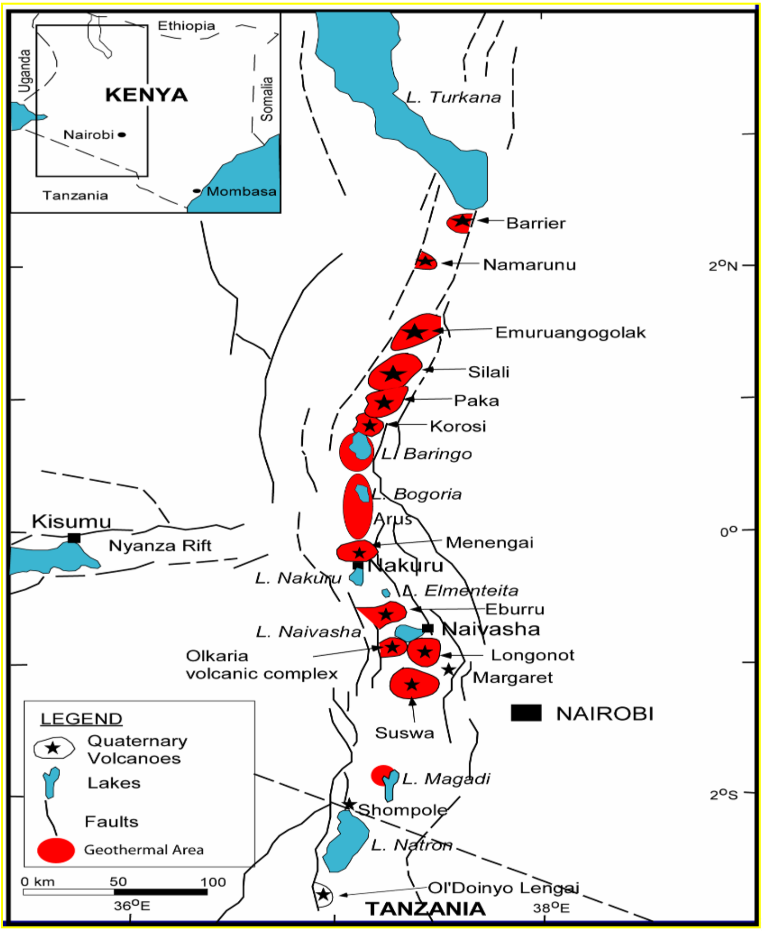

FIGURE 5: Location of geothermal prospect areas in the Kenyan Rift

The most explored and developed field in Kenya is the Olkaria geothermal field that is divided into seven areas. The Olkaria I area has a 45 MWe power plant based on three 15 MWe units commissioned in 1981, 1983 and 1985 and Olkaria II area has a 70 MWe power plant commissioned in 2003. These two plants and areas are owned by KenGen. The Olkaria III area with a pilot 13MWe plant is owned ORMAT (an IPP). Olkaria IV area (locally referred to as Domes) has three exploration wells drilled with temperatures up to 350ºC. A drilling operation is underway for a 140 MWe power plant. Other geothermal areas such as Eburru, Longonot, Suswa, Menengai etc. are at various stages of exploration (Figure 5). The current estimated geothermal potential in Kenya is about 3,000 MWe.

In the process of these activities, Kenya has acquired considerable expertise in geothermal related earth sciences and engineering. It has also led to a development of the institutional infrastructure that is necessary for geothermal resource exploration, development and utilization.

Tanzania

Geothermal exploration in Tanzania was carried out during 1976-79 by SWECO, a Swedish consulting group, in collaboration with Virkir-Orkint (Iceland), with financial support from the Swedish International Development Authority (SIDA). Reconnaissance studies for surface exploration were carried out in the north (near Arusha, Lake Natron, Lake Manyara and Maji Moto) and in the south (Mbeya region). Geothermal work in all locations in Tanzania is at the surface exploration stage.

Two potential target areas for geothermal exploration singled out so far are: (a) Arusha region near the Kenyan border in the North; and (b) Mbeya region between Lake Rukwa and Lake Nyasa in the southwest (Figure 6).

