Presented at Short Course V on Exploration for Geothermal Resources,
organized by UNU-GTP, GDC and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, Oct. 29 – Nov. 19, 2010.

Geothermal Development Company
Powering the Vision
UNITED NATIONS UNIVERSITY
GEOTHERMAL TRAINING PROGRAMME
KenGen
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OVERVIEW OF GEOTHERMAL RESOURCE UTILIZATION 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 that 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 tectonics and 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 vapor emanations (fumaroles). 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 more than 15,000 MW of energy from geothermal power. However, only 214MW is surrently generated in Kenya (209MW) and Ethiopia (5MW).

1. INTRODUCTION

The governments of East African Countries are committed to investigating and further developing geothermal energy in order to supplement and diversify energy consumption. This commitment arises from:

- Strong growth in electricity demand in the countries;

- Recent effects of drought that have rendered hydro power unreliable
- Silting of hydropower resources; 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 resource.

They use also traditional biomass fuels that represent the largest category of energy produced, ranging from 70-90% 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 use 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.

Hydropower is currently the predominant source of electricity production in the region (70%), yet recent droughts and the silting of reservoirs pose questions concerning the reliability of these resources. Thermal production (mainly diesel generation) is present in most countries and is the only source of production in Eritrea and Djibouti. Volatile prices and high import costs make diesel production a costly production source.

Therefore, to decrease imports and save foreign currency and in the face of the increasingly recurring severe drought in the region it is planned that geothermal energy will provide complementary generation option for future development. So most of the East African countries with geothermal resources are turning to their own indigenous resources to help them meet their growing energy needs. Geothermal energy also presents a clean and more environmentally friendly alternative to more traditional fuels.

Using today's technologies, Eastern Africa has the potential to generate over 15,000 MW of energy from geothermal sources and the figure would be higher if the low and intermediate temperature resources are also utilized. Despite this potential, only Kenya has active geothermal operations as part of the country's electricity generation infrastructure. The progress of development is affected by (a) lack of finance in this risky area that has been mitigated by finance from international donors, and (b) lack of technical capabilities in some aspects of development.

To put this in an international perspective, over 10,000 MW of geothermal power is generated worldwide. Philippines produces over 1900 MW and Indonesia produces about 589 MW of electrical power from geothermal energy. Kenya and Ethiopia have installed capacity of geothermal energy of about 209MW and 5 MW, respectively. Between 1981 and 2002, Kenya was producing 45MW geothermal power at Olkaria at greater than 98% plant availability. The same performance has been achieved by the additional generation of 105MW at Olkaria II.

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 Eritrea, Kenya, Djibouti, Ethiopia, Uganda and Tanzania. In addition, the governments in the region have embraced usefulness of small-scale geothermal plants for rural and mini grid systems.

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. Brief description of exploration and utilization of geothermal resources in each East African countries is given below in terms of alphabetical order.

