Geothermal Energy Exploration in Uganda, Country Update

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ABSTRACT

Exploration for geothermal energy in Uganda has been in progress since 1993. The studies by the Ministry of Energy and Mineral Development have focused on four major geothermal areas namely Katwe, Buranga, Kibiro and Panyimur. The overall objectives of the studies is to sustainably develop geothermal energy to complement hydro and other sources of energy to meet the energy demand of rural areas in sound environment. The studies have used geological, geochemical, hydrogeological and geophysical methods with the aim of elucidating subsurface temperatures and the spatial extent of geothermal resources, and in turn come up with conceptual models that would be a basis for drilling exploration wells. The results suggest that the geothermal activity in the four areas appear to be fault-controlled deep circulation systems rather than magmatically heated systems associated with central 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, 150-25°C for Kibiro, 110-140°C for Panyimur and 100-160° C for other areas, have been estimated by geothermometry and mixing models. In all the areas, the temperatures are good for electricity generation and direct use in industry, agriculture and tourism. Three areas namely Kibiro, Panymur and Buranga have reached advanced stages of surface exploration, conceptual models have been developed and temperatures gradient holes (TGH) sited at all the three prospects. Drilling of eight TGH was completed at Kibiro in 2020 and another eight TGH at Panyimur in July 2022, with results suggesting potential geothermal reservoirs underneath the Kibiro peninsula and the Panyimur basin. The results will be used to update the conceptual models that will be a basis for locating sites for deep exploration wells. The challenges for geothermal development include high geological risk; inability to attract financial support from development partners; inadequate data and information; unskilled workforce; low awareness amongst the public, and limited community participation in geothermal exploration and development.

1. INTRODUCTION

Uganda geothermal resources are estimated at 1,500 MWe from 25 areas in the Ugandan Rift System (Uganda Vision, 2040). Most of the geothermal areas of Uganda are located in the Western Branch of the East African Rift System (EARS) along the border with the Democratic Republic of Congo (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 leading 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. Temperature gradient drilling to test the conceptual models was done at Kibiro and Panyimur with eight TGH drilled at each prospect. The results will be used to update the conceptual models that will be a basis for drilling exploration wells. This will be followed by a feasibility study that will involve exploration drilling and well testing at selected prospects.

1.1 Legal and Institutional Framework

The Government established a Geothermal Resources Department by restructuring the Ministry of Energy and Mineral Development in 2014. The geothermal resources development is managed under the National Energy Policy 2022 and the Mining and Minerals Policy 2018. The geothermal exploration and development is regulated by the Mining and Minerals Act 2022, and Electricity Act 2022. The policies and legislation have been strengthened to focus on electricity production and to promote direct uses of geothermal energy in industry, agriculture and tourism.

1.2 The Energy Sector

Uganda, like the rest of the 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 100 kWh is among the lowest in the world. Access to electricity remains very low. Grid access stands at 27%. Access to solar energy is growing faster albeit with hardly any government support and now stands at 32%, making a total of 59%. Electricity production is approximately 6,950 GWh/yr with a peak demand of 793 MW and growing by 12% per year.

