Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

GEOTHERMAL ENERGY IN THE DEVELOPMENT OF UGANDA

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Keywords: Uganda, electricity, restructuring, geothermal, geological studies.

ABSTRACT

Previous geothermal energy investigations that began in the 1950s have highlighted the importance of the resource as a viable alternative source of energy in Uganda. Studies aimed at evaluating the geothermal potential areas have been undertaken to a limited extent to encourage the development of this sub-sector. However, development faces constraints that include the monopoly of hydropower in the energy sector. Yet measures have to be put in place to meet the future energy needs of the country that is being faced with a fast growing economy (average growth 6%/year for the last decade). A more serious attempt to articulate the strategic role geothermal energy research and development can play in the economic development of Uganda needs to begin now to enhance the development of the sub-sector.

1. INTRODUCTION

The primary objective of developing the geothermal energy resources of Uganda is to compliment the role of hydro- and other energy resources in the generation of electricity; a crucial element in the development process of the country.

Like with the other resources, secondary benefits that accrue from the development of geothermal resources are many. However, the term 'geothermal' is yet to become a catchword in the energy vocabulary of our people. The general feeling is that it is 'exotic' and/or 'ambitious' and so is not a priority. The terms 'Wind', 'Solar' and 'Biomass' energy systems are more familiar to the layman in Uganda than geothermal. It could be that these are aggressively marketed or because geothermal, like any other scientific programme, is dogged by long periods of the 'mysterious' scientific research as opposed to the normally short periods of technological and engineering innovation required to harness the other energy resources.

No doubt, hydropower enjoys a monopoly position in the 'energy mix' of the country as an indigenous resource, the sources of which the country is abundantly endowed with. The onus is on us, the geothermal community, to put forward our case, which is the subject of this paper.

2. ECONOMIC OVERVIEW

Uganda is one of the world's poorest countries with an annual per capita income of US$ 330 (World Bank, 1999). This has been brought about through years of political uncertainty and social unrest. However, since 1986 the economy has started to recover with moves to reform institutional bodies and bring about accelerated economic growth and poverty reduction through strong economic and social policies. However, Uganda is not home and dry yet. A continued effort by government in collaboration with external friends is required to propel Uganda to prosperity in the new millennium.

In 1987, the Government introduced its Economic Recovery Program (ERP). As a result of a market-driven, private sector-oriented development strategy and the country's strong natural resource base, the economy has grown by an average of 6.0% since 1987. It was 5.9% in 1989-1991 and 4.1% in 1991/2. During 1998/99 financial year alone, GDP grew by a robust 7.8% against a background of instability in foreign exchange markets, problems in the banking sector and low prices for coffee, the main export, on the World Market (Budget Speech, 1999/2000). GDP rates of 6.4, 5.8 and 5.8% in the past three years are still strong rates only comparable to those of China in the world for the decade. Uganda is an active member of the Common Market for Eastern and Southern Africa (COMESA), an economic grouping with a population of about 400 million including Egypt (the latest entrant). At the same time, Uganda is a keen advocate of the resumption of the East African Cooperation group (EAC). The former EAC (population of about 80 million) was made up of Uganda, Kenya and Tanzania. Rwanda and Burundi are pursuing membership in earnest and this will bring the population to around 100 million.

3. ELECTRIC POWER IN UGANDA

Hydropower is the main source of Uganda's electricity supply. 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 resources. As part of this effort, the Government is preparing an Energy Master Plan with the help of the World Bank under the Energy Sector Assistance Management Program (ESMAP). Geothermal energy represents a high priority alternative to hydropower, therefore, findings and recommendations from the geothermal project will be an important input to the Energy Master Plan.

Uganda, a country with a population of about 20 million (1999) has a *per capita* energy consumption of 0.3 TOE or 12.72 GJ, which is among the lowest in the world. Few people have access to modern energy supplies such as electricity and petroleum. Uganda remains one of the countries with the lowest *per capita* consumption in this sector, at a mere 0.02 TOE or 0.848 GJ (Mugyenzi, 1999).