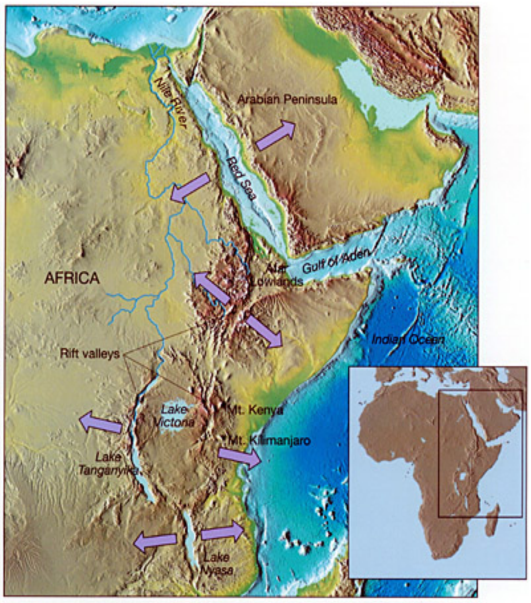

FIGURE 1: The Great East African Rift System

FIGURE 2: Location of Geothermal prospect areas in Djibouti

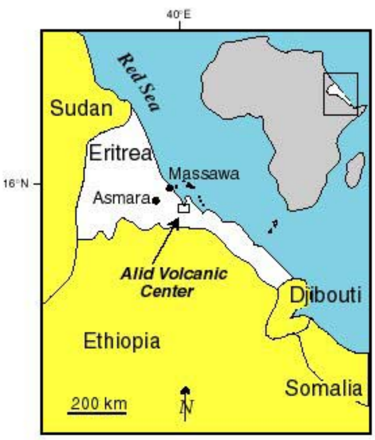

FIGURE 3: Location map of geothermal prospect area, Alid Volcanic Center in Eritrea

2.1 Djibouti

Djibouti lies at the junction of three active, major coastal spreading centers: (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 study by the Geothermal Energy Association (GEA, 1999), the geothermal potential in Djibouti is between 230-860MW from a number of prospects including: (a) Lake Asal; (ii) Hanle; (iii) Gaggade: (iv) Arta; (v) Tadjourah; (vi) Obock; and (vii) Dorra (Figure 2).

Much effort has been expended in Djibouti since the 1970s, in view of the country being deficient of indigenous energy resources. Djibouti's' current energy production is based on fossil fuels (Table 1). The first concerted effort to assess and explore Djibouti's geothermal resources took place in the Assal area from 1970-83 and was funded by French government. About six exploratory wells drilled in the Assal geothermal fields. While a very high temperature system has been successfully located, problems related to the high salinity of the discovered fluid, which is due to the close proximity of the Assal field to the Gulf of Aden, has delayed resource development and exploitation.

The Government of Djibouti is currently evaluating interest from private developers to develop Lake Asal field.

TABLE 1: Power sources in EA

Country	Thermal	Hydro	Geothermal	Wind/CoGen	Total
Djibouti	85	-	-	-	85
Eritrea	130	-	-	-	130
Ethiopia	112	671	7	-	790
Kenya	419	761	209	31.45	1395
Tanzania	202	561	-	-	763
Uganda	-	300	-	-	300

2.2 Eritrea

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

The Eastern lowlands of the country are of potential geothermal interest. First priority was given to the Alid Volcanic center for exploration as it has numerous manifestations in the form of hot springs and fumaroles. Detailed geoscientific investigations took place in the Alid that revealed a reservoir temperature of about

250°C. It is possible that there could be other sites suitable for the discovery of a high temperature resource.

2.3 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 (Figure 4). Of these areas, about sixteen are judged to have potential for high temperature steam suited to electricity generation. A much larger number are capable of being developed for non-electricity generation applications in agriculture, and agro-industry. The geothermal potential in Ethiopia for power generation exceeds 5,000MW$_e$.

