Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Geothermal Energy Exploration in Uganda, Country Update

Godfrey BAHATI and James Francis NATUKUNDA

Ministry of Energy and Mineral Development, Uganda

P.O. Box 9, Entebbe, Uganda

gbahati@gmail.com and jfnatukunda@gmail.com

Keywords: Policy, legislation, surface studies, conceptual models, temperature gradient drilling

ABSTRACT

Exploration for geothermal energy in Uganda has been in progress since 1993. The studies by the Ministry responsible for Energy and Mineral Development have focused on four major geothermal areas namely Katwe, Buranga, Kibiro, and Panyimur. The overall objective of the study is to develop geothermal energy to complement hydro and other sources of power to meet the energy demand of rural areas in sound environment. The studies have used geological, geochemical, hydrological and geophysical methods with the aim of elucidating subsurface temperatures and the spatial extent of geothermal systems, and in turn come up with conceptual models that would be a basis for drilling exploration wells. The results indicate that the geothermal activity in the four areas appears to be fault-controlled deep circulation systems rather than magmatically heated systems associated with volcanoes, which is consistent with the revised view on geothermal prospects in the Western Branch of the East African Rift System. Subsurface temperatures of approximately 130-150˚C for Katwe, 120-150˚C for Buranga, 150-250˚C for Kibiro, and 110-140˚C for Panyimur have been predicted by geothermometry and mixing models. In other areas, the current results suggest geothermal potentials with subsurface temperatures of 100-160˚C. In all the areas, the temperatures are good for electricity generation and direct use in industry, agriculture and tourism.

Three areas namely Kibiro, Panyimur and Buranga have reached advanced stages of surface exploration, subsurface conceptual models have been developed and temperature gradient wells (TGW) sited at all the three prospects. Drilling of TGW is to start in 2020 the results of which will be used to update the conceptual models that will be a basis for locating sites for deep exploration wells.

Other achievements of the Ministry include (i) Creation of a Geothermal Resources Department through restructuring of the Ministry of Energy and Mineral Development in 2014 to focus on exploration, promotion, licensing and management of geothermal resources; (ii) Formulation of a Geothermal Policy a draft of which is being finalized for presentation to Cabinet for approval; (iii) capacity building that includes equipment and training of Ugandans; (iv) Sensitization of local governments and communities about the benefits of geothermal energy; (v) Preliminary environmental baseline studies at Kibiro and Panyimur geothermal prospects; (vi) creation of a database and website to house all geoscience information and data related to the geothermal industry; and (vii) development of business and financial models to guide the explorers and developers on the most appropriate models to use in a specific prospect.

The challenges include inadequate policy, legal and regulatory frameworks to guide public interventions on a strategic basis; high geological risk; inability to attract significant financial support from International Development Partners; inadequate data and information to guide decision-makers; unskilled workforce capable of maintaining a sustainable geothermal industry; low awareness amongst the public and limited community participation in geothermal exploration and development.

1. INTRODUCTION

Uganda geothermal resources are estimated at about 1,500 MW from 24 areas in the Ugandan Rift System (Uganda Vision, 2040). Most of the geothermal areas of Uganda are located in the Western Rift Valley that runs along the border of Uganda with the Democratic Republic of Congo, and is part of the Western Branch of the East African Rift System (Figure 1).

The main geothermal areas are Katwe-Kikorongo (Katwe), Buranga, Kibiro and Panyimur located in Kasese, Bundibugyo, Hoima and Pakwach districts respectively. Other geothermal areas are located in the Southwest, North and Northeast Uganda.

A number of exploration activities have been carried out in the field of geology, geochemistry and geophysics which have led to development of subsurface conceptual models in the three prospects of Kibiro, Panyimur and Buranga. Detailed exploration is going on at Katwe and Ihimbo located in Kasese and Rukungiri districts respectively, the results of which will lead to the development of subsurface models like in the three prospects above. The next step is temperature gradient drilling to test the conceptual models which will be followed by a feasibility study that will involve exploration drilling and well testing at selected prospects.

