GEOTHERMAL ENERGY EXPLORATION IN UGANDA, COUNTRY UPDATE 2006

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Abstract

Uganda presently has a total installed capacity of 417 MW of electricity of which 300 MW is from Nalubaale and Kiira hydropower dams at Jinja, 17 MW from small hydros and 100 MW of thermal. The production at Jinja has been reduced to a mere 120 MW due to climatic fluctuations caused by a long spell of drought in the Lake Victoria basin. The peak demand is approximately 360 MW. The country is in a dire need of energy with electricity demand growing by 10% per anuum. Despite its considerable hydro resources in excess of 2000 MW, the Ugandan government recognizes that it must diversify its energy resources. The present level of uncertainty regarding the future of large hydro power projects and increasing environmental awareness, has prompted the government to take a closer look at the country's geothermal potential. The government is especially interested in including village-scale geothermal power plants as part of its rural electrification-program.

At present, two geothermal prospects Katwe and Kibiro are being assessed in West Uganda with support from the World Bank and the Government of Iceland. Katwe and Kibiro have subsurface temperatures of 140-200°C and 200-220°C respectively and are considered as potential geothermal prospects. These temperatures are suitable for electric power production and direct use in industry and agriculture. The Government of Uganda is currently carrying out temperature gradient drilling and measurement which once completed will mark the end of surface exploration in the two areas. Based on the results, a feasibility study will be carried out to fully assess the resource and its commercial viability. A similar study is planned for the third area called Buranga. Its subsurface temperature is estimated at 120-150°C from geothermometry. Uganda has other geothermal areas with subsurface temperatures in the range of 100-180°C from preliminary studies but further investigation is needed before the areas are recommended for development.

The government of Uganda recognizes the lack of sufficient geothermal data to negotiate binding power purchase agreements (PPAs) with geothermal developers at the present time. Nevertheless, the government is interested in negotiating preliminary "non-financial PPAs" with private geothermal energy companies willing to partner with the Ministry of Energy and Mineral Development to obtain grant or "partial risk guarantee" funds for the feasibility study.

1. INTRODUCTION

Geothermal energy resource in Uganda is still at surface exploration phase with two of the three most promising prospects Katwe-Kikorongo (Katwe) and Kibiro in advanced stage of surface exploration. Temperature gradient drilling is on going in the two areas to confirm the anomalous areas previously delineated by geological and geophysical surveys. The current studies in the two prospects once completed will pave way to drilling of exploration wells and installation of the first pilot geothermal power plants in the country. The country has 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 installed capacity of 317 MW of which 300 MW is from a single source on the River Nile; the Nalubale (formerly Owen Falls) and Kiira (Owen Falls extension) dams. The current climatic fluctuations that have reduced output at Nalubaale/Kiira dams from 300 MW to 120 MW and the socio-economic and environmental issues, have raised concern about the future of hydropower in Uganda and therefore a need to diversify the energy sources. Alternatives being investigated are mainly renewable sources that include geothermal, biomass, wind, peat, mini and small hydro, and solar energy.

This paper presents the current status of the geothermal exploration project, and planned exploration and development activities on the geothermal systems of Uganda.

2. UGANDA ENERGY OVERVIEW

Uganda's per capita energy consumption is 5 million tones of oil equivalent per year (toe/year) of which approximately 93% is biomass (wood, charcoal and agricultural residues) and is among the lowest in the world. Few people have access to modern energy supplies such as electricity and petroleum products. The grid electricity access rate is very low: 8% for the whole country and about 2% for the rural areas. Demand for electricity is growing by 10% per anuum. Demand for modern energy is growing fast in response to the fast growing economy of approximately 7.0% industrial GDP. In early 2006, Power Planning Associates Ltd., carried out a demand base forecast study on the Uganda power supplies. The results indicate a significant growth in electricity demand in Uganda (Table 1). The forecast is predicted on assumptions for the growth of the economy, connections to new consumers, and the reduction of system losses, in particular commercial losses. All oil products for Uganda are imported. Presently, the country is conducting an oil exploration programme with a view to reducing on this importation dependence.