The total energy consumption rate stands at about 5 million TOE/year of which approximately 90% is Biomass (wood, charcoal and agricultural residues).

The total generating capacity of the power system in Uganda is only 195 MW, and the total demand is estimated to be around 580 MW by the year 2005. The major hydroelectric plant is Owen Falls dam at Jinja with a rated capacity of 180 MW. An extension to this is currently under construction on the eastern side rated at 200 MW on completion. However, only 80 MW is expected on line by the first half of 2000, bringing the total generating capacity to 275 MW) (Table 1). Total continuous power theoretically available from the Victoria Nile is of the order of 2.5 million KW or 22,000 million KWh/year (Gibbs, et al., 1948). The geothermal potential of Uganda was estimated to be 450 MWe (McNitt, 1982).

Given the dismally low power available to a fast growing economy like that of Uganda today, the Uganda Electricity Board (UEB), the state utility responsible for generating and supplying electricity, has adopted what is called 'load shedding'. Load shedding is a technique for rationing the little power available among the ever-increasing power needs of electricity consumers.

4. ELECTRIC POWER DEVELOPMENT STRATEGY; RESTRUCTURING

Undoubtedly, Uganda is struggling under an energy crisis. Less than 5% of the population has access to electricity. Demand for power is growing at 3-4 MW a month (18%/year). According to the Ministry of Finance (MoF), the economy loses about 2% of economic growth annually, equivalent to about $US 150 million each year due to lack of enough electricity. It is estimated that manufacturing industries lose about 90 days a year of production. This devastating impact on the economy means fewer jobs, fewer people with access to electricity and ultimately a poorer Uganda, environmental degradation notwithstanding.

The provision of reliable electricity to the rural areas is also one way of facilitating the private sector, as an engine of growth, to invest in these areas. One of the major reasons why private investors have not invested outside the Kampala-Jinja area is due to lack of reliable power in areas outside this complex. If the private sector is to spread to other areas and therefore bring about balanced growth in the economy, then the need to electrify rural areas cannot be overemphasized. Government has indicated willingness to collaborate with any group in the development of energy sources that can quickly come on stream to meet the present and future demand.

At the same time, the electricity export market is still robust. Tanzania is committed to importing 100 MW to supply the Lake Victoria gold mining district. A 66 kV line to Bukoba is already in place with a possible upgrading when the need arises. Rwanda is committed to buying 30 MW once the existing transmission line is upgraded. Likewise, Kenya is committed to buying 100 MW, up from the current 30 MW it has been importing from Uganda since the 1950's. This scenario calls for a considerable increase in generating capacity over the next 10 years and so far several measures have been put in place by government in this respect.

Uganda Electricity Board (UEB), a 100% state utility, has hitherto held the monopoly in the electricity industry as per the Electricity Act of 1964. Currently, UEB possesses the dominant market position in electricity generation, contributing about 98% of the total.

An Energy Bill has been tabled before parliament with the main aim to restructure the utility and at the same time pave the way for the introduction of Independent Power Producers (IPPs). Monopolistic rights to future generation opportunities are to be rescinded by the new legislation enabling any person or company to enter the power generation and distribution business. The Bill has already been enacted into law (The Electricity Act, 1999) with a provision for setting up an entirely independent Electricity Regulation Authority within six months' time.

In response to the government's proposed liberalization of the energy sector, several IPPs have expressed willingness to invest in power energy generation. For example, AES Electric of USA, (250 MW) Norpak of Norway (200 MW), both with intentions to develop power along the River Nile have presented their EIA reports. An upgrading of the Mubuku River dam from about 5 MW to 10 MW was recently completed. The bulk of the power from Mubuku is supplying the cobalt plant at Kasese. The Nyagak River project is at the drilling stage. All these developments are geared toward stemming out wood usage, which now approximates to 28 billion cu.cm of firewood and charcoal.