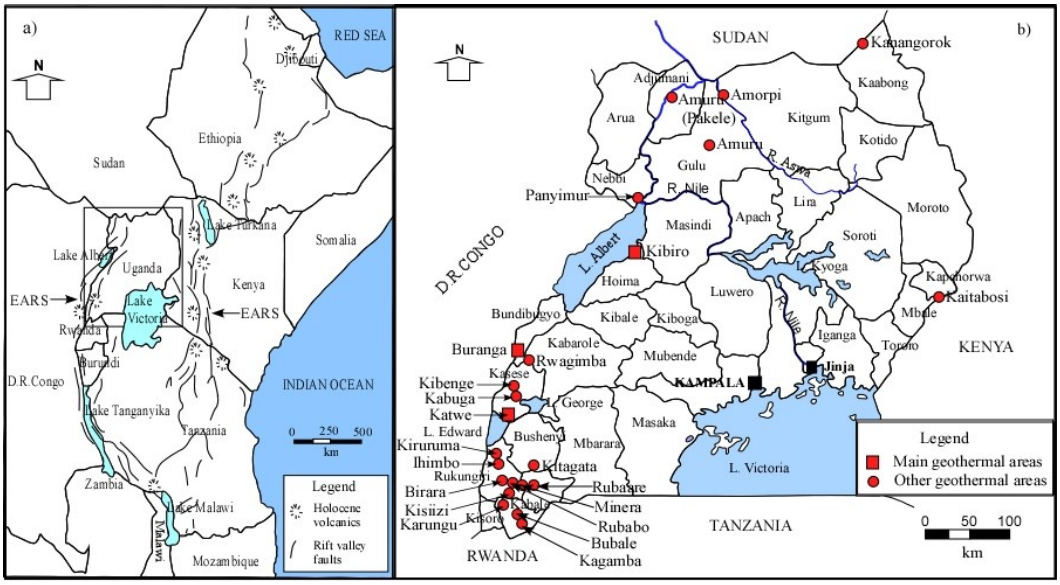


Figure 1: Location of the geothermal areas of Uganda. ***After Bahati et al., 2005.***

1.1 Legal and Institutional Framework

The Government established a Geothermal Resources Department through restructuring of the Ministry of Energy and Mineral Development in 2014. The Department has embarked on formulating a geothermal policy and legislation to promote exploration and development of the country's geothermal resources. The draft policy will soon be sent to cabinet for Government approval. The current policies used for geothermal exploration and development are the Energy Policy 2002 and Renewable Energy Policy 2007. The geothermal exploration is currently regulated by the Mining Act 2003, and development by the Electricity Act 1999. The current policy and legislation are inadequate and cannot promote geothermal exploration and development creating a risk profile for geothermal projects as they cannot be generalized with minerals and other energy resources. For example, the current policies and legislation do not cater for direct uses of geothermal energy in industry, agriculture and tourism. There is, therefore, a need for a specific policy and legislation for geothermal energy with a focus on electricity generation and direct uses.

1.2 The Energy Sector

Uganda, like the rest of world, has kept integrated development key to Government policy over the past two and half decades. Integrated development cannot be realized without paying sufficient attention to the energy sector. The energy sector is the power source for realization of Uganda's development agenda as enshrined in Vision 2040 and operationalized through National Development Plans (NDPs). The energy sector propels the national development agenda through the numerous benefits of energy resources which contribute to enhancement of investment opportunities, employment creation and enabling other sectors performance hence economic development.

Uganda has a potential for hydropower resources estimated in excess of 4,500 MW (Uganda Vision, 2040) of which 2,000 MW is either installed or under construction suggesting that hydropower resources will soon be exhausted. Other alternatives being investigated are mainly renewable sources that include geothermal, biomass, wind, peat, mini and small hydro, and solar energy. The discovery of oil in the Western Rift Valley in Uganda will also contribute to electricity generation. The country's *per capita* energy consumption of 150 KWh is among the lowest in the world. The grid electricity access rate is very low: 22% for the whole country and about 10% for the rural areas. Electricity production is approximately 6,630.77 GWh/yr with a demand for power growing by 10% per year.

1.3 Current Status of Electricity Generation and Utilization

Uganda presently has a total installed capacity of electricity production of 1,161.34 MW of which 920.34 MW is hydropower, the rest is from cogeneration in sugar industries, solar and thermal power plants. The effective capacity therefore is estimated to be in excess of 895 MW. The demand for electricity is estimated at 620MW. This demand is largely domestic consumption but government policy is to add value to the country's natural resources which calls for greater electricity generation. In March 2019, the Government commissioned a 183 MW power plant at Isimba and is contructing a 600 MW power plant at Karuma all along the River Nile. The Karuma power plant will raise the installed capacity to over 1,800 MW by 2020. In the long-term, government will develop Ayago (840 MW) and Oriang (392 MW) downstream Karuma on the River Nile.

1.4 Lead agencies

The lead agencies involved in geothermal development and funding are the Ministry of Energy and Mineral Development (MEMD); Ministry Finance, Planning and Economic Development (MOFPED); Uganda Electricity Regulatory Authority (ERA); Uganda Electricity Transmission Company Limited (UETCL); Uganda Electricity Generation Company Limited (UEGCL); and the National Environment Management Authority (NEMA). Their roles are as follows:

(i) MEMD is the executing agency of geothermal projects through its technical departments and regulates the private sector players.

(ii) MOFPED provides funding for geothermal development projects and also sources for funding from international organizations and donors.

(iii) ERA gives permits for feasibility studies and licenses geothermal power plants, regulates geothermal power plant operators and sets the tariff for electricity generated from geothermal energy.

(iv) UEGCL advises on financing opportunities and challenges for geothermal power plant development, is a Government implementing agency for the development of public geothermal power plants, operation and maintenance of the geothermal power plants, and in the event of using a PPP model, UEGCL would be the public representative in the Special Purpose Vehicle (SPV).