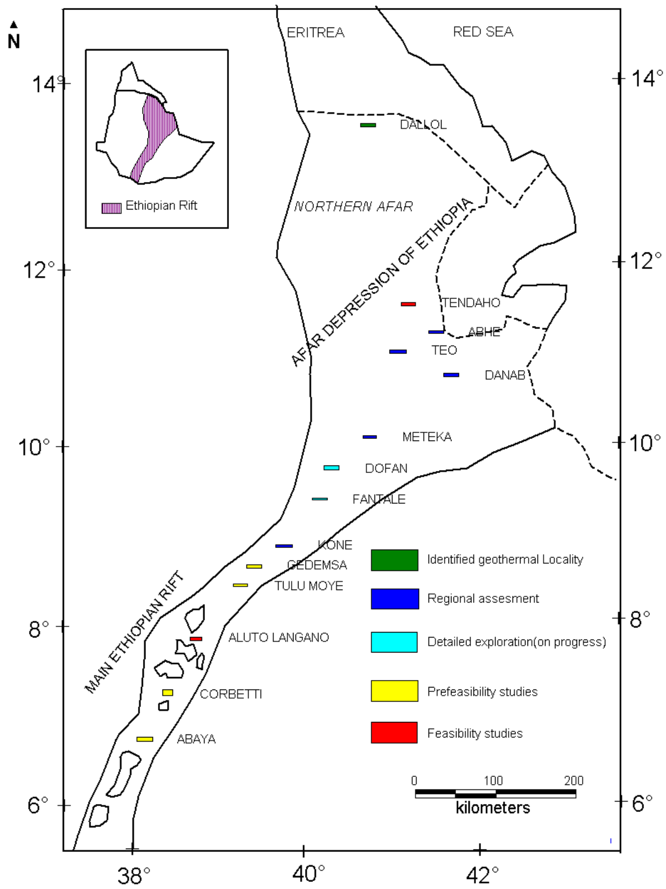

FIGURE 4: Location of Geothermal Prospect areas in Ethiopia

Exploration work peaked during the early to mid-1980s 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 2500m, and four are found to be potentially productive with a maximum geothermal reservoir temperature of about 350ºC. Resource utilization was delayed until 1998. The Aluto-Langano geothermal field was handed over to the Ethiopian Electric Power Company (EEPCo) for development in the year 1996. The first 7.2 MWe geothermal pilot power plant in the country was built under the turnkey contract by ORMAT International.

The 7.2 MW net capacity pilot plant installed at the Aluto- Langano has faced operational difficulties that are essentially due the technical problems and lack of the appropriate field and plant management skills. With the rectification of these problems, the plant should run more reliably and provide experience that would be useful in the exploitation of the country's extensive resources. This would augment power supply from hydro-resources and, thereby, diversify the energy supply structure. In 2005, EEPCo sought international bids for problem identification and putting the plant back into operation. A number of companies submitted bids and Geothermal Development Associates, an American firm was awarded the contract. Phase one of the rehabilitation is complete and the plant currently generates 5MW.

During the early 1990s exploration drilling was also carried out at Tendaho (Northern Afar), three deep (2100m) and three shallow wells (500m), proving the existence of high temperature (270ºC) and pressure fluid. The Ethiopian Government has planned for appraisal drilling to be undertaken at Tendaho in 2011 and to be followed by development of a 5MW pilot plant. However, the field is expected to exceed 20MW when fully developed.

Utlilization of geothermal energy in Ethiopia dates back many years when Emperor Menelik II founded Addis Ababa city in 1886 at a site with abundant hotsprings. The hot springs exist to date and have largely been used for recreational activities, e.g:

- Hilton Hotel: The Swimming-pool is heated from hot springs.
- Filowha: Shower and bathtubs heated by hot water.
- Finfinne Resturant: Natural hot water flowing out from the taps.

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

(i) Tulu-Moye and Corbetti.
(ii) Abaya and Dofan Fantale.
(iii) Teo, Danab, and Kone.

During the three decades that the geothermal resources exploration work was carried out in Ethiopia, a good information base and a good degree of exploration capacity, in terms of human and infrastructure, has accumulated, ensuring that selected resources sites can be advanced to the resource development phase much more rapidly than before.

2.4 Kenya

In the East African Rift region, Kenya was the first African country to tap geothermal energy for electric power generation. This has partly also been due to the problems that it has in developing its limited hydro resources and the successes that it had in small scale development since 1982. Kenya's geothermal sites are all located within the Kenya rift valey (Figure 5).

Kenya's first electricity generating plant has been operating now for 27 years and has proven reliable and economic, running at over 95% availability. This has encouraged Kenya to speed up its geothermal power development program. Kenya now has an installed capacity of 209 MWe. This has been achieved over a period of over 50 years since the first exploration was undertaken in 1956. To date, a total of over 130 wells have been drilled for exploration, production, monitoring and re-injection with depths varying from between 600m and 3,000 meters depth. The long term least-cost power development program foresees a total generating capacity of 16,000MW by the year 2030 of which about 5,000MW willcome from geothermal resources. It is notable that in Kenya other than electricity production, geothermal water and carbon dioxide are used in 100 hectare complex of green houses for growing roses.