5. GEOTHERMAL RESOURCES EXPLORATION ACTIVITIES; A REVIEW

The history of geothermal exploration in Uganda is best summarized by Mboijana (1994) in addition to the technical reports for Geothermal Energy Exploration Project I - UGA/92/002 & UGA/92/E01 by the UN. The reports include: an inventory of the three geothermal areas (Gislason, et al., 1994), geology and geochemistry studies (Gislason, 1994 and Armannsson, 1993, 1994), Recommendations for Geophysical Studies (Arnason, 1994) and a Geothermal Utilization Study (Matthiasson, 1994).

Preliminary geological and geochemical investigations of three geothermal fields in the western sector of the East African Rift System indicate all of them to be electrical-grade hydrothermal systems depending on the kind of technology to be used. Temperatures of 140-200°C, 120-135°C (150°C max.) and 200°C and above for Katwe, Buranga and Kibiro respectively were predicted by geothermometry. Buranga and Kibiro fields are clearly hot-water dominated systems.

Katwe could easily pass for a vapour-dominated system akin to the Geysers in California using the principle of 'analogy' (McNitt, 1982). The principle uses the knowledge and experience gained in a relatively well-explored region as a basis for extrapolating limited data to a relatively unknown region.

By the same principle, Buranga is akin to the Lake Bogoria hotsprings of Kenya save for the lack of exposed volcanics in the former case.

The Katwe field is characterized by feeble hotsprings, warm and cold mineral springs, etc. whereas the Buranga field is characterized by impressive surface manifestations in form of vigorous boiling springs, pools and warm ground and yet geochemistry predicts the lowest temperature.

While the two fields of Katwe and Kibiro are amenable to conventional geothermal power producing systems, Buranga is clearly amenable to binary power technology.

6. EXPLORATION STATUS

Although all the three areas above are potential geothermal targets, some more work is required to raise the confidence level of the results especially those of Katwe and Buranga.

A selection of one of the three areas for detailed studies is not possible at this stage without carrying out geophysical investigations to ascertain the size and structural characteristics of the geothermal reservoirs, this is the subject of Geothermal Energy Exploration Project (GEEP) IIA.

The origin, age and flow patterns of the water feeding the geothermal systems is the subject of 'Isotope Hydrology for Exploring Geothermal Resources' - Project UGA/8/003 funded by the International Atomic Energy Agency. The funds committed under this programme amount to $US 78,575 (Table 2). It is envisaged that the results of this project will aid in generating hydro-geochemical models of the geothermal areas and perhaps improve on the accuracy level of the results from Katwe and Buranga. The resulting integrated geothermal model(s) will aid in the siting of the first exploration wells. For cost-effectiveness of the investment, a minimum of 20 MWe geothermal development is targeted (USDOE, 1998).

Local legend has it that the earth breathes from somewhere in this part of the world. This is corroborated by the name of one crater in the area 'Nyindo Zensi', which means 'earth's noses'. Could this be indicative of a fumarole? This crater lies to the northwest of Lake Kitagata crater.

The hottest spring (70.1°C) in Lake Kitagata crater discharging beneath the lake. Recent to locate it proved futile owing to lack of time. Once located, the water chemistry results obtained earlier could be upgraded with the vapour phase interpretation. Otherwise, some indication of the hidden treasure beneath the Katwe field is implied from geochemistry where it falls in the steam-heated waters corner on the Giggenbach diagram.

7. GEOTHERMAL ENERGY DEVELOPMENT; RELEVANCE TO OTHER GEOLOGIC STUDIES

Apart from providing specific information about an energy resource, geothermal studies are also relevant to other geologic studies of national concern. Because most geologic processes are ultimately driven by the Earth's internal heat engine, geothermal research contributes to an understanding of such natural phenomena such as mineral-deposit formation, earthquakes and volcanic eruptions (Duffield et al., 1994). No where else can this be truer than in the above sector of the Rift Valley System as the account below illustrates.