(v) UETCL is responsible for executing value for money PPAs that are sufficient to support economically-viable geothermal power plant developments, acts as an off-taker for geothermal generated electricity to the national grid, providing infrastructure for connections to the national grid and management of electricity systems to ensure safe operation and despatch of geothermal power.

(vi) NEMA coordinates processes of environmental impact assessments for geothermal activities, monitors and audits geothermal activities, and issues guidelines for strategic environmental assessment.

2. THE GEOTHERMAL RESOURCES AND POTENTIAL

2.1 Geology of the western rift

The main geothermal areas of Uganda are located in the northern part of the Western Branch of the East African Rift System. The rift believed to have opened in the Miocene time, about 15 million years ago, runs from NW Uganda towards SW, through Lake Albert and the Semuliki basin to the west of the Rwenzori Mountains. South of the Rwenzori Mountains it swings eastwards to Lake Edward where it continues in a NE direction and eventually fading at the Toro plateau to the east of the Rwenzori Mountains (Figure 2).

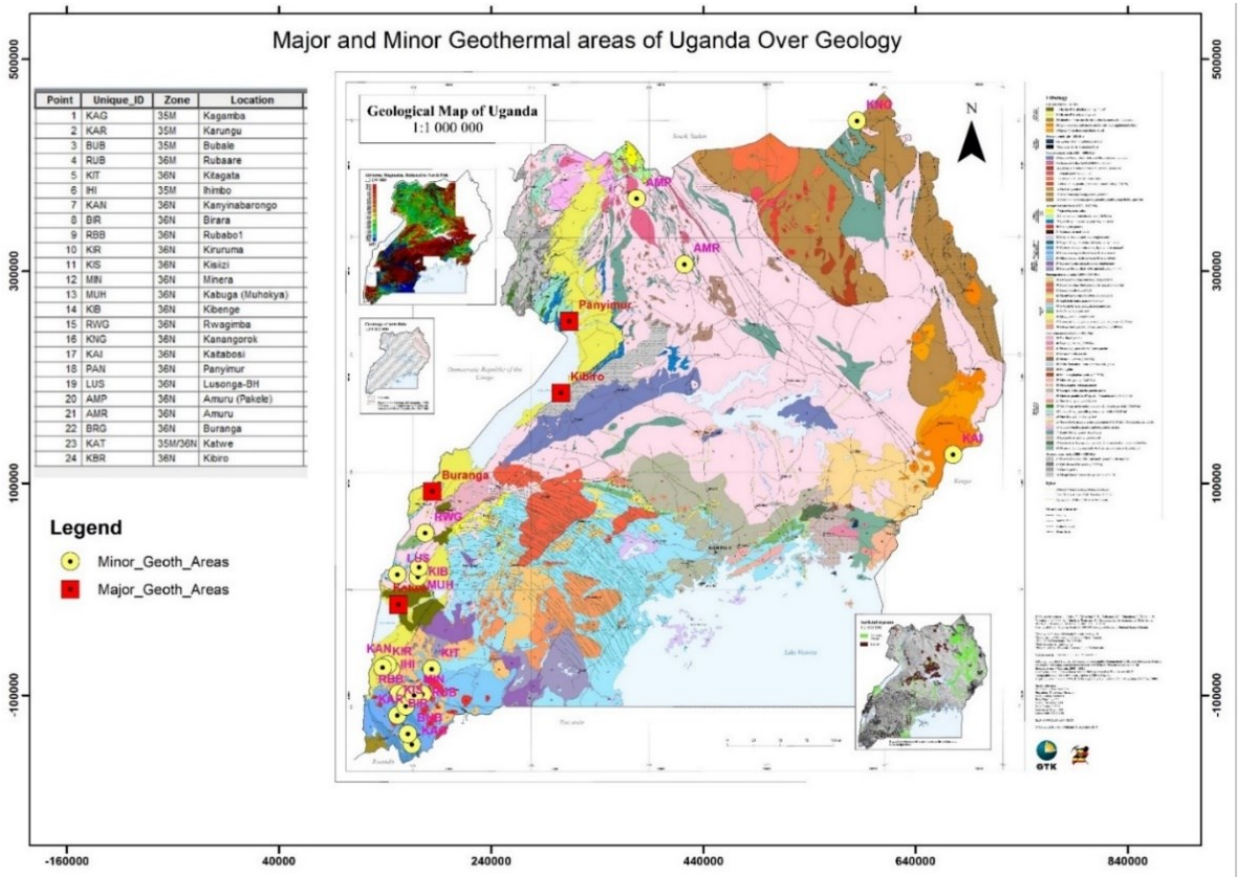
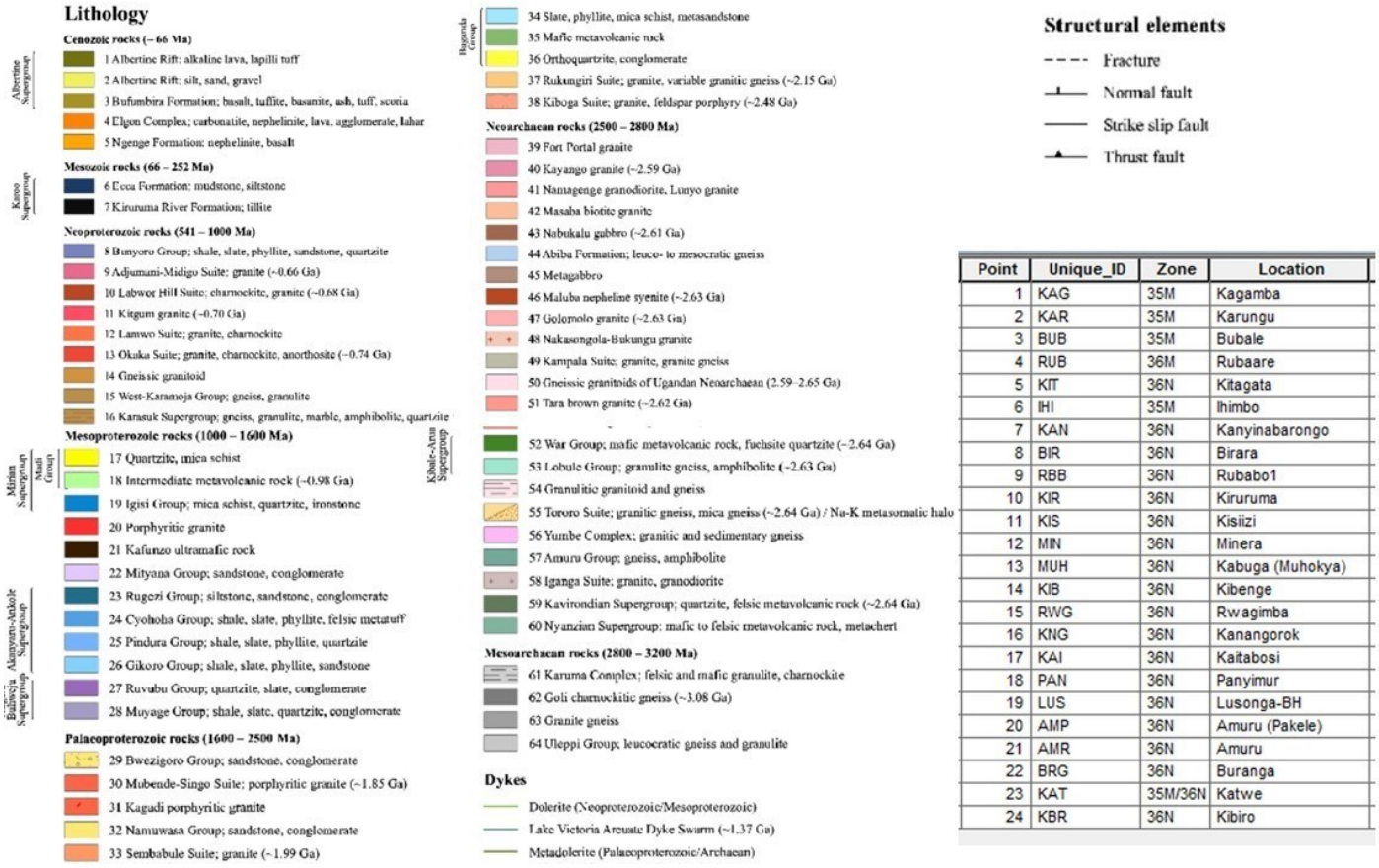