Table 1: Base case forecast for Uganda

Year	Peak demand	Generation (Net)	Sales
	(MW)	(GWh)	(GWh)
2005 (actual)	354	1921	1131
2010	389	2110	1634
2015	548	2974	2452
2020	789	4287	3535

The current hydropower output stands at 120 MW from the source of the River Nile at Jinja. The rest of the hydropower is from small sources in W-Uganda namely Mubuku (15 MW) and Maziba (2 MW) located in Kasese and Kabale districts respectively, bringing the total out put to 137 MW. The total generation was 1921 GWh and the peak demand of about 354 MW for the year 2005. The government is also importing 20 MW of electricity from Kenya. The proposed Bujagali (250 MW) and Karuma (150 MW) hydropower dams both located on the River Nile downstream the present Nalubaale/Kiira dams, are pipelined for development in the next five years.

In early 2005, the government entered into a three-year leasing agreement for 50 MW of emergency short-term thermal plant comprising packaged high-speed diesel units burning distillate fuel. These units are installed and operated at Lugogo, Kampala by Aggreko International, and have been in production since May 2005. The same company installed another 50 MW of thermal at Kiira in Jinja in October 2006 bringing the total thermal generation to 100 MW. The Ministry of Energy and Mineral Development (MEMD) is currently pursuing a further 100 MW of emergency thermal plants either as IPPs or on a leased basis to alleviate the current energy crisis.

3. ENERGY POLICY

Government overall policy is to improve the quality and quantity of energy supplies at least cost to the national economy and to the consumers; improve the performance of the sector through reforms and legislation, and also promote efficient use and conservation of energy resources.

The Uganda Power Sector is regulated by the Electricity Act of 1999. The Government of Uganda, through the MEMD, is responsible for policy formulation and operational oversight. The Electricity Act has liberalized power generation, and distribution and supply. The transmission entity remains a government parastatal in foreseeable future.

The Act provides for an independent Electricity Regulatory Authority (ERA) and a licensing regime for projects, private sector participation in power generation and distribution with transmission remaining a government parastatal in the medium term. It also gives powers to a Minister to create a rural electrification fund and obliges government to promote, support and undertake Rural Electrification Programmes. In order to introduce competition and bring about efficiency in the power sector, the Act allows independent power producers to generate and supply electricity.

4. 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 since then. Geothermal energy has the potential to contribute to the country's energy mix 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; Uncertainty of continued availability of hydropower arising from climatic fluctuations and therefore need to diversify energy sources; Location of geothermal fields in isolated areas without grid connection; international treaties; and being an environmentally benign energy source.

5. GEOTHERMAL AREAS

Most of the geothermal areas of Uganda are located in the Albertine graben that runs along the border of Uganda with the Democratic Republic of Congo (DRC). The Albertine graben is part of the western branch of the East African Rift System (EARS) commonly known as the Western Rift Valley (Figure 1). The major areas under study are Katwe, Buranga and Kibiro. The three areas were chosen as priority areas because of their volcanic and tectonic features that are indicators of a strong heat source and permeability. The other geothermal areas are located on the outskirts and/or close to the Rift Valley in SW, NW and NE-Uganda.