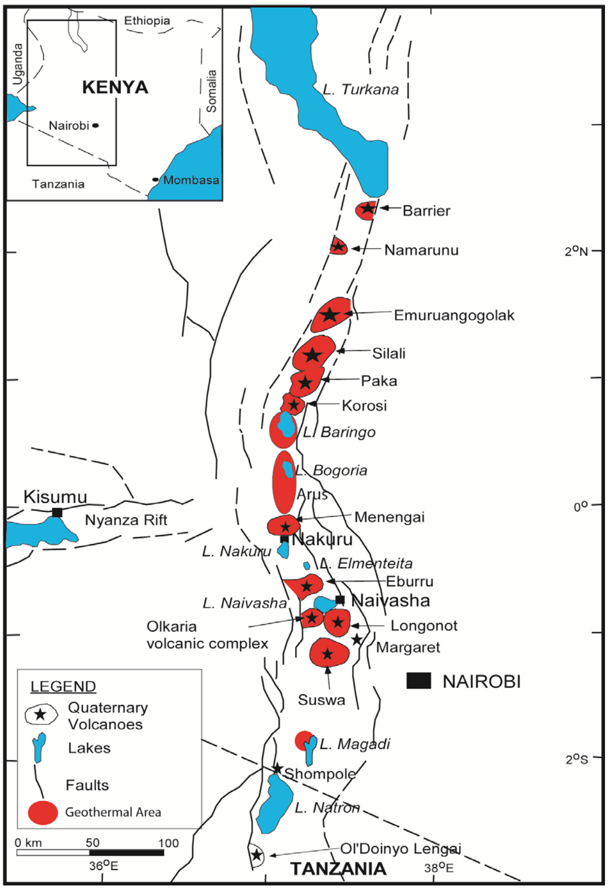

FIGURE 5: Location Map of Geothermal prospects in Kenya

The most explored and developed field in Kenya is the Olkaria geothermal field (Figure 6). The field has been divided into five main sectors: East, West, North East, Cenytral and Domes fileds. The

Olkaria I plant is in the East field and hosts a 45 MWe power plant based on three 15 MWe units. The plant is owned and operated by the Kenya Electricity Generating Company (KenGen). The individual units were commissioned in 1981, 82 and 85. Production drilling is currently being undertaken by GDC and steam will be sold to KenGen for a new 140MW plant to be commissioned in 2013.