Figure 2: The geology of Uganda with the location of the geothermal areas. After Lehto et. al., 2014.



Point	Unique_ID	Zone	Location
1	KAG	35M	Kagamba
2	KAR	35M	Karungu
3	BUB	35M	Bubale
4	RUB	36M	Rubaare
5	KIT	36N	Kitagata
6	IHI	35M	Ihimbo
7	KAN	36N	Kanyinabarongo
8	BIR	36N	Birara
9	RBB	36N	Rubabo1
10	KIR	36N	Kiruruma
11	KIS	36N	Kisiizi
12	MIN	36N	Minera
13	MUH	36N	Kabuga (Muhokya)
14	KIB	36N	Kibenge
15	RWG	36N	Rwagimba
16	KNG	36N	Kanangorok
17	KAI	36N	Kaitabosi
18	PAN	36N	Panyimur
19	LUS	36N	Lusonga-BH
20	AMP	36N	Amuru (Pakele)
21	AMR	36N	Amuru
22	BRG	36N	Buranga
23	KAT	35M/36N	Katwe
24	KBR	36N	Kibiro

Legend to Figure 2

Figure 2 shows the Rift Valley sediments which are marked by the yellow color in the western part of the country whose continuity is interrupted by two bodies, the Lake Albert to the north and the Lake Edward-Kazinga Channel-Lake George complex to the south. The four Geothermal prospects Katwe, Buranga and Kibiro and Panyimur all lie in the Rift valley. The Rwenzori Mountains lie east of the Buranga geothermal prospect, a fault-controlled system by the Bwamba fault which marks the western end of the Rwenzori Mountains. The Kibiro prospect is controlled by Lake Albert and the Tooro-Bunyoro fault which also marks the eastern escarpment of the rift valley, while the Katwe prospect is the only area in a volcanic set up between the Lake Edward-Kazinga Channel-Lake George complex and the Rwenzori Mountains.

