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GEOTHERMAL EXPLORATION IN RWANDA: A COUNTRY UPDATE

Uwera Rutagarama
Energy Development Corporation Limited
Rwanda Energy Group
Kigali
RWANDA
urutagarama@edcl.reg.rw

ABSTRACT

Rwanda is steadily making efforts of raising available electricity from current 150MW to 560MW by the year 2018 and increasing electricity access from current 18 percent to 70 percent within the same period. Rwanda has no indigenous fossil fuels and the small hydro resources are almost fully developed. To resolve the increasing demand of electricity and diversify its energy resources, Rwanda has put its focus in developing potential sources from peat, shared hydro sites, methane gas from Lake Kivu and geothermal. Systematic exploration of geothermal resource in Rwanda started in 2006 and consequently to prove the existence of this resource, two exploration wells were drilled in the southern slopes of Karisimbi volcano, one of the four geothermal prospects identified in the country. This paper outlines the background and current status of geothermal exploration including the initiatives and proposed way forward for future exploration and development of geothermal resource in Rwanda.

1. INTRODUCTION

Rwanda is currently confronted with energy supply problem due to rapid growth of population and limited energy resources. Most of the population use wood as their basic energy need leading to an increasingly scares of fuel wood and thus creating deforestation. Biomass dominates as the principal source of primary energy for 85% of the population followed by imported petroleum fuels for 11% dominating the local industries energy supply. In the third level is electricity which account for 4% and is used by 18% of the population.

Overall, the country vision is to ensure universal access to electricity from both grid and off-grid solutions, over the EDPRS II period (Economic Development and Poverty Reduction Strategy). Detailed plans have been developed to spread the electricity network across the country. In tandem with the relocation driven by urbanisation and resettlement policy, this should bring the grid within reach of around 48-50% of the population (Energy Sector Strategic Plan, 2013).

The Strategic Plan (2013-2018) projects electricity demand of 563 MW to be generated from a sustainable generation mix of hydro, methane, geothermal, peat to power and solar to gradually phase out thermal power within two years. The Government of Rwanda plans to achieve additional 408 MW compared to current installed capacity. The present total installed generation capacity available in Rwanda is 155 MWe from hydro, thermal, Solar and Methane gas. The cost of electricity is still high with an average end-user cost at US$ 23 cents/kWh for domestic consumers despite heavy government subsidies. For industrial consumers, the tariff is US$ 29 cents/kWh during peak hours and US$ 16

cents/kWh for off-peak hours under a time-of-use tariff regime. This situation cannot allow a financially sustainable off-taker and discourages investments into the sector. Therefore, to minimize the dependency on energy imports, save foreign currency and create conditions for the provision of safe, reliable, efficient, cost-effective and environmentally appropriate source of energy, geothermal development seems to be one of the long term solutions that could end the current energy crisis.

The development of geothermal energy resources in Rwanda is at early stages compared to some East African countries such as Kenya and Ethiopia. The exploration of this resource really boomed in 2006 with a view of diversifying energy sources for electricity generation and meets the electricity demand in the country. The volcanoes area, the geological context and the hydrothermal manifestations of Rwanda are an indication of the possible existence of potential geothermal systems. Early geothermal investigations (Egbert et al., 2009; Mariita et al., 2010) pointed out the north-west area as a potential for large, high temperature geothermal systems, while the rift in the south-west part of the country along the Lake Kivu is believed to present an environment for low to moderate temperature resources (Demange et al., 1983 and Newell et al., 2006) but these predictions are being reviewed in consideration with the recent exploration drilling results of the Northern part of the country.

The strategy of the Government of Rwanda (GoR) is to know how much geothermal potential is available for the country to meet its energy demand. This step will be implemented by analysing in detail the previous exploration work and identifying the gaps to design a new exploration programme for Rwanda geothermal resources.