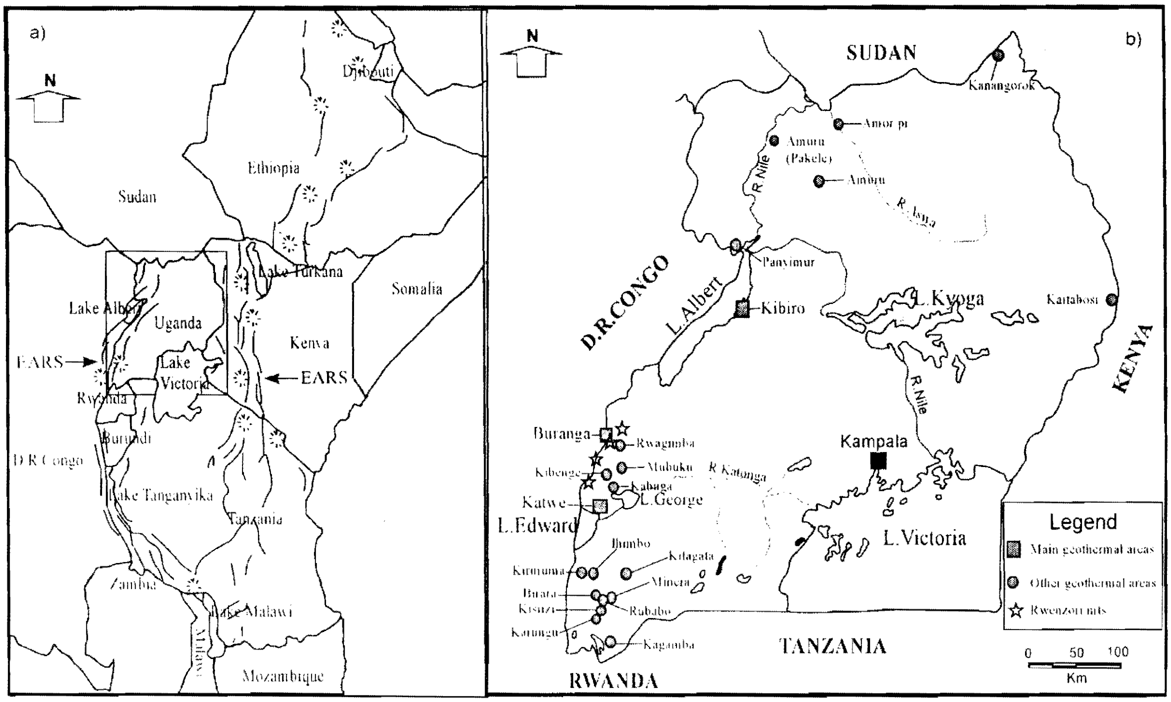

Figure 1: a) East African Rift System (EARS), b) Locations of the geothermal areas of Uganda.

6. RECENT STUDIES

1993–1994: Geothermal exploration on the three areas Katwe, Buranga and Kibiro was carried out with the aim of selecting the most promising area (s) for further detailed analysis. The project was funded by the Governments of Uganda and Iceland, United Nations Development Programme (UNDP) and Organisation of Petroleum Exporting Countries (OPEC). The results indicated that all the three areas are suitable for geothermal utilization and should be explored and developed.

1999 to present: The Government of Uganda with support from the International Atomic Energy Agency (IAEA) has carried out hydrological studies with the aim to delineate flow characteristics of geothermal waters and identify their recharge areas. The project which is using environmental isotopes in water has established the source of the geothermal waters as from high ground in the Rwenzori Mountains for Katwe and Buranga, and from Mukihani-Waisembe Ridge in Kitoba for Kibiro.

2003-2006: The Government of Uganda with support from the Government of Iceland, African Development Bank (AfDB) and the World Bank (WB), carried out detailed geological and geophysical surveys in both Katwe and Kibiro. Anomalous areas were delineated and shallow boreholes of 200-300 m for temperature gradient measurements sited.

2005-2006: Government of Uganda with support from the Germany Geological Survey (BGR) carried out micro-seismic surveys in Buranga with the aim to locate active faults that could be conduits for the geothermal fluids.

7. CURRENT RESULTS

The current geothermal models are based on the results of the geological, geochemical, geophysical and isotope hydrological surveys that have been carried out since 1993. These investigations were focused on the three areas Katwe, Buranga and Kibiro. The current results are summarized in the following subsections.

7.1 Katwe

The Katwe geothermal prospect is located in the Queen Elizabeth National Park in Kasese district, West Uganda (Figure 2). The geology of the Katwe prospect is dominated by explosion craters, ejected pyroclastics, tuffs with abundant granite and gneissic rocks from the basement. Lava flows are scanty and have been located in Lake Kitagata and Kyemengo craters.