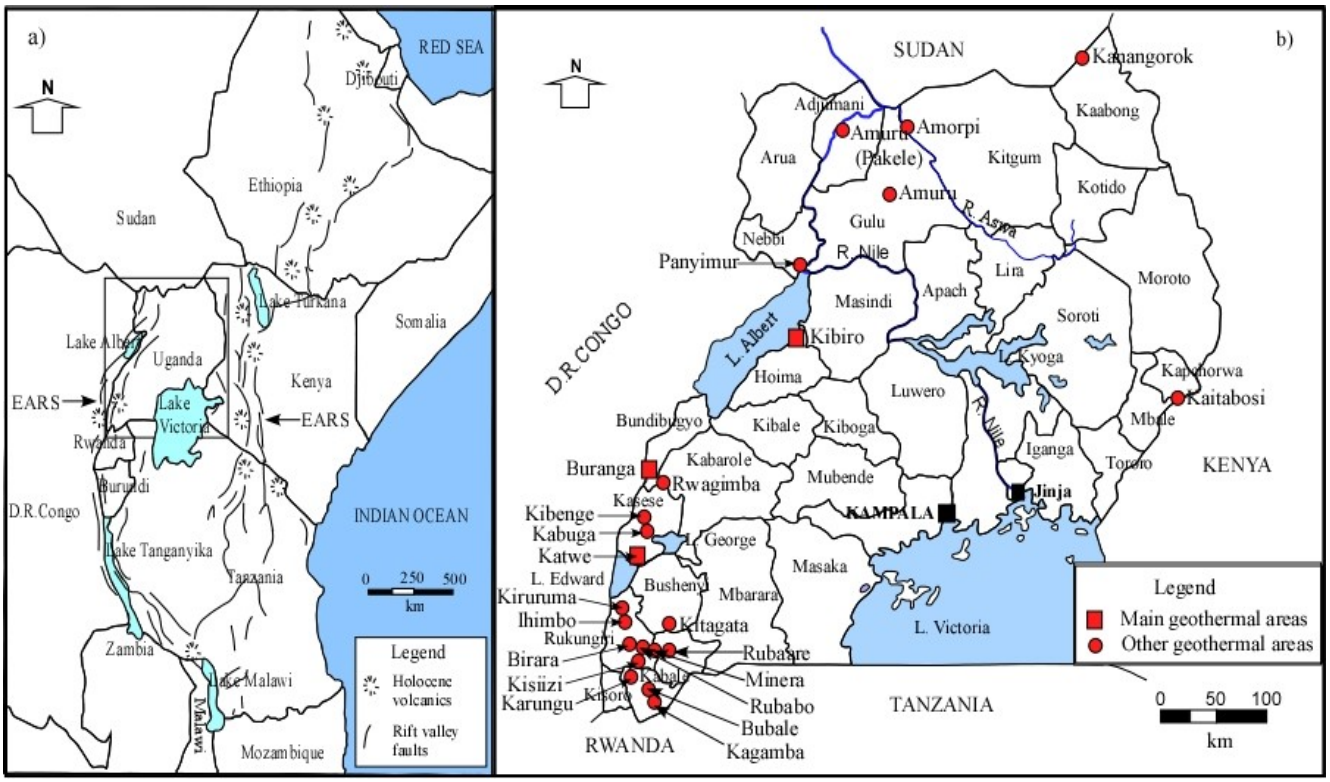


Figure 1: Location of the geothermal areas of Uganda. ***After Bahati et al., 2005.***

2. CURRENT STATUS OF ELECTRICITY GENERATION AND UTILIZATION

As of October 2022, electricity generation capacity in Uganda stood at 1,346.6 MW and is to reach 2000 MW by June 2023 after fully commissioning of the 600 MW Karuma hydroelectric power plant and some mini hydros now under construction, cogeneration in sugar industries, solar and thermal power plants. In the long-term, government will develop the hydroelectric projects of Ayago (840 MW) and Oriang (392 MW), downstream Karuma on the Nile River.