2. BACKGROUND ON GEOTHERMAL EXPLORATION

Rwanda is located along the Western branch of the Great Rift Valley. The geothermal potential was estimated at 170-340 MW by the Geothermal Energy Association in 1999 (GEA, 1999). Geothermal investigations in Rwanda started in the 1980's but the existence of geothermal resources in identified geothermal prospects is still to be confirmed. Several reports exist, indicating two areas as prospective zones for geothermal energy; the first zone (Gisenyi, Karisimbi, and Kinigi) in the north-western region associated with volcanoes and the second zone (Bugarama) in the southern region associated with faults in the East African Rift (Figure 1).

Serious investigations on Rwanda geothermal resources started in 2006 with a view of diversifying energy sources for electricity generation and meet the electricity demand in the country. Surface exploration studies to prove the resource have been carried out in several phases:

In 1983, the French Bureau of Geology and Mines (BRGM) identified Gisenyi and Bugarama as potential sites for geothermal energy with estimated reservoir temperatures of over 100°C.

In 2006, Chevron carried out geochemistry studies in the Bugarama and Gisenyi geothermal prospects and estimated the geothermal reservoir temperatures to be more than 150°C.

In 2008, the Germany Institute for Geosciences and Natural Resources (BGR), in collaboration with the Kenya Electricity Generating Company (KenGen), the Icelandic Geo Survey (ISOR) and the Spanish Institute for Technology and Renewable Energies (ITER) carried out surface studies in the Gisenyi, Karisimbi and Kinigi areas. The results from this study concluded that a high temperature geothermal system (>200°C) may exist on the southern slopes of Karisimbi volcano and that a medium temperature geothermal system may exist around Lake Karago (150-200°C).

