# Geothermal energy in Uganda, country update

Godfrey Bahati
Department of Geological Survey and Mines, P.O Box 9, Entebbe, Uganda.
Email: godfrey_bahati@hotmail.com or gsurvey@starcom.co.ug

**Abstract**

Recent studies on the Uganda geothermal systems have focused on three geothermal prospects, Katwe, Buranga and Kibiro, all located in the tectonically active and Recent volcanic belt in the Western Rift valley along the border of Uganda and the Democratic Republic of Congo. Geothermal systems and saline and fresh water lakes characterize the Rift Valley. The three areas were chosen for study because of their volcanic and tectonic features that indicate a powerful heat source and high permeability. The objective is to develop geothermal energy as an alternative energy source to hydro and others to meet the energy demand of rural areas in sound environment. The geology and geochemistry results for the surface hot springs indicate that potential geothermal systems exist at depth. The subsurface temperatures of 160-200°C, 200°C, and above 200°C for the Katwe, Buranga and Kibiro prospects, respectively, have been inferred by geothermometry and mixing models. These temperatures are suitable for electric power production and direct use in industry and agriculture. Other areas outside the tectonically active and recent volcanic belt have typical fluid temperatures suitable for direct application to domestic use, agriculture and industrial heating. Surface exploration studies have reached advanced stages in the three areas with the execution of the ongoing geophysical survey, the results of which will be used to upgrade the current geothermal model of geology and geochemistry and develop an integrated model that will be a basis for siting the exploration wells.

***Keywords:*** *Katwe-Kikorongo, Buranga, Kibiro, geothermometry, isotopes, geophysical surveys.*

## 1 Introduction

Uganda is situated in East Africa and has borders with the Democratic Republic of the Congo (to the West), Kenya (to the East), Rwanda and Tanzania (to the South) and Sudan (to the North). Uganda has an area of approximately 241,000 $km^2$ and a population of about 24.7 million people with an annual growth rate of 2.5%. The country's *per capita* energy consumption of 0.3 tonnes of oil equivalent (TOE) or 12.72 GJ is among the lowest in the world. Few people have access to modern energy supplies such as electricity and petroleum products. The energy consumption rate stands at about 5 million toe/year of which approximately 93% is biomass (wood, charcoal and agricultural residues). The grid electricity access rate is very low: 6% for the whole country and about 2% for the rural areas. Demand for power is growing at 3-4 MW a month.

The country is well endowed with considerable hydropower resources with the potential capacity estimated to be in excess of 2,000 MW. Hydropower is the main source of Uganda's electricity supply with a total generating capacity of 317 MW. The total demand is estimated to be around 580 MW by the year 2005. The major hydroelectric plant, the Nalubale (Owen Falls) dam on River Nile at Jinja, was rated at 180 MW by 1999. An extension to this, the Kiira plant was commissioned in 2001 and is rated at 200 MW. However, only 120 MW have been put on line, bringing the total generation capacity to the current 317 MW.

The Government of Uganda is presently rehabilitating the existing power generation and distribution installations and is studying ways to meet the increasing

energy demand by other indigenous energy sources. As part of this effort, the Government is in the process of formulating a long term integrated least-cost "Alternative Energy Resources Development Programme (AERDP)" for the country, and defining projects that are optimal within the framework of the programme. Geothermal energy presents a high priority alternative to hydropower and therefore, findings and recommendations from the geothermal project will be an important input to the programme.

# 2 Geothermal potential

The country's geothermal resources were estimated at about 450 MW (McNitt, 1982) in the Ugandan Rift System and no new estimates have been put forward. Geothermal energy cannot be left out of Uganda's energy plans for the following reasons:

- Hydro - electricity sites are more or less concentrated in one area (along the river Nile) resulting in long transmission distances and high energy losses;
- Lack of security in case of reduction in hydropower output arising from climatic fluctuations and therefore need to diversify energy sources;
- Location of geothermal fields in isolated areas such as Buranga in Bundibugyo district; far from the national grid.
- It is environmentally benign.