Geochemical surveys estimate the subsurface temperature at 140-160°C using solute geothermometers (Armannsson, 1994). However, high levels of H_2S (30 - 40 ppm) were measured in some hot and warm springs in Lake Kitagata and Lake Katwe respectively (Bahati, 2003). This suggests a high temperature geothermal system (with higher subsurface temperatures) in Katwe and the source of the geothermal water to be volcanic and hydrothermal. Isotope hydrology results indicate that the Katwe geothermal system is most likely recharged from high ground in the Rwenzori Mountains. The major source of salinity is rock dissolution, but some magmatic input is suggested (Bahati, et. al., 2005).

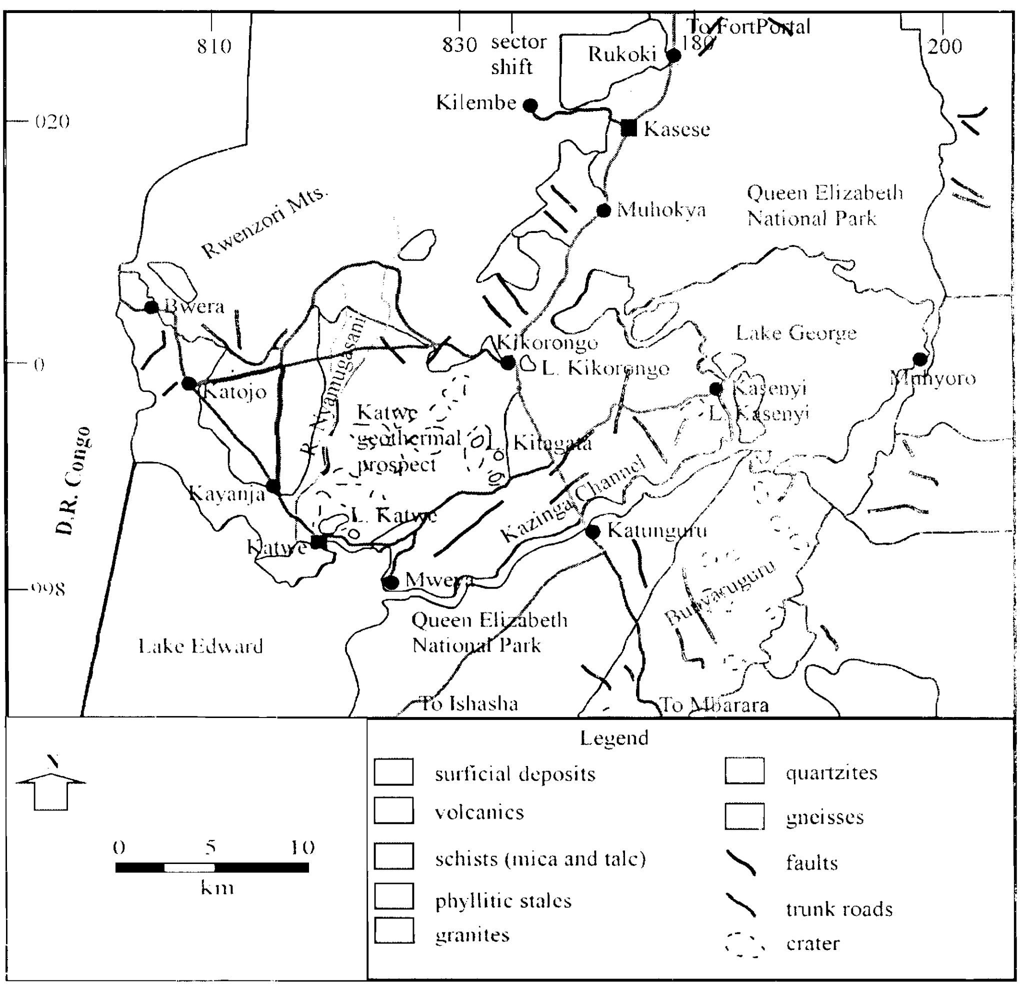

Figure 2: The geology of the Katwe geothermal prospect and surroundings.