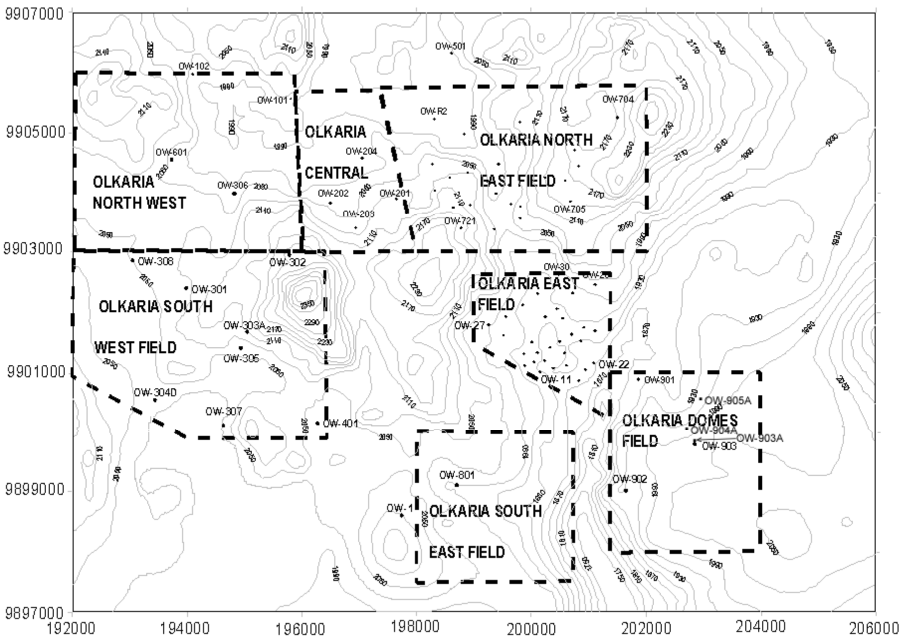

FIGURE 6: Olkaria Geothermal field

The Olkaria II plant is located in the North East field and has an installed capacity of 105 MWe. The plant owned and operated by KenGen was developed in two phases with the 70MW plant commissioned in 2003 and 35MW plant commissioned in 2009. The Olkaria III plant is owned and operated by an IPP and currently has an installed capacity of 55 MWe. Production drilling has commenced for development of an additional 36MW from the field.

The Olkaria Domes field in the easternmost of the greater Olkaria field. Exploration drilling was undertaken in 1998 and appraisal drilling in 2005. Currently production drilling is in progress for 140MW Olkaria IV plant. Drilling is being undertaken by GDC while power plant will be developed and operated by KenGen. GDC and KenGen will have a steam sale agreement to cover steam supply for the plant. Currently, over 90% of the steam required for the plant is available on the well head. The plant will be commissioned in 2013.

Oserian Development Company Ltd (ODLC) constructed a 2.0 MWe binary plant Ormat OEC in Olkaria Central to utilise fluid from a well (OW-306) leased from KenGen. The plant, which provides electrical power for the farm's operations, was commissioned in July, 2004. A second 2MW plant was commissioned in 2006 giving a total of 4MW. ODLC who grow cut flower for export is also utilizing steam from a 1.28 MWe well to heat fresh water through heat exchangers, enrich CO_2 levels and to fumigate the soils. The heated fresh water is then circulated through greenhouses. The advantage of using geothermal energy for heating is that it results in drastic reduction in operating costs.

Geothermal resource potential of prospects to the south and north of Olkaria has been studied and Eburru is the only field amongst these that has had exploration wells drilled. The other fields are at various exploration stages ranging from reconnaissance studies to advanced surface exploration with wells sited (Figure 5). GDC plans to undertake a four well exploratory drilling programme in Menengai from January 2011. It is planned that if exploratory drilling is successful then appraisal drilling will be fast tracked to result in 400MW phase one development by 2013.

In the process of these major achievements over the last few years, Kenya has acquired considerable expertise in the earth science and engineering fields and in the institutional infrastructure that are used in geothermal resource exploration, development and utilization.

2.5 Tanzania

Geothermal exploration in Tanzania was carried out between 1976-79 by SWECO, a Swedish consulting group, in collaboration with Virkir-Orkint (Iceland), with the financial support of the Swedish International Development Authority (SIDA). Reconnaissance studies of surface exploration were carried out in the north (near Arusha, Lake Natron, Lake Manyara and Maji Moto) and in the south (Mbeya region). More than 15 thermal areas (T>40°C) have been identified.

Two potential target areas for geothermal exploration singled out so far are: (a) Arusha region near the Kenya border in the North; and (b) Mbeya region between Lake Rukwa and Lake Nyasa in the southwest (Figure 7). 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 by BGR of Germany included MT surveys and indicated the occurrence of a geothermal system at Rungwe prospect. So far, no commercial development of any fields has been undertaken.