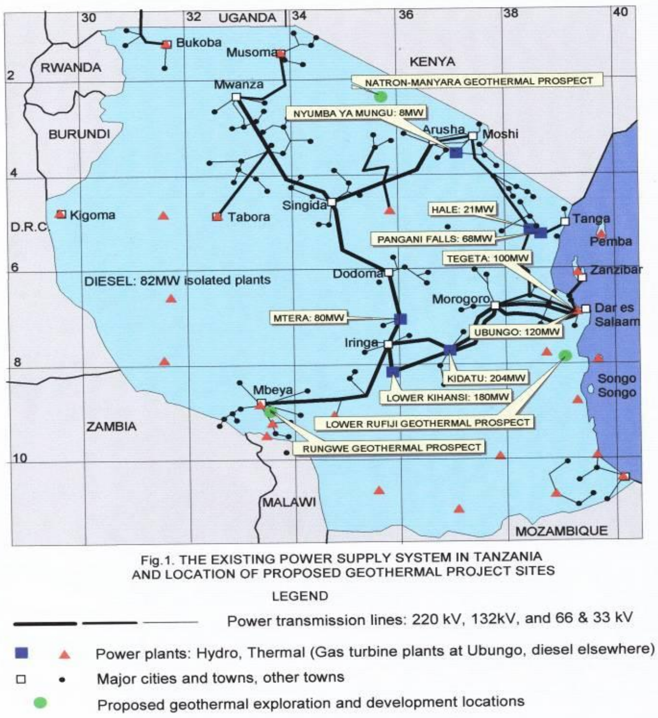

FIGURE 6: Geothermal prospect areas in Tanzania

Another potential area (Luhoi) was prospected during 1998-2002 by First Energy Company (a local firm). It conducted important project definition and reconnaissance evaluation work. This area is located 160 km south of Dar es Salaam. The work conducted so far indicates the existence of a geothermal reservoir with a temperature greater than 200°C.

Uganda

Reconnaissance surveys have been carried out on geothermal areas of Uganda since 1935 when the first documentation of hot springs was made (Bahati and Joshua, 2002; Bahati, 2006). Uganda recognizes the need to develop its geothermal resources to diversify its electricity generation, to support hydro and to improve the electricity supply in the western part of the country. Recent geoscientific studies have focused on three geothermal systems of Buranga, Katwe and Kibiro, all located in the active belt in the western Rift valley along the border of Uganda and Democratic Republic of Congo (Figure 7). The three areas are chosen for study because of their volcanic and tectonic features that may indicate a strong heat source and high permeability.

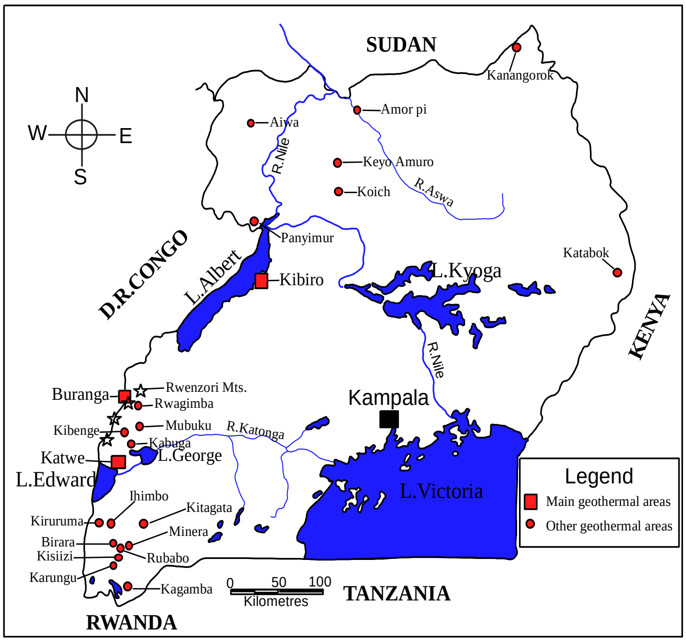

FIGURE 7: Geothermal prospects in Uganda

The African Development Bank with the Uganda Alternate Energy Resource Agency (UAERA) conducted research at Katwe. The Icelandic International Development Agency (ICEDA) has financed a surface exploration survey at Kibiro incl. geological and geophysical surveys. The ICEDA has also completed the started survey of the UAERA study in the Katwe geothermal prospect area. The German Geological Survey (BGR) has carried out a micro seismic survey in the Buranga geothermal prospect areas.

At the Katwe and Kibiro geothermal prospect areas, shallow wells (200-300 m) for a temperature gradient measurement were drilled. The temperature gradient measurement of shallow wells will prove the existence of the resource and update the geothermal model that will be a basis for the drilling of deep exploration wells.

Figure 8. Map of Zambia showing the location of Kapisya Geothermal Prospect

FIGURE 8: Map of Zambia showing location of Kapisya geothermal prospect

Zambia

The Zambian Geological Survey (ZGS) has carried out reconnaissance surveys on geothermal areas of Zambia since the 1950's. In 1986, the ZGS together with an Italian company studied various hot springs. As a result, development has been considered on two prospects (i) Kapisya and (ii) Chinyunyu (Figure 8).