The results of the geophysical surveys indicate the existence of potential geothermal systems in the Katwe prospect. Low resistivity anomalous areas have been located around Lake Katwe and between Lake Kitagata and Lake Kikorongo (Gislason, et. al., 2005).

7.2 Kibiro

The Kibiro geothermal prospect is located along the escarpment of the Western Rift Valley in Hoima district, West Uganda (Figure 3). The Kibiro geothermal prospect is divided into two entirely different geological environments by the escarpment, which cuts through the prospect from SW to NE. To the east of the escarpment the geology is dominated by an ancient crystalline basement, characterized by granites and gneisses. Also present are quartzites, mafic intrusives, laterites and diorites. To the west lie an accumulation of thick sequences of Rift Valley sediments of at least 5.5 km thickness, but without any volcanic features on surface.

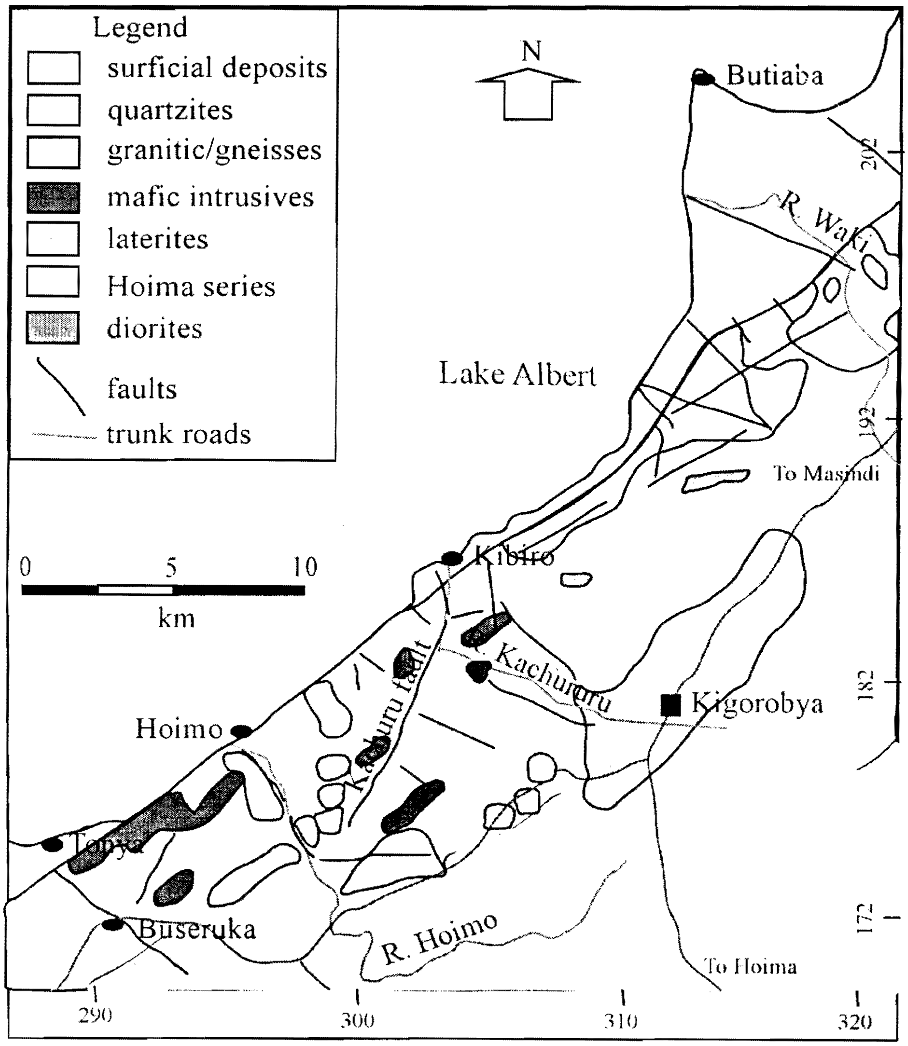

Figure 3: The geology of the Kibiro geothermal prospect and surroundings.