The Rwenzori massif rises over 4,000 m above its surroundings, bordered to the east and west by two branches of the rift indicating that the rock mass between the two branches of the rift has been subjected to an uplift relative to the surrounding crust. Gravity and magnetic data have estimated up to 4.5 km of sediments in the Albertine depression (EDCON, 1984). The thickness of the sediments becomes gradually thinner towards SW of Lake Albert under the Semuliki plains and to the Northeast of Lake Albert. The Northwest part of the Rwenzori is bounded by steep fault planes of the Bwamba escarpment while the Southeast slopes of the Rwenzori are gentler. In the Lake Edward part of the rift, the sediments are about 3 km thick but get thinner Northeast of Lake Edward towards Lake George. The sediments in the Lake Edward and Lake Albert rifts are of lacustrine and fluvial origin. They have been divided into the Kisegi (lower Miocene to Pliocene) and Kaiso series (earlier Pleistocene). There are a number of oil seepages in the Lake Albert rift indicating oil bearing sediments in the rift graben. These seepages have led to the exploration and discovery of oil in Uganda.

The northern part of the western branch of the rift has sparse volcanism. In Uganda, the volcanic areas lie between Lake Edward and Lake Albert. The Bunyaruguru and Katwe-Kikorongo lie to the East and Northeast of Lake Edward respectively. Further Northeast of Lake Edward lies the Kyatwa, Kichwamba, and Fort Portal volcanos. The most impressive volcanism is found further to the south in Virunga Mountains along the border of Uganda, Rwanda and Democratic Republic of Congo (DRC). The volcanic activity is characterized by explosion craters and ejected pyroclastics and tuffs with abundant granite and gneissic rocks from the basement. Minor occurrences of lava are found mainly in the northerly volcanic areas (Kichwamba and Kyatwa) and in Lake Kitagata and Kyemengo craters in Katwe-Kikorongo. The age of the volcanic activity is placed at Pleistocene to Holocene (Musisi, 1991).

2.2 The current status of exploration

Geothermal resources exploration in Uganda is still at the pre-feasibility phase with three prospects Kibiro, Panyimur and Buranga in advanced stages of surface exploration and will soon be subjected to feasibility studies. The feasibility study will include drilling of exploration wells, well testing and construction of pilot power plants. The three prospects are followed by Katwe which is at detailed surface exploration study. Subsurface temperatures of approximately 150-250˚C for Kibiro, 110-140 ˚C for Panyimur, 120-150˚C for Buranga, 130-150˚C for Katwe have been predicted by geothermometry and mixing models (Armannsson, 1994; Alexander et. al., 2016). The temperatures are suitable for electricity production, direct use in industry and agriculture, and spas and swimming pools in the tourism industry. Reconnaissance investigations have also been done in the rest of the geothermal areas of Uganda. The

results suggest reservoir temperatures in the range of 100 - 160˚C also suitable for electricity production and direct uses (Bahati, et. al., 2007).

Recent exploration focused on structural geology, geochemistry and geophysics and development of subsurface conceptual models. The detailed exploration was carried out by the Ministry of Energy and mineral development with technical support from the East African Geothermal energy Facility (EAGER) sponsored by the United Kingdom Department for International Development (DFID). The study developed conceptual models for Kibiro, Panyimur and Buranga prospects (Figures 3, 4 and 5).