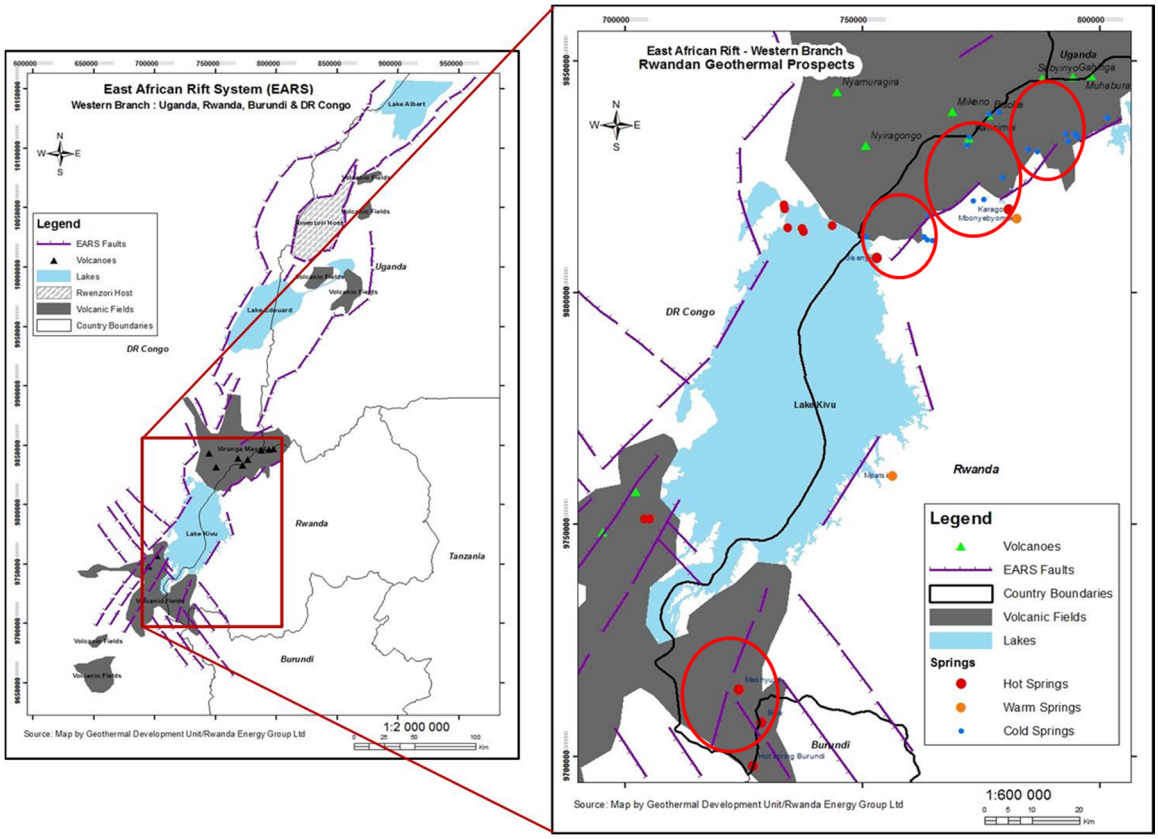

FIGURE 1: Location of Rwanda geothermal prospects (GDU, 2014)

In 2009, KenGen acquired additional surface studies (geochemistry and geophysics) and carried out baseline environmental impact assessment (EIA) on the southern slopes of the Karisimbi Volcano. Findings recommended drilling three exploration wells in the Karisimbi prospect.

In 2011, an additional geothermal survey was done by the Institute of Earth Science and Engineering (IESE) through Auckland UniServices, New Zealand aiming at developing a conceptual model for the entire western region and locating sites for exploration drilling in the three prospects, Karisimbi, Kinigi and Gisenyi.

Workshops were organised in 2012 and 2013 with panel of experts aiming at merging all findings, to come up with one unified model for the Karisimbi area allowing for the definition of the location of sites for exploration drilling in Karisimbi. (EWSA, 2012 and EWSA, 2013)

In 2013-2014, two exploration wells were drilled in the southern slopes of the Karisimbi volcano to 3,015 and 1,367 m depth, respectively. Alteration mineralogy and measured temperatures are consistent with normal continental geothermal gradient (i.e. ~30°C/km) conclusively demonstrating that there is not a geothermal reservoir under the southern slopes of Karisimbi.

Presently, the four geothermal prospects can be ranked as shown in Table 1.

TABLE 1: Exploration status for Rwanda prospect

Geothermal prospects	Reconnaissance study	Detailed survey	Gradient wells	Wells sited	Wells drilled
Karisimbi	yes	yes	no	yes	yes
Kinigi	yes	yes	no	yes (1)	no
Gisenyi	yes	yes	no	yes (1)	no
Bugarama	yes	yes	planned	no	no

3. CURRENT DEVELOPMENT

3.1 Karisimbi geothermal prospect

The Karisimbi area is located near the Karisimbi volcano within the National Volcano Park and Virunga volcanic chain complex. No geothermal manifestations such as fumaroles or alteration have been reported in the Rwandan part in this area. Couple of hot springs are located south and out of the volcanic field with the highest temperature of 64°C at Karago (Figure 2). Detailed surface geo-scientific studies have been completed and two exploration wells drilled.

FIGURE 2: Location of Karisimbi geothermal prospect (ISOR, 2014)

Drilling of three deep exploratory wells was planned and funded by GoR but only two wells (KW01 and KW03 in Figure 3) were drilled. The drilling contractor was Great Wall Drilling Company (GWDC). Drilling materials were supplied by the China Petroleum Development and Technology Corporation (CPTDC). The rehabilitation of the road to the drilling site was carried out by a local company ERGECO and the contract for water supply system to the site and drilling pads was awarded to a Kenyan Company, YASHINOYA limited.