Geochemical surveys suggest a high temperature geothermal system in the Kibiro prospect. A subsurface temperature of 200 - 220°C has been predicted by geothermometery (Armannsson, 1994). The geothermal water is believed to be from high ground represented by the Mukihani-Waisembe Ridge in Kitoba subcounty, located 20 km southeast of Kibiro. Strontium isotopes in water and rock ($^{87/86}Sr_{H2O}$, $^{87/86}Sr_{Rock}$) indicate an interaction between the granites/gneisses and the geothermal fluids. The reservoir rock types in Kibiro are, therefore, granitic gneisses (Bahati, et. al., 2005).

The results of the geophysical surveys indicated the existence of low resistivity anomalous areas east of the escarpment in the Kibiro prospect which are in agreement with geological and geochemical observations (Gislason et. al., 2005).

7.3 Buranga

The Buranga geothermal prospect is located at the foot of the Rwenzori massif in Bundibugyo district, West Uganda (Figure 4). It is localized by the major Rift Valley faults. The surface manifestations (hot springs) emerge through, 'Epi - Kaiso' beds and 'Peneplain Gravels' (of Upper to Middle - Tertiary age), sediments which consist of boulder beds and unsorted scree overlying sands and clays. These sands and clays are described as Kaiso - Kisegi beds. Buranga has no evidence of volcanism but is highly tectonically active. Geothermal surface activity is intensive, with sprouting hot springs which are boiling (maximum surface temperature of 98°C), with high gas flow and deposits of travertine. Surface hydrothermal alteration is scarce but many of the springs have developed terraces and mounds of travertine.

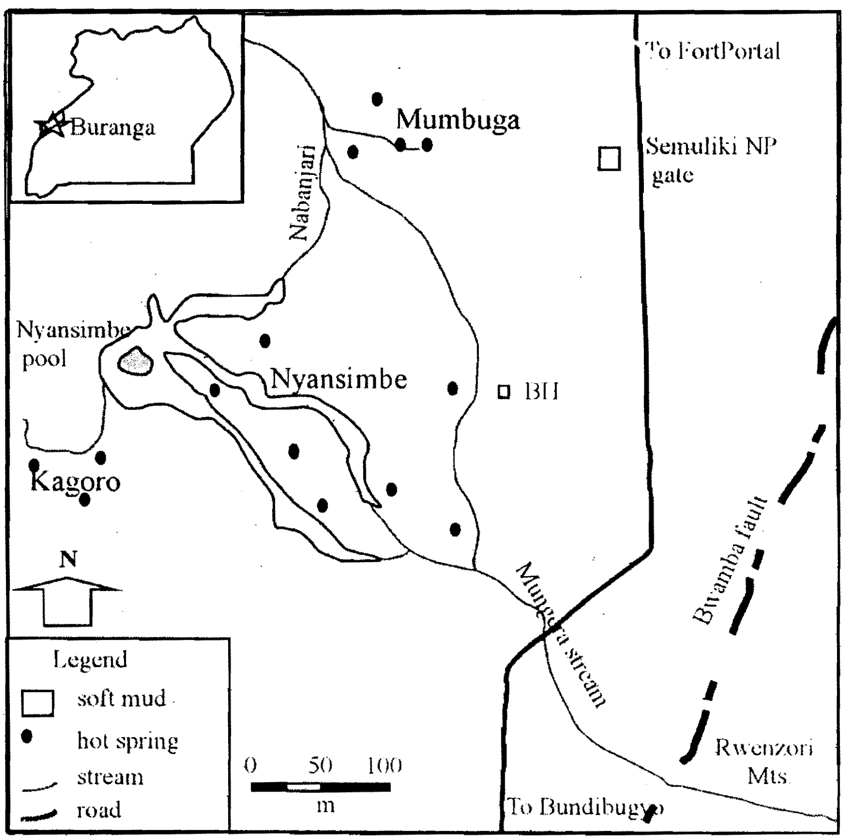

Figure 4: Buranga geothermal area. Location of hot springs.