2.6 Uganda

Reconnaissance survey has been carried out on geothermal areas of Uganda since 1935 when the first documentation of hot springs was made. Uganda recognizes its need to develop its geothermal resources to diversify its electricity generation capacity, to support hydro and to improve electricity supply in the western part of the country. Recent geoscientific studies have focused on three geothermal systems of Buranga, Katwe and Kibiro, all

TANZANIA GEOTHERMAL PROSPECTS

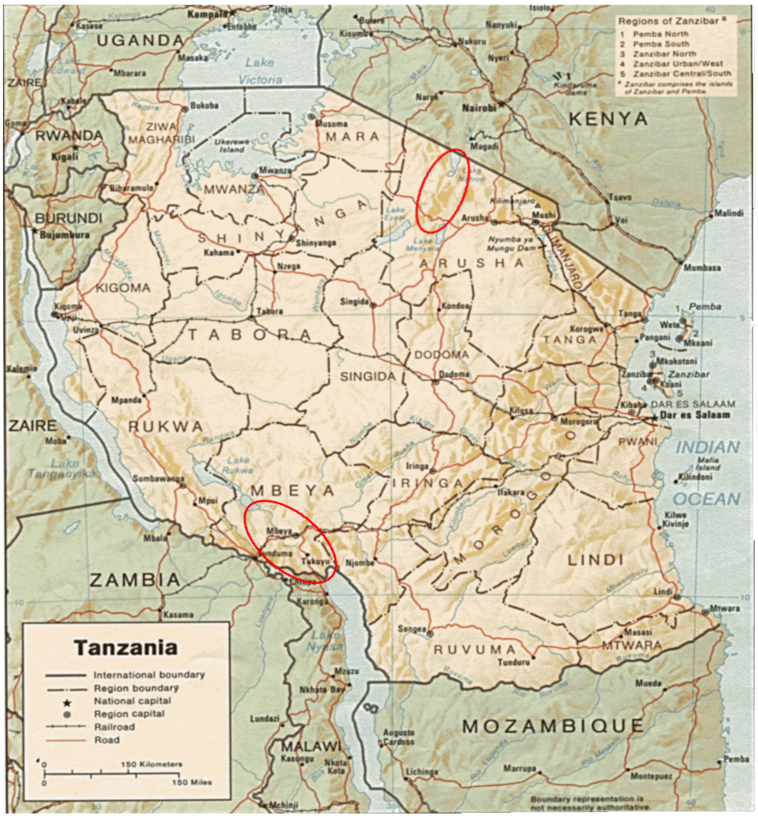

FIGURE 7: Geothermal Prospects in Tanzania

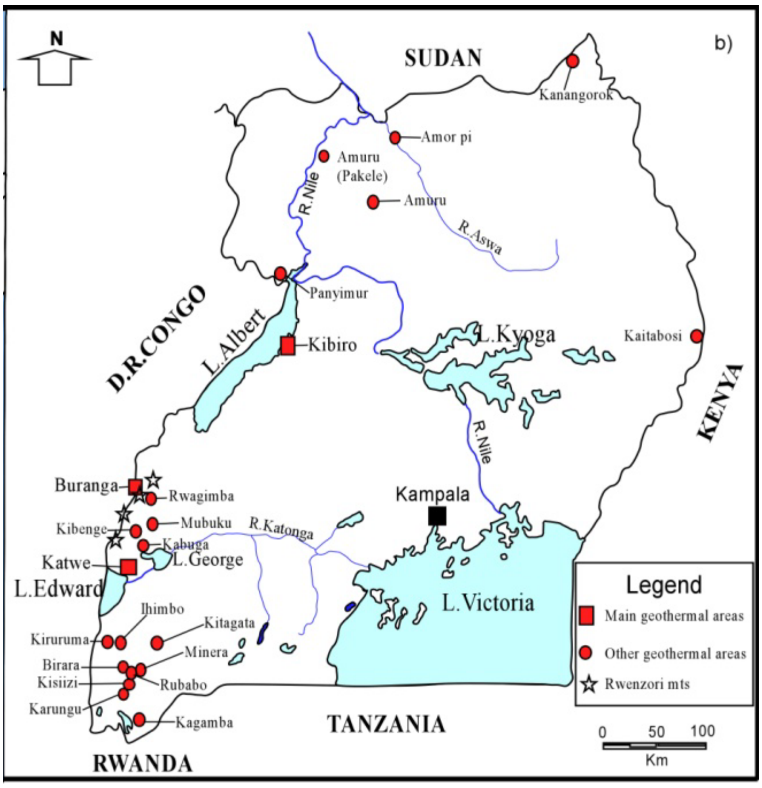

FIGURE 8: Geothermal areas in Uganda

located in the active volcanic belt in the western Rift valley all along the border of Uganda and Democratic Republic of Congo (Figure 8).

The African Development Bank with the Uganda Alternate Energy Resource Agency (UAERA) conducted research at Katwe, Kibiro and Buranga. Also, ISOR of Iceland through ICEIDA conducted a geophysical study at Kibiro Geothermal prospect area which led to the drilling of 200-300m temperature gradient wells in order to locate target areas for deep exploratory wells. However, the wells did not encounter geothermal reservoirs.

2.7 Zambia

Zambian Geological Survey (ZGS) has carried out reconnaissance survey on geothermal areas of Zambia since 1950's. In 1986, the ZGS together with Italian company studied various hot springs. As a result, development has been considered on two prospects (i) Kapsiya and (ii) Chinyunyu projects (Figure 9).