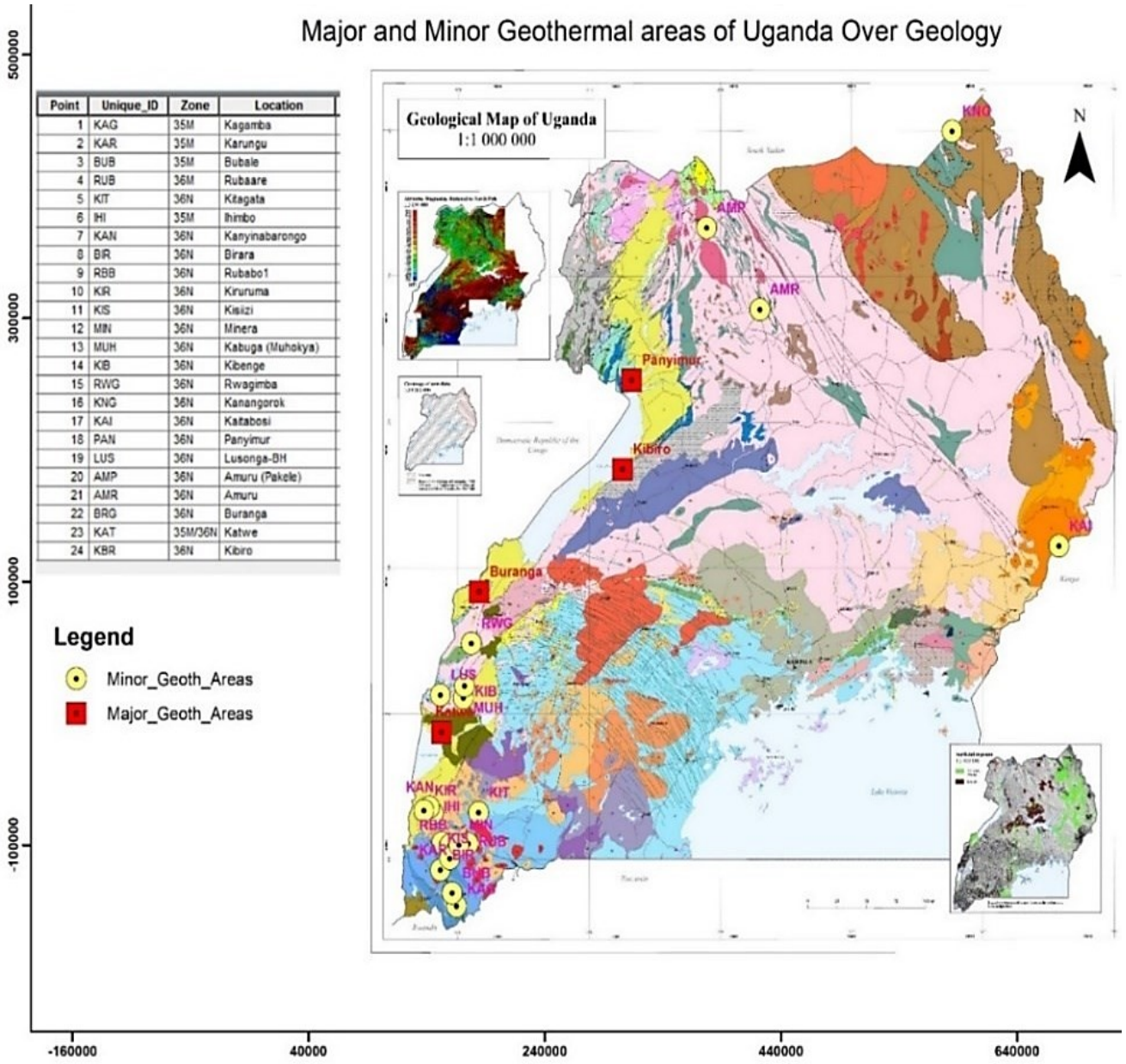
Geothermal resources have potential to support the Government's strategic direction as stipulated in the National Development Plans (NDP) and Uganda Vision 2040, which projects per capita electricity consumption to rise from the current 100 kWh to 3,668 kWh by 2040. The Ministry is projecting that within the next 10 years, hydropower potential (4,500 MW) will be exhausted and that Government should promote the Energy Mix by intensifying development of renewable energies, including geothermal, to address shortage of power supply. The prioritized interventions under the NDP III include: (i) Develop renewable off-grid energy solutions, (ii) Review of the Atomic Energy Act, 2008, while (iii) develop policy and legislation to promote exploration, development and utilization of Uganda's geothermal resources for power generation and direct uses in industry, agriculture and tourism.