With respect to the tectonic and geologic setting, this sector of the rift valley and its immediate environs, are hosts to a variety of minerals; economic and uneconomic alike:

- Base metals (e.g. copper and cobalt at Kilembe),
- Precious metals (gold and silver) on the flanks of the Buhwezu plateau.
- Limestone at Hima, Muhokya and Dura
- Mixed salts of Lake Katwe,
- Gypsum at Kibuku to the north of Buranga, Kanyantete and Muhokya to the north of the Lake Edward - Kazinga Channel - Lake George water system,
- Petroleum shows and diatomite in the Albertine Rift sector.
- Strong indications of Rare Earth Elements (REEs).
- Zeolites, bentonite clays.
- Workable and worked deposits of tin, wolfram, beryl, columbite-tantalite, uranium and diamond traces.

These deposits and formations one way or the other, owe their origin to processes involving the circulation of hydrothermal fluids. A good example is a silver black metallic mineral, pyrrhotite (Fe_nS_{n+1}), which is issuing at the Kibiro hotsprings. Could this be indicative of the classical 'black smokers'? This warrants further scientific research.

Normally, the traditional geothermal energy industry is set within a volcanic environment characterized by calderas, active volcanoes associated with extensive lava flows and pyroclastic material, etc. However, this sector is unique in that only profuse volcanism, characteristically peralkaline in nature and only limited to nodes where rift strikes intersect or change occurs.

The Ruwenzori Mountain Range (120 km × 50 km) is a horst block set in a graben structure on either side. It lies at a double node of structural importance (McConnell, 1972). It is here likened to the Plate Tectonic Setting of the Salton Trough and the associated Cerro Prieto Geothermal Field (CPGF) as in Elders, et al., (1997) except that the lack of spreading of the rifts may be due to the compression of the African Plate between the spreading Mid-Atlantic and Mid-Indian Ocean Ridges (McConnell, 1972). Therefore, the mystery surrounding the CPGF with respect to what lies beneath it could also be true for this sector of the Rift System. For example, apart from the large uncompensated negative Bouguer anomaly in this sector of the rift as opposed to the large positive regional gravity anomaly for the CPGF, similarities occur in anomalous seismic velocities in the deep crust, high heat flow, high seismicity and the occurrence of Quaternary volcanics associated with the geothermal fields (e.g. Maasha, 1974).

While these volcanics appear on the surface in Katwe, their presence is indicated, from aeromagnetic data, to occur beneath the other two fields of Buranga and Kibiro (EDCON, Inc., 1984). These facts compare favourably with those at CPGF.

Geological evidence indicating the role of magmatism has been deduced from the floats of gabbro and dolerite dykes recently discovered around the hotsprings (Isabirye, et al., 1999). They are believed to come from the rift scarp above Kibiro. Likewise, the presence of charnockite intrusions in the vicinity of Kibiro as reported by Simmons (1919), is further evidence of zones where magmatic and metamorphic processes merge.

From seismological records, the Ruwenzori region is the most seismically active (Katwe and Buranga), followed by the Toro-Bunyoro fault (Kibiro).

The high heat flow is exemplified by the geothermal manifestations in form of hotsprings found in each of the areas. Indications of high temperatures involved in the generation of the complex chemistry of the ultramafic xenoliths found in the craters of Katwe underscores the role of the mantle in the sector (e.g. Lloyd, 1985, Lloyd, et al., 1991). However, oceanic crust similar to the Afar Triangle cannot be ruled out (e.g. Duffield, et al., 1997). In the author's opnion, it is a 'passive' pull-apart basin perpetually in tension. It is only through geothermal research and development that these theories can be tested in an economic way.

Isotopic data could be useful a source of hydrological/hydro-geological information for elucidating the probable origin, age and history of the Lake Katwe brines. Attempts to utilize these brines for salt production and associated chemicals in the 1970's came to naught because of poor technical decisions leading to poor design that overlooked scientific findings about the nature of the brines. The brines were found to be corrosive owing to their gaseous components which included ammonia and hydrogen sulphide. The result was total corrosion of the processing plant from inlet to outlet. Had geothermal research been incorporated in the scientific studies, this problem could have been averted.