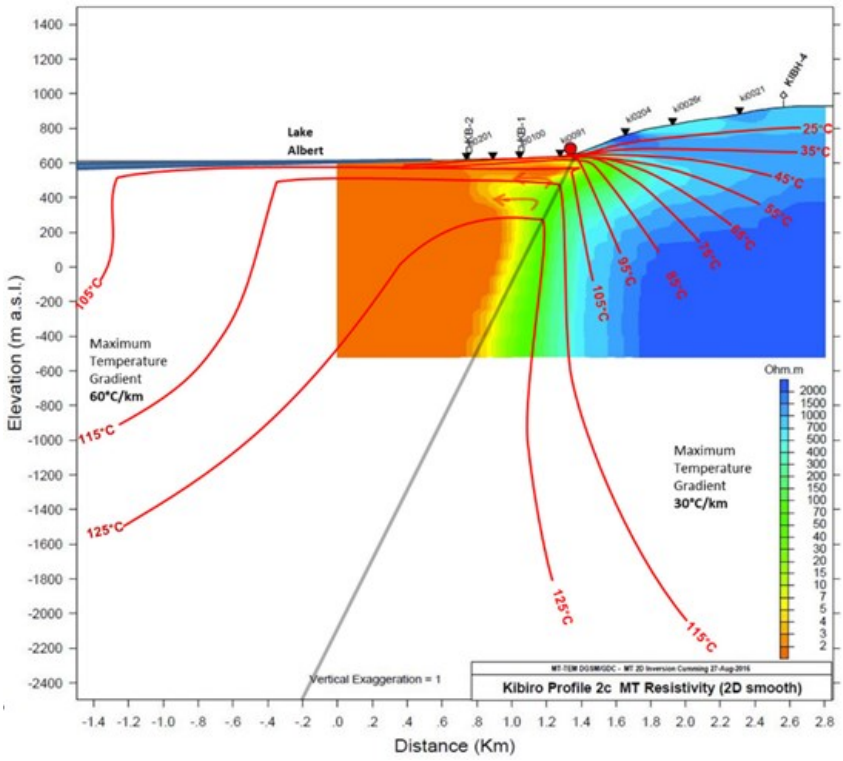


Figure 3: MT Geophysical Conceptual Model for Kibiro with a 65° dipping fault. The purported reservoir is in green/yellow while red is the cap rock shielding the reservoir. After EAGER-GRD, 2018.

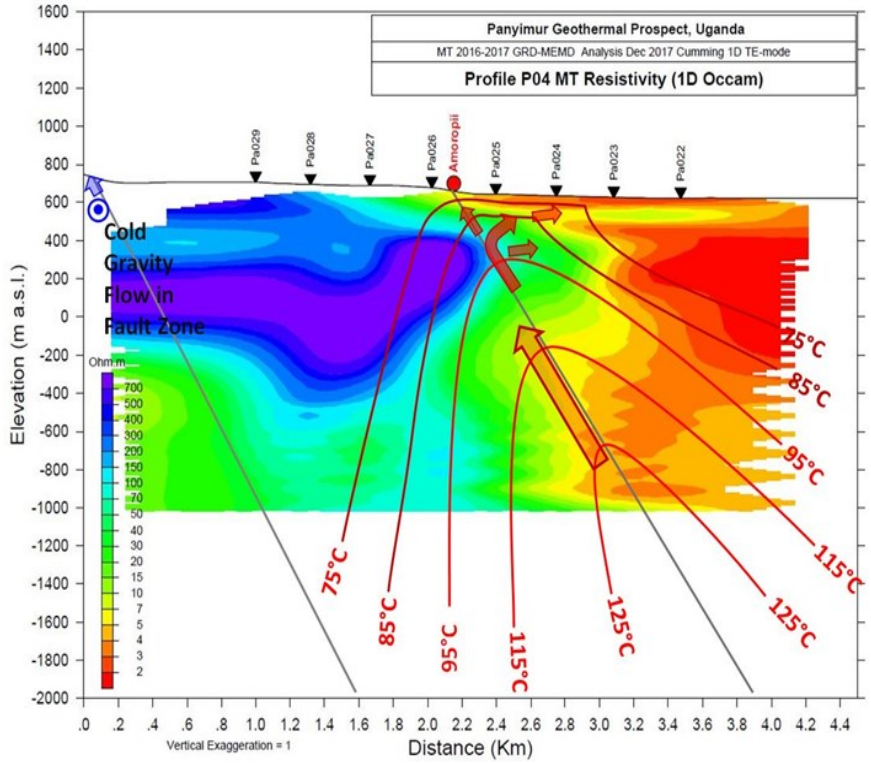


Figure 4: Panyimur. Conceptual model through Amoropii hot springs. After EAGER-GRD, 2018.