# 3 Geothermal areas

The major areas under study are Katwe-Kikorongo (Katwe), Buranga and Kibiro. They are all situated in the Western branch of the East African Rift System that runs for most of its length along the border of Uganda with the Democratic Republic of Congo (DRC) (Figure 1). The three areas were chosen as priority areas because of their volcanic and tectonic features that are indicators of powerful heat sources and permeability. Other geothermal areas are located on the outskirts and/or close to the rift valley in SW-Uganda and Northern Uganda (Figure 1). Surface exploration in the three areas has reached advanced stages while in the other areas it is still at preliminary level (Bahati, 1996).

# 4 Recent studies

Recent studies have concentrated on the three geothermal prospects of Katwe, Buranga and Kibiro under two projects, Geothermal Energy Exploration I (UGA/92/002) and Isotope Hydrology for exploring Geothermal Resources (UGA/8/003).

## 4.1 Geothermal energy exploration I

This project was carried between 1993 and 1994. It was funded by the Government of Uganda, UNDP, the OPEC Fund and the Government of Iceland and was executed by the Department of Development Support and Management Services of United Nations (UNDDSMS) and implemented by the Geological Survey and Mines Department (GSMD) of the Ministry of Energy and Mineral Development (MEMD) of Uganda. The study employed geological and geochemical methods with the aim of selecting one of the geothermal areas for further surface geophysical analysis and exploratory drilling (Armannsson et al., 1994).