From the preliminary results of Geothermal Energy Exploration Project (GEEP) I, the chemical composition of the thermal waters from Katwe and Buranga shows that the anions of Cl, HCO_3 and SO_4 occur in about equal proportions. This is an unusual composition of geothermal water whose utilization may prove problematic. This was also a major concern in the salt project. However, research elsewhere has indicated that these may be products of shallow processes which alter the chemistry of the hydrothermal fluids as they ascend to the surface (e.g. Truesdell, 1991). Note that gypsum and limestone are ubiquitous in this sector of the rift. They are being economically exploited at Kibuku (north of Buranga) and at Muhokya and Hima respectively. Isotopic studies could unravel this mystery and therefore the possibility of intercepting more dilute fluids at depth cannot be ruled out; a fact also recognized under GEEP I.

The possibility of intercepting freshwater lenses in this characteristically saline environment could be made possible through isotope hydrology studies coupled with the deep penetrating geophysical exploration techniques used in the search for geothermal resources. Drilling for domestic water supplies for the communities of Katwe sector of the rift valley by the UNICEF/GoU project in the early 1990's put forth water of inferior quality (brackish). Typical examples are the boreholes around Katunguru, the fishing village astride the Kazinga Channel. Boreholes WDD 5151, 5152 and 5455 have conductivities of 4.9, 3.6 and 4.9 mS/cm respectively. This compares unfavourably with the 0.2 mS/cm for the Channel water. The result has been their abandonment for the 'sweet' water of the Channel.

An example of a freshwater lens is the Svartsengi Peninsula, SW Iceland. Through geothermal research, a freshwater lens was discovered sandwiched between an advancing seawater front and the geothermal water plume. The Svartsengi Power plant utilizes a brine fluid at 240°C and heat is mined through heat exchangers. The Power plant has a combined use of the geothermal resources; producing hot water for space heating and electricity for the communities on this peninsula which includes the NATO base and Keflavik International Airport. The spent fluids are home to the famous 'Blue Lagoon’, a popular tourist attraction. A salt plant was utilizing the same brine from geothermal wells. This scenario could be possible at Katwe.

The results of isotope hydrology and geophysical exploration studies could also pave the way for the revamping of the long shelved proposed Sugar Plantation Project near Chambura Game Reserve, at the foot of the escarpment to the east of Katwe. In 1954, an electrical resistivity survey that was conducted by the Geological Survey of Uganda (GSU) failed to prove sufficient underground water resources to supply an irrigated sugar plantation (Dyke, 1954).

High CO_2 gas flows are characteristic of this sector of the rift. While borehole WDD 5455 in the Katwe field measures 1000 mg/kg CO_2 and >2000 mg/kg CO_2 for geothermal fluids (Armannsson, 1993), high gas flows have also been noted in the isolated Kichwamba Volcanics near Fort Portal, some 100 km north of Katwe. Small animals (including birds, rodents, lizards, etc.) die by suffocation in crevices owing to the high CO_2 gas flow. This unfortunate scenario could be turned into a money-spinning project through geothermal research and development. This abundant gas could form the basis of a liquid CO_2 industry very useful in the soft drinks industry. A case in point is the Haedarendi CO_2 plant, Grimsnes, South Iceland. While drilling for geothermal energy, the result was more CO_2 instead of water to a ratio of 12:1.

8. COMPARISONS WITH OTHER ENERGY SOURCES

Although Uganda's electric energy supply industry is skewed in favour of hydropower, the limitations attached to large dams using conventional technology are numerous. Not only do they require huge foreign-sourced funds, they always cause social concern for they involve large dammed-up areas. More often than not, in Uganda, the areas required for hydro dams are prime agricultural lands

One can say that geothermal power can compete with small hydro and with the most favourable assumption with large hydro (Table 14 in Matthiasson, 1994)..Geothermal energy can be developed step by step in response to funds available and energy requirements at the time. Proceeds from the initial investment can then be recouped back into the project for expansion. Issues regarding the environment are well taken care of through technical design and can only follow hydro (with zero emission) in terms of releasing greenhouse gases to the atmosphere, which is the subject of an EIA.