The Government of Uganda endorsed the 2030 Agenda for Sustainable Development whose Goal 7 is to "Ensure access to affordable, reliable, sustainable and modern energy for all". The Agenda's targets by 2030 include: (i) ensure universal access to affordable, reliable and modern energy services; (ii) increase substantially the share of renewable energy in the global energy mix; (iii) double the global rate of improvement in energy efficiency; (iv) enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy and promote investment in energy infrastructure and clean energy technology; (v) expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries.

3. GEOTHERMAL RESOURCES AND POTENTIAL

3.1 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. It is believed the rift opened in the Miocene, about 15 million years ago, and it 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).



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	Katabosi
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

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

Figure 2 shows the Rift Valley sediments which are marked by yellow color in the western part of the country, and 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, 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 that 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 these two branches 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 volcanoes. 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).

3.2 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. These feasibility studies will include drilling of exploration wells, well testing and construction of pilot power plants if possible. The three prospects are followed by Katwe that is at a detailed surface exploration phase. 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 estimated by geothermometry and mixing models (Alexander et. al., 2016; Armannsson, 1994; and Bahati et. Al., 2005). The temperatures are suitable for electricity production, beside direct applications 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 subsurface temperatures in the range of 100-160°C also suitable for electricity production and direct uses (Bahati et. al., 2007).

Recent exploration is 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).