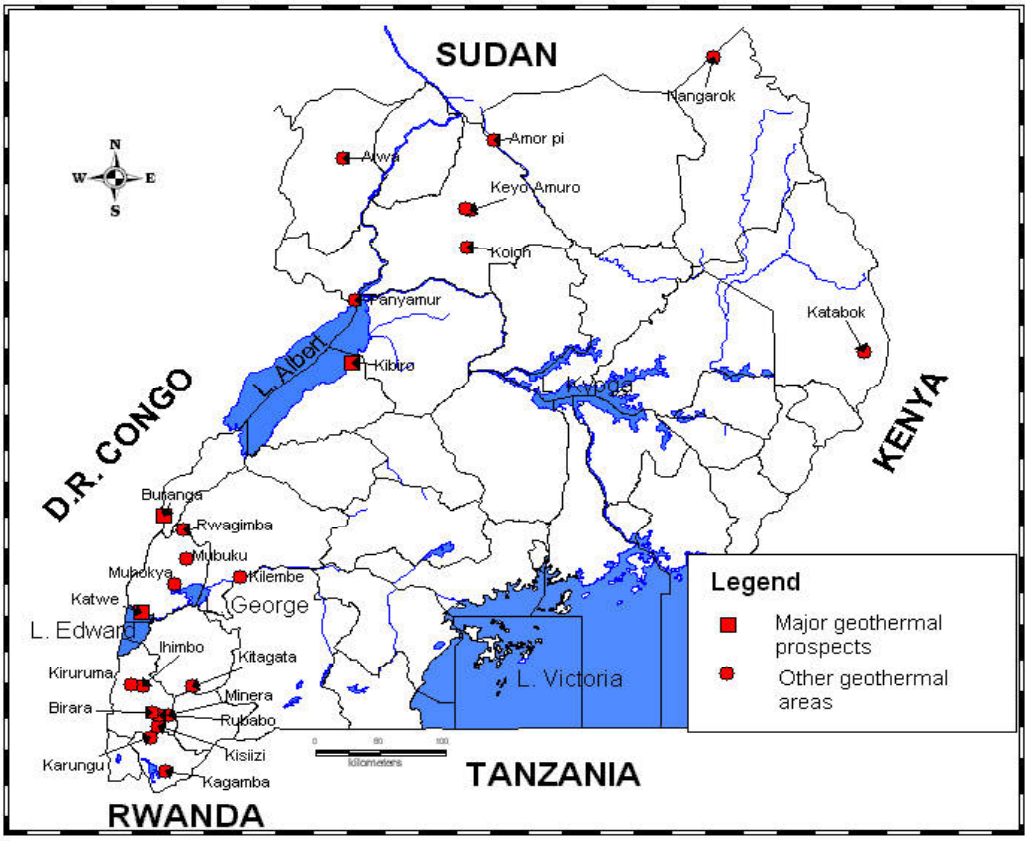


**Figure 1: Location of geothemal areas of Uganda.**

## Main findings

- The three study areas are considered as potential geothermal targets.
- The geothermal activity is clearly related to the tectonic and volcanic activity of the rift, which has higher heat flow than the surrounding Pre-Cambrian crust.
- All three hydrothermal systems appear to be relatively old and rise from volcanic rocks rather than from the young overlying sediments.
- At Katwe, the size of the volcanic field, the high subsurface temperature of about 160-200°C, as well as various geological observations and proximity to the national grid make the prospect attractive for electricity production.
- The Buranga prospect appears to have a significant volume of water at 120 - 150°C and may be appropriate for electricity generation from a binary power plant, and drying of agricultural products.
- The Kibiro prospect has a relatively simple geologic structure and waters indicative of subsurface temperatures of above 200°C suitable for conventional electricity production.

## Recommendations

- Execution of the geophysical survey followed by a drilling programme. This would provide information on reservoir size and characteristics.
- To install a small power plant to supply Bundibugyo district with electricity and to build a pilot plant for drying agricultural produce.

- To install power plants in the Katwe and Kibiro prospects to supply power to the surrounding areas and national grid.
- Uganda should pursue the development of its geothermal resources, in order to reduce the dependence on the hydropower single-source on the River Nile.

## 4.2 Isotope hydrology for exploring geothermal resources

Hydrological studies that were carried out as part of the geochemical investigation under the UGA/92/002 left many questions about the origin of the geothermal fluids, their age, source of salinity and recharge areas of the fields unanswered. Detailed studies of the above problems have been carried under UGA/8/003, funded by the International Atomic Energy Agency (IAEA) and the Government of Uganda (UGA/8/003 Terminal Report). This project started in 1999 and ended in 2002 (Bahati and Pang, 2003).

**Main findings**

- The thermal waters show isotopic composition compatible with the local meteoric water line, confirming the meteoric origin of the water circulating in the geothermal systems.
- The tritium concentration indicates some admixture of modern water close to the surface in Kibiro but not in Buranga and Katwe, where hot springs discharge tritium-free waters.
- A slight $\delta^{18}O$ enrichment of about 1‰ observed in the hot springs at Kibiro suggests high temperature water-rock interaction, old age, or low water/rock ratio. A similar enrichment in Katwe may have similar causes, and/or be due to high carbonate in the subsurface rock.
- Sulphur isotopes ($\delta^{34}S_{SO4}$) of hot water samples show magmatic contributions of sulphate, which confirm earlier results of chemical investigations.
- Recharge water to hot springs comes from higher elevations in the nearby Rwenzori Mountains in the case of Katwe and Buranga, and Mukihani-Waisembe ridge for Kibiro.
- Subsurface temperatures predicted by sulfate-water oxygen isotope geothermometry are highest for Buranga (200°C), but 100-140°C for Kibiro and 140°C for Katwe. Mixing with cold water may have lowered the temperature estimates for Kibiro and Katwe.
- Reservoir rock types for Katwe are most likely Basalt (Leucites and Melilites) and Granitic xenoliths; Granitic gneisses for Buranga and Kibiro.
- Major source of salinity is from water-rock interaction, but some magmatic inputs in the case of Buranga and Kibiro are also evident.

# 5 Present geothermal programs

## 5.1 The Uganda alternative energy resources assessment and utilization study (UAERAUS)

The UAERAUS is a cooperative project between the African Development Bank (ADB) and the Government of Uganda whose aim is to formulate a long-term integrated least cost AERDP. The energy resources being considered include geothermal, biomass, wind, peat, solar and mini- and micro-hydro. A core activity of this study is geophysical surveys and collection of additional geological and geochemical data. The results of the geophysical surveys when completed, will be

used to upgrade the geothermal models of Katwe and Buranga to near pre-feasibility status. The study started in October 2002 and will last for 13 months.

## 5.2 Further surface analysis of the Kibiro geothermal area

Iceland through the Icelandic International Development Agency (ICEIDA) and the Government of Uganda have a joint project to complete surface exploration in the Kibiro geothermal prospect (Gislason, 2002). Kibiro will not be surveyed under the UAERAUS. The project will upgrade the existing geological and geochemical models by carrying out geophysical surveys and additional geological studies. The project is scheduled to start in October 2003 and will take three months to complete. Under this project the data from the other areas, Katwe and Buranga, will be evaluated and reviewed to get a second opinion and the three models will be compared, and arranged in an order based on their predicted geothermal potential.