Geochemistry predicts a subsurface temperature of 120-130°C with a possible maximum of 150°C (Armannsson, 1994). Isotope hydrology suggests that the source of the thermal water is from high ground and is possibly from the Rwenzori Mountains (Bahati et. al., 2005).

8. CURRENT UTILIZATION

The Uganda geothermal project is still at the surface exploration stage with no geothermal wells drilled yet and therefore the current utilization is from the fluids discharges from hot springs which are used locally and has not been quantified. The geothermal water is used as a source of salt at Kibiro and Katwe (Bahati et. al., 2005). At Kibiro the geothermal water is concentrated using dry soil by capillary attraction, the impregnated soil is then scooped and the salt recovered by dissolution and evaporation to dryness. At Katwe, the method is different from that one at Kibiro. The brine is channeled into concentration ponds from which the salt solidifies on the surface by natural evaporation during the dry weather (Figure 5).

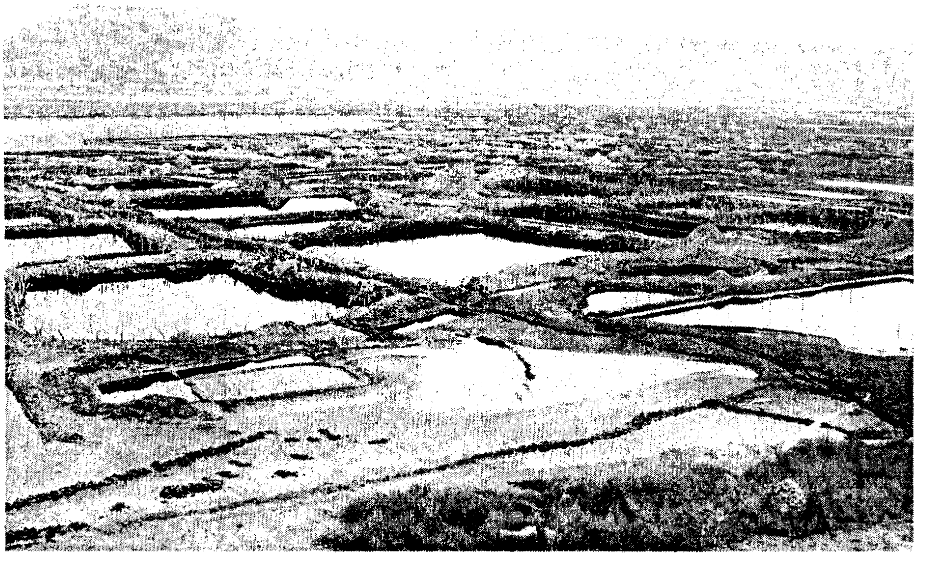

Figure 5: Salt production at Lake Katwe

Most of the Uganda hot spring waters are currently used for spas and are believed to cure skin diseases and rheumatics. The only known in-house use of geothermal energy is at Kisiizi hospital situated in Rukungiri district, SW-Uganda, where warm water at a temperature of 32°C is tapped from a hot spring and used in hospital for bathing and other domestic uses. The hot water is also used for watering animals as a substitute for salt licks because of its high salt content. And lastly, hot springs are a tourist attraction.

9. ON-GOING PROGRAMS

The Government of Uganda with support from the WB and ICEIDA is currently drilling shallow boreholes to a depth of 200 to 300 m for temperature gradient measurement in Kibiro and Katwe geothermal prospects. This programme is a follow-on the recommendations of the previous geological and geophysical surveys that located and delineated anomalous areas in the two prospects in 2005. The current programme scheduled to end in 2007 will pave way for drilling of deep exploration wells in the two prospects. The objective of the drilling programme is to confirm the existence of the geothermal resource and the results will assist in siting deep exploration wells. Along side the drilling programme is the geochemical investigation of other areas of Uganda whose aim is to prioritize the areas for detailed surface analysis and development.