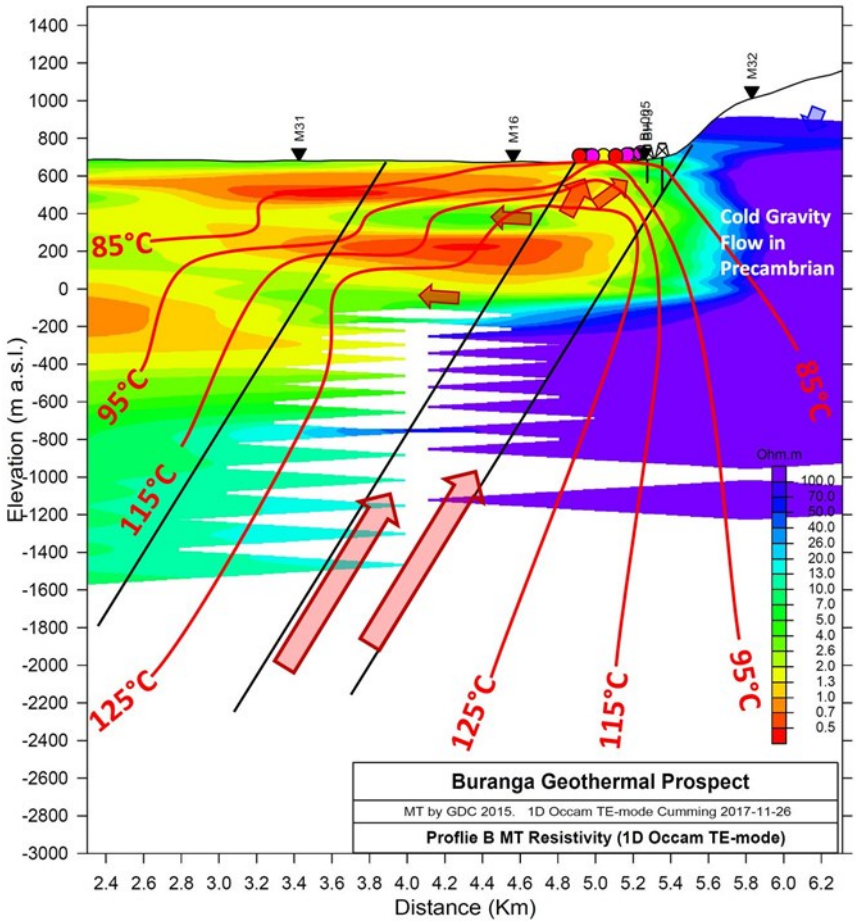


Figure 5: Buranga. MT Geophysical Conceptual Model. After EAGER-GRD, 2018.

The models were used to site Temperature Gradient Wells (TGW) at the three prospects. Drilling of the TGW is to start with Kibiro and Panyimur in 2020. Upon completion of the TGW, the conceptual model(s) and resource assessment would be updated to support targeting deeper slim holes or full-sized wells as appropriate based on these updated models and risk assessments.

3. GEOTHERMAL 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 fluid's discharges from hot springs. This thermal energy is not yet quantified into MW. Tables 1, 7 and 8 summarize the current status of energy sources for Uganda, the human capacity and the total expenditure for geothermal exploration and development (Appendix I). The geothermal water is being used as a source of salt at Kibiro and Katwe prospects. 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, salt extraction is done by channeling the brine into concentration ponds from which the salt solidifies on the surface by natural evaporation during the dry weather. The rest of the Ugandan hot spring waters are currently used for spas and are believed to have curative powers for skin diseases and rheumatics. The only known in-house use of geothermal energy is at Kisiizi hospital situated in Rukungiri district, SW-Uganda, where hot 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 spring waters are 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 and also has some cultural attachments.

4. DISCUSSION

Previous studies on the geothermal systems of Uganda focused on surface geology, geochemistry and geophysics with the aim of determining the structures controlling the flow of the geothermal fluids, subsurface temperatures, and the spatial extent of the geothermal systems. The results indicate that the Uganda geothermal systems are fault-controlled deep circulation systems with less or no magmatic input. Subsurface temperatures of approximately 100 - 250˚C have been predicted by geothermometry in most of the potential geothermal areas. The temperatures are good for electricity generation and direct use in industry, agriculture and tourism.

Since 2015, the Ministry of Energy and Mineral Development has carried out detailed structural mapping, geochemistry and geophysics, and developed the first conceptual models in three prospects of Kibiro, Panyimur and Buranga. The conceptual models have been used to locate sites for temperature gradient drilling. The drilling of TGW is to start in 2020 the results of which will be used to update the conceptual models that will be a basis for locating sites for deep exploration wells.

Other achievements of the Ministry include (i) Creation of a Geothermal Resources Department through restructuring in the Ministry of Energy and Mineral Development in 2014 to focus on exploration, promotion, licensing and management of geothermal resources;

(ii) Formulation of a Geothermal Policy, a draft of which is being finalized for presentation to Cabinet for approval; (iii) capacity building that includes procurement of equipment and training of Ugandans; (iv) Sensitization of local governments and communities about the benefits of geothermal energy; (v) Preliminary Environmental Baseline Studies carried out at Kibiro and Panyimur geothermal prospects; and (vi) creation of a Database to house all geoscience information and data related to the geothermal industry; (vii) development of Business and Financial models to guide the public and private sector on the most appropriate models to use in a specific prospect.

The Government of Uganda has never before established a policy dedicated solely to the management of geothermal resources. Both the Energy Policy, 2002 and the Renewable Energy Policy, 2007 recognise the potential of the technology for power generation, although they make only superficial consideration of issues for its development. The approach to regulating geothermal activities using the Mining Act 2003, and Electricity Act 1999 is inadequate, and a new legal framework to separate geothermal tenure rights from minerals and more effectively manage the expectations of both public and private developers through the licensing process is needed.