9. CONCLUSIONS AND RECOMMENDATIONS

The monopoly of government in the electricity industry has been a key factor in inhibiting the entry of private power generators in the Uganda electricity supply industry.

The location of the three geothermal areas fits in perfectly with the government's rural electrification programme. No doubt, the developments taking place in this part of the country (the western axis) call for prudent planning and the availability of cheap power nearby is the key.

Kasese, 30 km north of Katwe is already a growth centre courtesy of the mining industry; the strong agricultural base notwithstanding. The proposed US$ 35 million upgrading of Kasese Airstrip further enhances the viability of investments in this region. It is possible to introduce floriculture in the district just like it is the case with Naivasha, Kenya.

The isolated position of Bundibugyo District (home to the Buranga geothermal prospect coupled with the strong agricultural base (including coffee, cocoa, palm oil, etc.), renders the geothermal project a viable investment. The US$ 60 million IFAD/GoU Vegetable Oil Development Project (VODP) with a Palm Oil sub-component is a good candidate for the direct uses (as process heat) of geothermal energy development. The Kibiro power, on top of feeding the main grid, can be used to open up this part of the country. Fish processing on Lake Albert is the primary candidate, whereas process heat can be employed in the sugar processing plant at Kinyara and tobacco drying in Hoima and Masindi Districts, if proved feasible.

The tectonic and geologic setting of these geothermal resources in a feature of scientific importance as the East African Rift System with its associated mineral occurrences make it a suitable candidate for economic scientific research.
Finally, the failed projects in this sector of the Rift System underscore the need to respect the role scientific research plays as a basis for successful technological and engineering design. It can only be expensive in terms of time, whereas the price of hasty decisions are high cost, failure and ultimately fatigue, thereby overshadowing the viability of the project in question.

It is, therefore, recommended that government funds the exploration stages of geothermal as a matter of priority since knowledge obtained from this project is crucial in constraining the genetic models of the mineral resources existing in this sector of the Rift. This will go a long way in stimulating private sector participation in their development for the benefit of society. As one Kenyan Minister remarked: Geothermal is here to stay and the sooner we learn how to use it the better for our people.

ACKNOWLEDGEMENTS

The author is greatly indebted to Mr. D. Okumu, General Manager-Services, UEB for the Electricity data making up the table. To the Commissioner, Energy Department, through Mr. Henry Gidasala, for critically reviewing the paper. It is only regrettable that the solar data did not come through but Ms. Cecilia Nakiranda's efforts in this regard are highly regarded. To my superiors at the Department, my sincere thanks for editing the paper and making useful suggestions.

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Table 1. Present and Planned Production of Electricity in Uganda.

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity Mwe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity Mwe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in January 2000	-	-	1.6	0.96	275.0	1445.4	-	-	-	-	276.6	1446.36
Under construction in January 2000	-	-	0	0	120.0	630.72	-	-	-	-	120.0	630.72
Funds committed, but not yet under construction in January 2000	-	-	0	0	0	0	-	-	-	-	0	0
Total projected use by 2005	-	-	1.6	0.96	580	3048.48	-	-	-	-	581.6	3049.44

Table 2. TOTAL INVESTMENTS IN GEOTHERMAL IN (1999) US$

Period	Research & Development Incl. Surface Explor. And Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1985-1989	-	-	-	-	-	-
1990-1994	0.576565	-	-	-	-	100
1995-1999	0.078575	-	-	-	-	100

Table 3. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	3	-	-	-	-	-
1996	4	-	-	-	-	-
1997	4	-	-	-	-	-
1998	4	-	-	-	-	-
1999	7	-	-	1	-	-
TOTAL	7	-	-	1	-	-