10. FUTURE PROJECTS

Geothermal studies on the Ugandan geothermal systems are at different stages in each of the areas. In Katwe, Buranga and Kibiro subsurface temperatures, geological structures and flow characteristics of the surface and ground waters in the geothermal systems have been delineated using various analytical methods. The conceptual geothermal models of Katwe and Kibiro based on results of geochemical, geological, and hydrological studies have been upgraded with geophysical surveys. The result of the current temperature gradient measurement is the final input to the models. The models will then be used as a basis for siting deep geothermal exploration wells. It is, therefore, foreseen that surface exploration is coming to an end in the two prospects.

The immediate future geothermal projects for Uganda in line with the "*invest best practices*" (Gislason and Arnason, 2005) can be summarized in Table 2 below.

Table 2: Proposed future projects for Uganda.

Area	Stage of exploration	Immediate future project
Katwe and Kibiro	Surface exploration	• Exploratory drilling and well testing, • Sociological and environmental baseline studies, • Infrastructure and pre-feasibility assessment.
Buranga	Surface exploration	• Detailed geophysical exploration and additional geological and geochemical surveys.
Other areas	Resource prioritization	• Detailed geological and geochemical surveys.

10.1 Geothermal Energy Exploration II

The immediate future projects for Uganda under Geothermal Exploration II will be based on the results of the current studies. In Katwe and Kibiro, drilling of deep exploratory wells is the next step. In Buranga, detailed geophysical exploration and additional geological and geochemical surveys are needed before the area is recommended for drilling. In other areas, detailed geological and geochemical surveys are needed to select promising areas for detailed surface analysis.

The program for Katwe and Kibiro is divided in two phases; Pre-feasibility study and Feasibility study.

Phase I: Pre-feasibility study

The pre-feasibility study will involve exploratory drilling on identified targets and well testing. This will be accompanied by sociological and environmental baseline studies, and infrastructure and pre-feasibility assessment (Gislason and Arnason, 2005). The objective of the pre-feasibility study is to upgrade the geothermal models and site exploratory wells; drilling 2-3 wells in one or both areas to prove the resource. The results from the pre-feasibility study will be used as a basis for the feasibility study on the two areas. The cost of drilling a geothermal well of 2000 m depth is approximately 4.5 Million USD. This project is estimated to cost approximately 15 Million USD in each prospect.

Phase II: Feasibility study

This project is proposed to carry out the feasibility study on the most promising area(s) once the pre-feasibility study is completed. This study will involve drilling of extra wells to prove sufficient production capacity for the initial generating plant; provide data for assessing the long–term production capacity; economically determine capital and operating costs for an appropriately sized power plant; and compare the costs of generating power from geothermal with 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.

11. CONCLUSIONS

Uganda is in a terrible energy deficit with hydropower production reduced tremendously from 300 MW to 120 MW at the source of the River Nile at Jinja. This situation is not likely to improve in the near future and the country must diversify its energy sources.

Geothermal energy could provide and alternative source of electricity if properly explored and developed. Subsurface temperatures of 140-200°C, 120-150°C and 200-220°C have been predicted for Katwe, Buranga and Kibiro respectively. The temperatures, if confirmed, are high enough for electricity production and for direct use in industry and agriculture.

Two areas, Katwe and Kibiro, have reached advanced stages of surface exploration and their geothermal models are nearing completion. The next stage is to carry out a feasibility study in the two areas.

12. RECOMMENDATIONS

The Government of Uganda should diversify its sources of electricity by promoting renewable energies among which geothermal is a potential resource that could produce base load electricity. The energy mix for the country is the only long-term solution for the current energy crisis.
The ongoing geothermal programs should be completed as soon as possible as their results will be needed to upgrade the geothermal models that will be a basis for drilling deep exploration wells in Katwe and Kibiro prospects.

It is recommended that Uganda should move the geothermal exploration to the next stage, exploratory drilling that will pave the way to a feasibility study in at least one or two prospects.

Exploration and development of other geothermal areas should continue following the results of the current preliminary geochemical investigations. Some of these areas have potential for installation of small scale power plants to produce electricity for rural areas if properly explored and developed.

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