The overarching goal of the geothermal policy is to provide a framework that facilitates effective and sustainable exploration, development and utilisation of Uganda's geothermal resources for social and economic transformation. The policy outlines the principles, objectives, and strategies for achieving the above goal to include: (i) accelerating geothermal resource exploration through enhanced actions by Government; (ii) optimising development to ensure efficient use of geothermal resources; (iii) promulgating a new legal framework to improve the management of geothermal resources; (iv) ensuring environmentally safe deployment of geothermal energy technologies; (v) promoting a geothermal industry of the future through improved human resource development and local content requirements for geothermal development activities; (vi) institutional framework in which the objectives and strategies are to be established, and (vii) an implementation plan describing the actions to be taken that will assist in achieving the goal and objectives.

5. FUTURE DEVELOPMENT AND INSTALLATIONS

The geothermal strategy is to put in place adequate Policy, Institutional and Regulatory frameworks for geothermal energy development. The geothermal policy will help to, amongst other things, give clearer direction in Uganda as to how geothermal energy projects can be developed, by whom, over what time frame, and using which sources of finance and support mechanisms. The legal and regulatory framework will strengthen licensing of the geothermal areas and regulation of private sector players.

The temperature gradient drilling of shallow boreholes (200-300m) to confirm the presence of heat in the subsurface will be followed by; (i) drilling of two (2) exploration wells and two (2) injection wells, installation of pumps and well testing; (ii) installation of a well-head generator (pilot power plant) and a facility for direct uses in industry, agriculture, tourism and extraction of minerals in each prospect; and putting in place infrastructure for a mini grid or connection of the power plants to the national grid.

6. ACKNOWLEDGEMENTS

The authors wish to thank all the organizations/governments that have supported the Uganda geothermal exploration and development programme since 1993. They include the United Nations Development Programme (UNDP), Organization of Petroleum Exporting Countries (OPEC), International Atomic Energy Agency (IAEA), African Development Bank (AfDB), World Bank (WB), Federal Institute for Geosciences and Natural Resources (BGR) of Germany, Japanese International Cooperation Agency (JICA), United Kingdom Department for International Development (DFID), UN Environment, African Union Commission (AUC), and Governments of Iceland and Uganda.

REFERENCES

Alexander, K., Cumming, W.B., and Marini, L., 2016. Geothermal Resource Assessment Report, Kibiro geothermal prospect, Uganda, 71pp.

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.

Ármannsson, H., G. Bahati, V. Kato, 2007. Preliminary investigations of geothermal areas in Uganda, other than Katwe-Kikorongo, Buranga and Kibiro *Final Report. ICEIDA, MEMD, Uganda*, 19 pp.

Bahati, G., Z. Pang, H. Armannsson, E.M. Isabirye, V. Kato, 2005. Hydrology and reservoir characteristics of three geothermal systems in Western Uganda, *Geothermics,* 34, p.568-591.

EAGER-GRD, 2018. Terminal Report on a technical cooperation project under a memorandum of understanding between the Government of Uganda and Adam Smith International (ASI) on behalf of EAGER and sponsored by the UK DFID, 31 pp.

EDICON, 1984; Aeromagnetic interpretation of Lake Albert/Edward portion of the Western Rift Valley; Unpub. report, EDICON inc., Denves Colorado, Sept. 1984.

Lehto, T., Westerhof, A.B., Lehtonen, M.I., Manninen, T., Makitie, H., Virransalo, P., Pokki, J., Harma, P., Koistinen, T., Saalmann, K., Kuosmanen, E., Manttari, G., Katto, E., Baguma, Z., de Kock, G., and Elepu, D., 2014. Geological Map of Uganda, Scale 1:1,000,000. Geological Survey of Finland, Espoo, Finland.

Musisi, J., 1991. The neogene geology of the Lake George – Edward basin, Uganda. PhD thesis.

Uganda Vision, 2040. Government of Uganda, April 2013.

APPENDIX I

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	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 December 2019	0.00	0.00	100.0	122.64	920.34	5,643.52	0.00	0.00	141.00	864.61	1,161.34	6,630.77
Under construction in December 2019	0.00	0.00	0.00	0.00	714.00	4,378.25	0.00	0.00	0.00	0.00	714.00	4,378.25
Funds committed, but not yet under construction in December 2019	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estimated total projected use by 2020	0.00	0.00	100.0	122.64	1,634.34	10,021.8	0.00	0.00	0.00	0.00	1734.34	10,634.97

TABLE 7: ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

Year	Professional Person – Years of effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	15	0	0	3	4	8
2016	18	0	0	3	3	6
2017	20	0	0	3	3	10
2018	20	0	0	6	0	5
2019	20	0	0	0	0	5
Total	93	0	0	15	10	34

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

TABLE 8: TOTAL INVESTMENTS IN GEOTHERMAL IN US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0.078				0	100
2000-2004	1.13				0	100
2005-2009	1.33				0	100
2010-2014	2.27				22	78
2015-2019	6.19				16	84