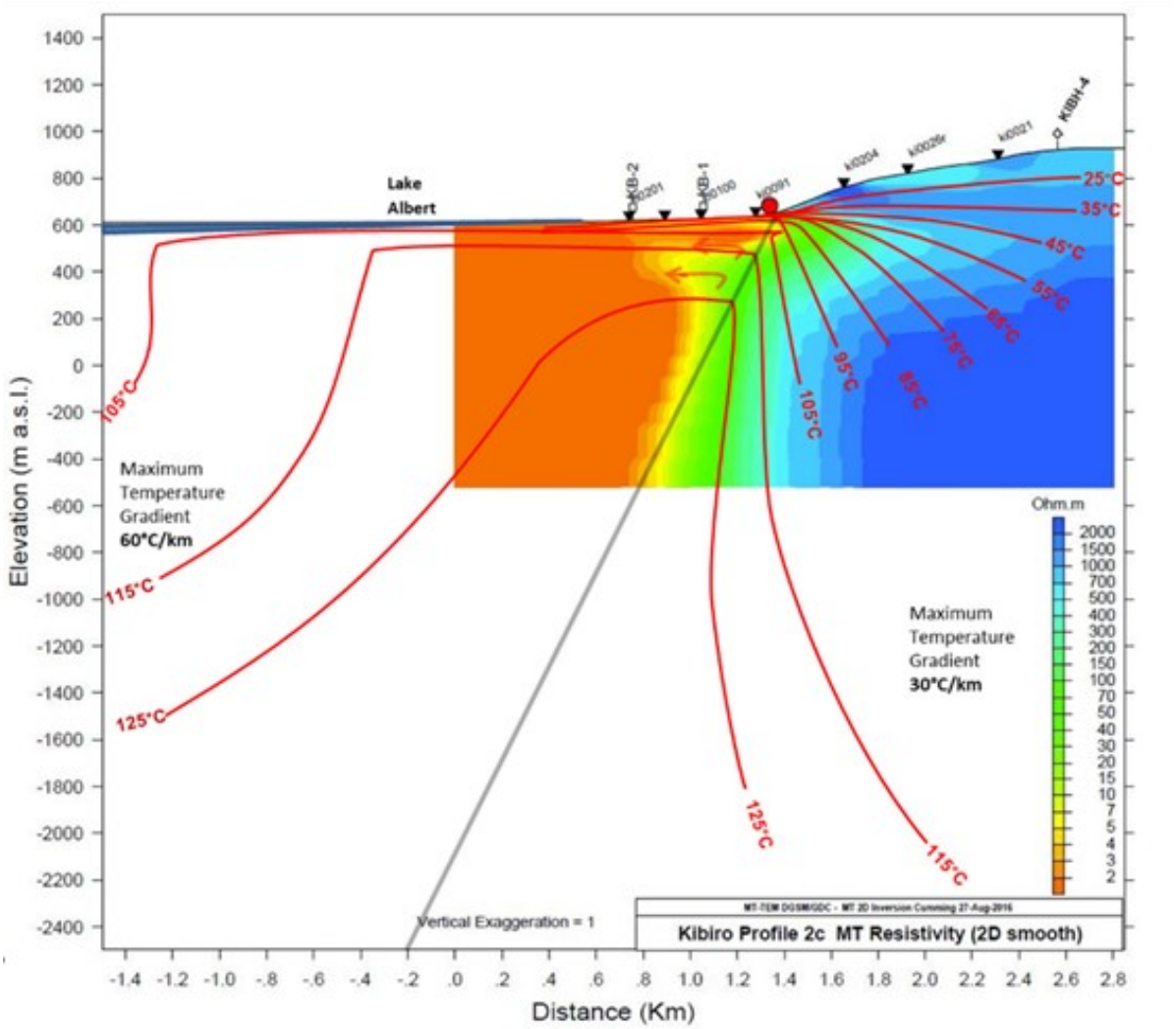


Figure 3: MT Geophysical Conceptual Model for Kibiro with a 65° dipping fault. The purported reservoir is in green/yellow while red is the cap rock shielding the reservoir. ***After EAGER-GRD, 2018.***