FIGURE 9: Map of Zambia showing the location of Kapisya and Chinyunyu geothermal areas

Mini geothermal pilot power plant (200 KW) located in Kapisya was installed on the basis of limited exploration work, and the plant never became operational. The plant was financed by the Italian government. Government of Zambia is currently exploring options for commissioning and refurbishing the plant after being idle since 1986.

Geothermal use in Zambia is mainly for recreation, healing and spiritual purposes. Chinyunyu hotsprings discharge at 65°C and is popular with locals who come as far as from Lusaka to use the spring water.

2.8 Rwanda

The best known geothermal areas in Rwanda are Gisenyi at the northern shores of Lake Kivu and Mashyuza to the south of Lake Kivu (Figure 10). Gisenyi has the largest discharge at 75°C and is mainly used for hot bath and tourists are known to visit the site.

2.9 DR Congo

Geothermal manifestations occur in many areas within and near Virunga volcanic field. At Kiabukwa, a 0.2MW$_e$ binary plant was installed in 1952 but stopped operation soon after due to lack of proper

maintenance of the equipment (Figure 11). The equipment was then vandalized and no trace of installation is visible. The shallow wells that supplied hot water to the plant discharged at 91°C with a flow rate of 40 l/s. Exploration is as yet to re start in DRC despite immense interest in geothermal from the Government.