The Italian government in 1987 funded a mini geothermal pilot power plant (200 kW) at Kapisya hot springs located in the Sumbu National Park on the shores of Lake Tanganyika. The plant was installed on the basis of limited exploration work, and it never became operational. The government of Zambia is currently exploring options for refurbishing and commissioning the plant after being idle for 20 years.

3. MAIN OBSERVATIONS

Exploration and utilization of geothermal energy resources in the East African region for the last three decades has indicated that:

- The region has a large untapped geothermal resource potential;
- The geothermal resources are an indigenous, reliable, environmentally clean and economically viable, renewable energy resource;
- Development of geothermal resources are constrained by (i) the risks that are associated with resource exploration and development; (ii) the financial risks that are associated with investment in power development projects ; and (iii) lack of appropriate investment and institutional settings in many East African countries;
- Diversified use of geothermal energy augments energy supply from hydro power plants and improves the generation mix. It avoids vulnerability to drought and oil price fluctuations.

4. STRATEGIES FOR DEVELOPMENT

In order to promote the geothermal resource exploration and utilization each government of the East African countries has a plan to:

- Look for loans and grants from international organizations to finance the projects for further exploration and development;
- Look for private sector participation and financing from developers, investors, equipment suppliers and development banks;
- Establish long-term conducive policies and incentives that attract private investment;
- Establish a risk guarantee fund by donor and development agencies for exploratory and appraisal drilling of projects;
- Set up a regional network of geothermal agencies to ensure the promotion and use of geothermal expertise in the East Africa Region.

5. UPCOMING PROJECTS

Towards the objective of developing this energy resource, a number of multi and bilateral agreements are underway. Among these, the African Rift Geothermal Energy Development Facility (ARGeo) Project is a critical component (BCSE, 2003). The objective of the project is to promote geothermal resource utilization by removing the risks related to resource exploration and development and by reducing the cost of power development project implementations. The African Rift Geothermal Energy Development Facility Project is planned to deliver a package consisting of financial and technical inputs as a means of realizing that promotion. Policy support will aim at cultivating the recognition that the resource is reliable and indigenous with respect to other sources of power. Utilization of the resource in direct uses such as agriculture, horticulture, aquaculture and industry will be promoted.

The project's implementing and executive agencies are the United Nations Environmental Programme (UNEP) and the World Bank. The project is a 7-year Eastern Africa Regional Geothermal programme financially supported by the Global Environment Facility (GEF), donors and project sponsors. In June 2006, the GEF council approved US$ 17.75 Million to launch the project. The countries targeted by the project are Kenya, Ethiopia, Djibouti, Eritrea, Tanzania, and Uganda. Institutional capacities that already exist in these countries will form a network that will be the main instrument for project implementation and capacity building.

ARGeo implementation will be preceded by an initial project development stage which will identify the most suitable resource areas for support, survey the already existing human, institutional and infrastructure capacities in the region, and assist with the creation of the collaborative institutional aims to support initially one to two projects in the subject countries.

REFERENCES

Abraha, M., 2005: Geothermal exploration opportunities in Eritrea. *Proceedings of the World Geothermal Congress 2005, Antalya, Turkey,* CD, 6 pp.

BCSE (Business Council for Sustainable Energy) 2003: Market assessment report. *East Africa Geothermal "Market Acceleration" Conference, Nairobi, Kenya.*

Bahati, G., 2006: Status of geothermal exploration in Uganda. *Geothermal Resources Council, Transactions, 30*.

Bahati, G., and Joshua, T., 2002: *Geothermal energy in Uganda.* Geological Survey of Uganda.

Chideh, A., 2006: Pilot project for energy and mining economic beneficiation from Assal (Djibouti) geothermal and mineral resources. *Geothermal Resources Council, Transactions, 30*.

Geothermal Energy Association, 1999: *Geothermal energy, the potential for clean power from the earth.*

Ministry of Mines and Energy, Geological Survey of Ethiopia and Ethiopian Electric Power Corporation, 2008: *Project pipeline proposal on geothermal resource exploration and development in Ethiopia.* Draft proposal, July 2008.

Mwangi, M., 2005: Country update report for Kenya 2000-2005. *Proceedings of the World Geothermal Congress 2005, Antalya, Turkey,* CD, 10 pp.

Teklemariam, M., 2006: Overview of geothermal resource utilization and potential in East African Rift System. *Geothermal Resources Council, Transactions, 30.*

Teklemariam, M., and Beyene, K., 2005: Geothermal exploration and development in Ethiopia. *Proceedings of the World Geothermal Congress 2005, Antalya, Turkey*, CD, 9 pp.

UNDP, 1973: *Geology, geochemistry and hydrology of the East Africa Rift System within Ethiopia.* United Nations, NY, report DDSF/ON/116.