# 6 Geothermal energy exploration II

In order to move ahead with geothermal exploration and development in Uganda, it is important to build on work already, done and carry out further analyses which, should lead to exploratory drilling at one or more sites, if successful. This activity is proposed under the Geothermal Exploration II project the funding of which has not yet been brought to be.

**Project objectives**

- Upgrading of geothermal models and siting of boreholes in one or more selected areas.
- Drilling at selected sites, in one or more of the identified target areas.
- Preparation of technical and financial/investment plans for the installation of an appropriately sized power plant and feasibility of direct use in industry and agriculture.
- Increasing the number of Ugandans with experience in geothermal resource testing, evaluation, project design, and financing.

**Project description**

The Geothermal Energy Exploration II project is divided in two phases - A and B. The purpose of the studies in Phase A is to provide additional detailed information about the size and structure of the reservoirs as well as to aid in the siting exploration wells. Phase B will depend on the results of Phase A and, if Phase A is successful, will involve drilling into one or more prospects.

**Phase A: Pre-feasibility**

Prospect investigation to locate drillsites within a chosen prospect area, which will include:

- Careful review of and second opinion on the previous results.
- A further exploration narrowed down to the most promising anomalies in order to further sustain siting of exploratory wells. This includes detailed structural mapping and geophysical surveys.
- Design of exploratory wells and preparing of tender documents.
- Environmental impact assessment.
- Pre-feasibility report.

**Phase B: Feasibility**
This will include exploratory drilling that will involve drilling of 2-3 wells, in a selected prospect, to discover a geothermal reservoir, prove sufficient production capacity for the initial generating plant and provide data for assessing the long–term production capacity, and economically determine capital and operating costs for a generating plant and to compare the costs of generating power from other available sources. The possible economic uses of the resource for purposes other than power generation will be determined and the environmental impact of development assessed. The output is a feasibility report.

# 7 Conclusions

- The geochemical model for the three areas is almost complete.
- Results of geophysical surveys in the three prospect areas will soon be available and the geothermal models upgraded to enable prioritization of the three areas for detailed surface analysis and exploratory drilling.
- More detailed investigations (the feasibility phase) are required to give confidence to the private sector.

# 8 References

Ármannsson, H. (1994). *Geochemical Studies on three geothermal areas in West and Southwest, Uganda. Final Report.* Geothermal Exploration UGA/92/003, UNDESD, GSMD, Uganda, 85pp.

Árnason, K. (1994). *Recommendations for Geophysical Studies on Three Geothermal Areas in in West and Southwest Uganda. Geothermal Exploration - 1*, UGA/92/002 & UGA/92E01. UNDDSMS - Geol. Surv. & Mines Dept., Uganda.

Bahati, G. (1996). Preliminary geothermal investigation of Kisiizi, Minera, Rubabo, Birara, Ihimbo and Kiruruma hot springs in Rukungiri district, South-west Uganda. Unpubl. GSMD Report GBB/12.

Bahati, G. and Pang, Z. (2003). *Isotope Geochemistry for Geothermal Resources Exploration. Application to Geothermal Areas in Southwest Uganda*. *Terminal Report*. Technical Cooperation Project, Isotope Hydrology for Exploring Geothermal Resources. IAEA UGA/8/003

Gíslason, G. (1994*). Geothermal Exploration - I, UGA/92/002 & UGA/92E01*. *Terminal Report*. UNDDSMS - Geol. Surv. & Mines Dept., Uganda.

Gíslason, G. (2002). Geothermal Energy in Uganda. A second status report ICEIDA/MEMD Report 2002

McNitt. J.R. (1982). The geothermal potential of East Africa. *Proceedings of the Regional Seminar on Geothermal Energy in Eastern and Southern Africa*, Nairobi, Kenya. pp 3 - 8.

Matthíasson, M. (1994). Geothermal Utilization Study. UNDDSMS UGA/92/002.