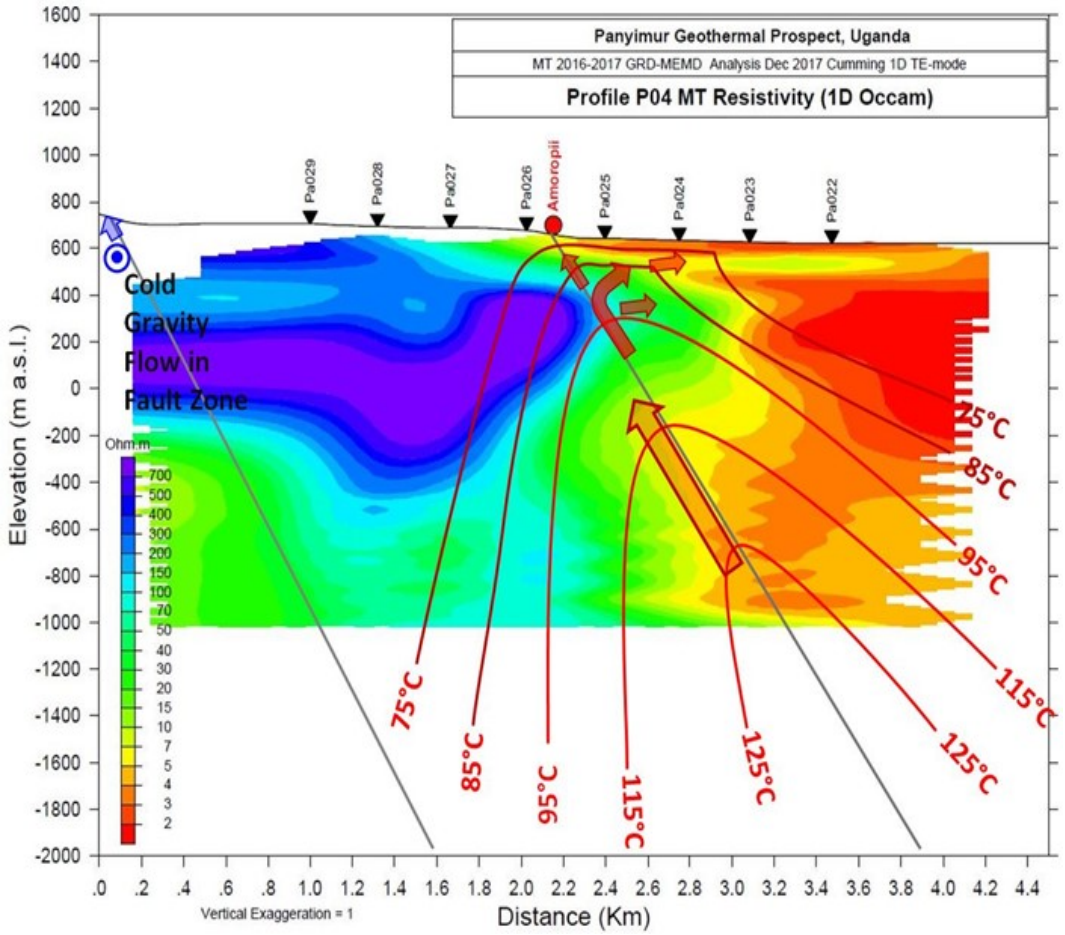


Figure 4: Conceptual model through Amoropii hot springs in Panyimur. ***After EAGER-GRD, 2018.***

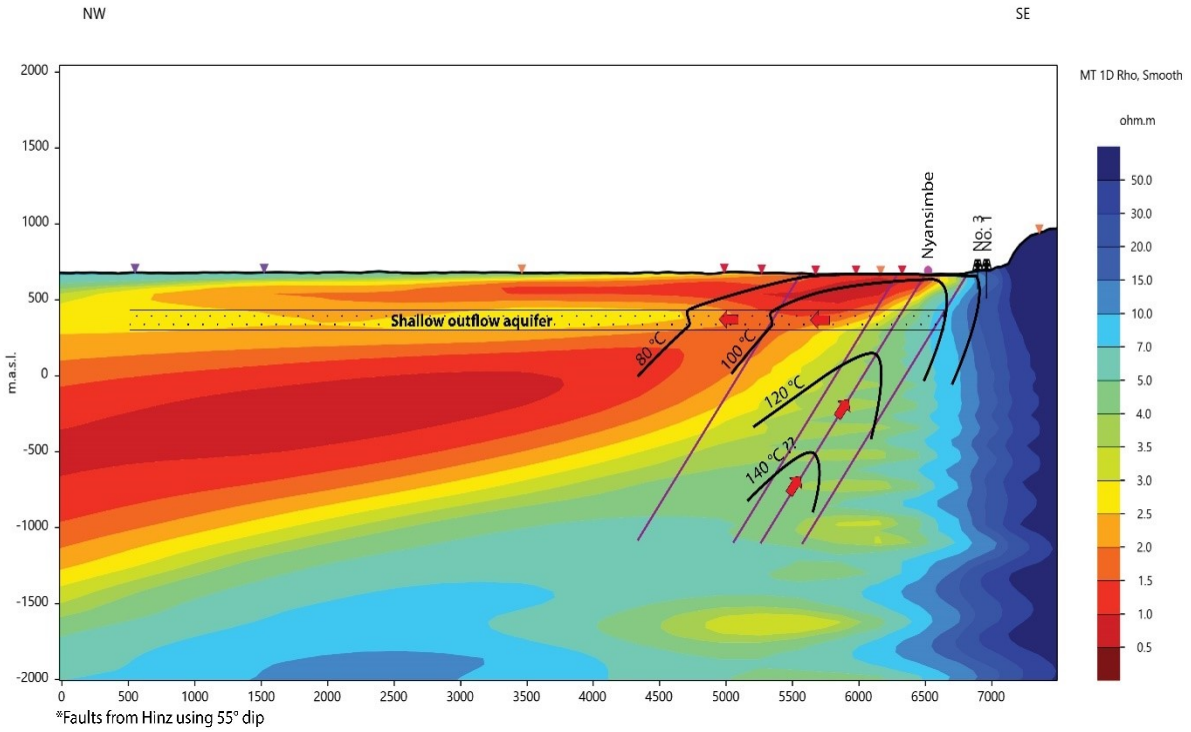


Figure 5: MT Geophysical Conceptual Model for Buranga. After Sewell et al., 2021.