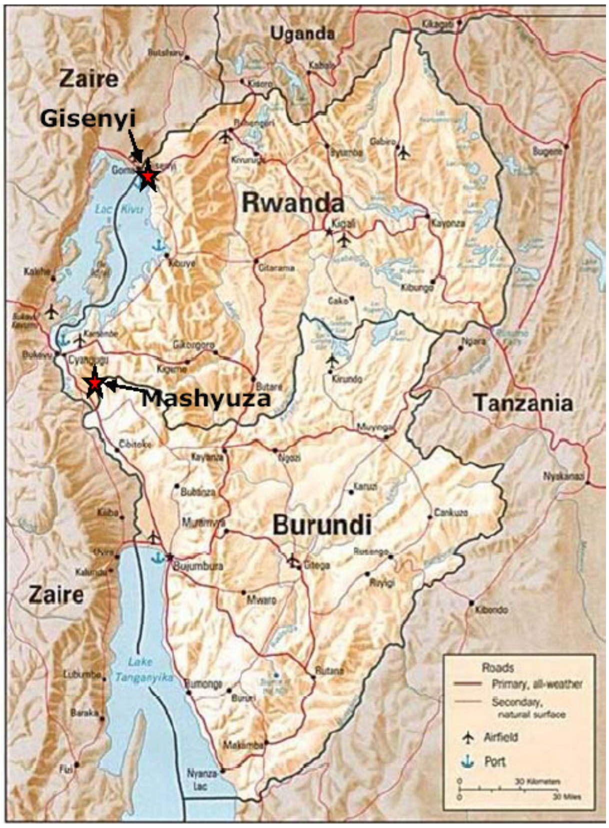

FIGURE 10: Map showing geothermal areas in Rwanda

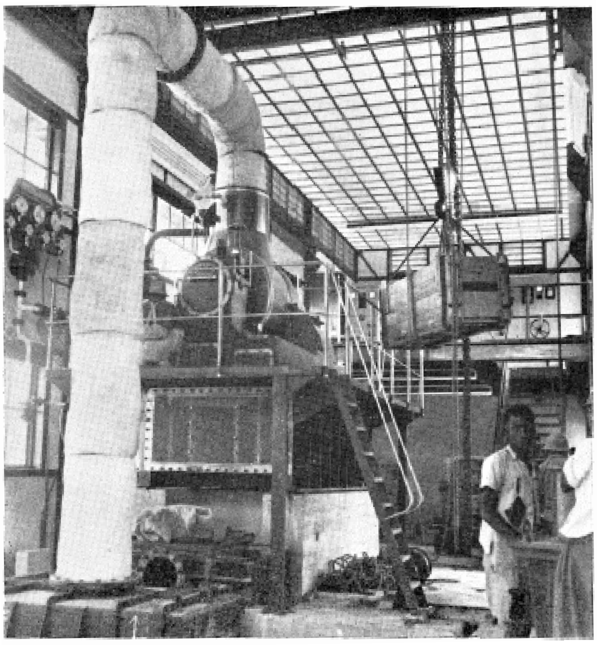

FIGURE 11: Photo of 0.2MW Kiabukwa binary plant, DRC

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 resource is an indigenous, environmentally clean and economically viable, renewable energy resource;
- Development of geothermal resource is 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 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 objectives of further exploration and development of the geothermal resource in the region, multi and bi-lateral projects are underway.

5.1 ARGEO program

Among these, the African Rift Geothermal Energy Development Facility (ARGeo) Project is a critical component. 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 implementation.

The African Rift Geothermal Energy Development Facility Project is planned to deliver a package consisting of financial and technical inputs as means of realizing that promotion. Policy support will aim to help in cultivating the recognition that the resource is reliable and indigenous with respect to other sources of power. The utilization of the resource in direct uses such as agriculture, horticulture, aquaculture and industry will be promoted.

The project's implementing agency is the United Nations Environmental Programme (UNEP). Its executing agency is the World Bank. Projects will be executed in collaboration with a network of national institutions in the region. Other institutions that are involved in development financing will also contribute resources, including the Global Environment Fund (GEF), ICEIDA, and BGR.

The countries targeted by the projects are Djibouti, Eritrea, Ethiopia, Kenya, Tanzania and Uganda. The institutional capacities that already exist in these countries will form a network institutions that will be the main instruments 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, assist with the creation of the collaborative institutional aims to support initially 3 to 4 investment projects in the subject countries. A total of US$ 250 million will be allocated to implement the project.

5.2 KFW RMF program

The KFW Facility is expected to be hosted by the African Union Commission (AUC) and to have funds of between €20 million and €50 million. The AUC will be supported by a suitably qualified and experienced technical consultant. The Facility will reduce geothermal exploration drilling risk by supporting two key activities:

- Surface studies to determine the optimal location of exploration wells at the most promising geothermal prospects

- Drilling of exploration wells at the most promising geothermal prospects to assist developers secure finance for subsequent exploration or appraisal wells. It is anticipated that the facility will be rolled out within 2011.

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