The models were used to site Temperature Gradient Holes (TGH) at the three prospects. Drilling of eight TGH was completed in March 2020 at Kibiro and another eight TGH in July 2022 at Panyimur. Temperature gradient calculated was between 70°C and 350°C/km, which is above the global average of 30°C/km. This suggests the presence of a heat source in the subsurface at Kibiro. The results shall be used to update the conceptual models for Kibiro and Panyimur prospects. The conceptual model(s) and resource assessment will be updated to support targeting deeper slim holes or fully-sized exploration wells.

4. CURRENT GEOTHERMAL UTILIZATION

Geothermal development in Uganda is still at the surface exploration stage, with no geothermal wells drilled yet and therefore the current utilization is limited to the fluid discharges from hot springs. However, the thermal energy oh hot springs has not been yet quantified. Geothermal water is being used as a source of salt at Kibiro and Katwe prospects. At Kibiro 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 therapeutic treatments 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 because of its high salt content. And lastly, hot springs are a tourist attraction.

5. 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 suggest 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 estimated by geothermometry in most of the potential geothermal areas. Estimated temperatures are appropriate 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: Kibiro, Panyimur and Buranga. Conceptual models have been used to locate sites for temperature gradient drilling. Eight Temperature Gradient Holes (TGH) were drilled at Kibiro in 2020 and another eight TGH at Panyimur in 2022. The results 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 by restructuring the Ministry of Energy and Mineral Development in 2014 to focus on exploration, promotion, licensing and management of geothermal resources; (ii) Policy and legislation to promote the development of a geothermal industry; (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) Environmental and Social Impact Assessment at Kibiro and Panyimur geothermal prospects; (vi) creation of a Database to house all geoscience information and data related to the geothermal industry; and (vii) development of Business and Financial models to guide the public and private sector on the most appropriate models to use in specific geothermal prospects.

Private sector participation in geothermal projects is a challenge due to high upfront costs and high geological risk in the upstream stages of geothermal exploration. Other challenges facing geothermal energy development in Uganda include: inability to attract significant financial support from International Development Partners; inadequate data and information to guide decision-making; lack of a skilled workforce capable of maintaining a sustainable geothermal industry; low awareness amongst the public; and limited community participation in geothermal exploration and development. Therefore, it is recommendable that the government take up the exploration and successive stages up to the feasibility study, when the areas can attract private sector investments.

6. FUTURE DEVELOPMENT AND INVESTMENT OPPORTUNITIES

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 exploration wells and two 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; (iii) construct the necessary infrastructure for a local mini grid or for connection to the national grid.

Regarding opportunities, out of the 24 geothermal areas of Uganda, only two, Buranga and Panyigoro, are licensed to the private sector. The remaining areas are still in the hands of the government which is carrying out surface exploration to prepare them for feasibility studies and facilitate the later private sector investment.

The key strategies for fostering investment include: (i) implementing through public private partnerships (PPP), innovative financing mechanisms, including targeted subsidies to stimulate the market penetration of renewable energy technologies; (ii) introduction of specific regimes that favor renewable energy, such as preferential tax treatment, tax exemption and accelerated depreciation; (iii) implementation of innovative risk mitigation mechanisms and credit enhancement instruments, to provide confidence to project lenders.

Business and Financial models to guide the public and private sector players on specific prospects have been developed. The models incorporate the geothermal development process, and tax and investment incentives.

7. ACKNOWLEDGEMENTS

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	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe		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		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	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
Estimated total projected use by 2020	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

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

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

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