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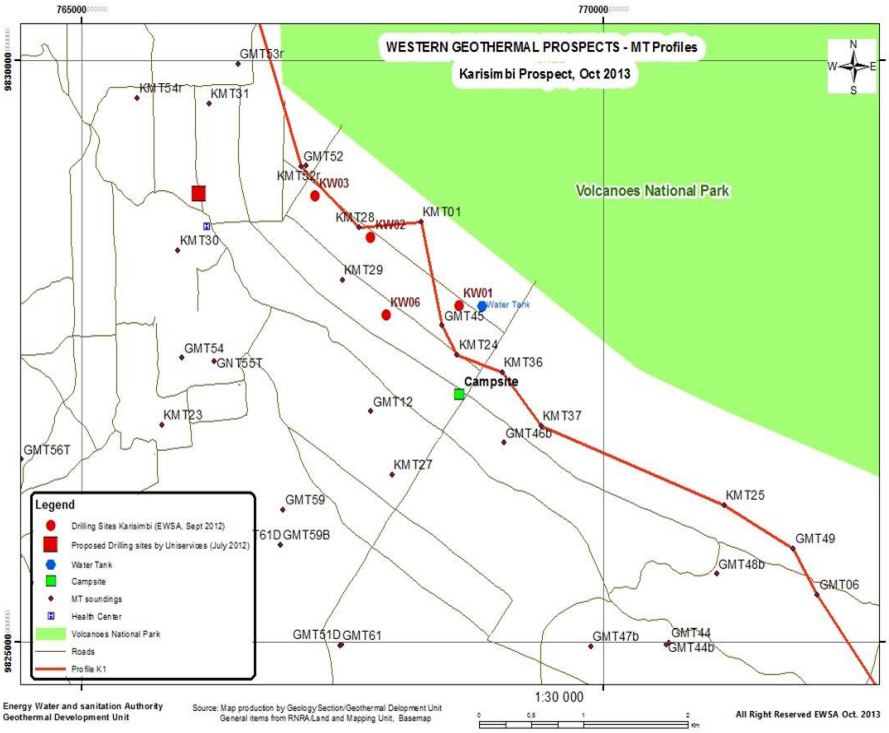

FIGURE 3: Location of drilled wells in Karisimbi prospect (GDU, 2013)

Well testing services were provided by the Geothermal Development Company (GDC) from Kenya. Technical assistance prior to drilling was provided to the Geothermal Development Unit by the Japan International Corporation Agency (JICA). On job training was provided by the Icelandic Geological Survey (ISOR) through funding from the Icelandic Development Agency (ICEIDA). The drilling supervision for the first well was carried out by Reykjavik Geothermal Company (RG) and funded by the Nordic Fund through the Nordic Environment Finance Corporation (NEFCO) while the drilling management and geology supervision of the second well was provided by Geothermal Resources Group (GRG) in collaboration with GDC as drilling supervisor.

Exploration drilling began with the Karisimbi prospect area in July 2013 with the first well KW01 to a depth of 3,015 m and with the second well KW02 on December 2013 to a depth of 1,367 m. From these two wells, there was no evidence of the existence of a geothermal system in the area and this led to the decision of halting the drilling activities on March 22nd, 2014.

The existing geo-scientific data and drilling data have been reviewed by ISOR and JICA and the results of the analysis will be the basis for the elaboration of a new strategy for Rwanda geothermal exploration and development

3.2 Kinigi geothermal prospect

The Kinigi geothermal area is located to the east of Karisimbi (Figure 1). Detailed surface studies as well as Environmental and Social Impact Assessment (ESIA) have been completed. Additional studies are required to decide on the way forward for the exploration of this prospect.

The Government of Rwanda has submitted an Expression of Interest to the Geothermal Risk Mitigation Facility (GRMF) for support in infrastructure and exploration drilling in the prospect. The recent conclusions from the Geothermal Master plan study that is financed by the JICA have indicated Kinigi prospect as the most promising prospect for geothermal exploration.

3.3 Gisenyi geothermal prospect

The Gisenyi geothermal prospect is located south-west of Karisimbi (Figure 1). Hot springs of about 75^{o}C are located in the prospect at the shores of Lake Kivu. Detailed surface studies have been completed. Tender document for additional studies to complement existing geophysical, geological and structural data in the Gisenyi area and to quantify geothermal potential are being prepared and will be funded by the European Union Commission (EU).

3.4 Bugarama geothermal prospect

The Bugarama geothermal prospect is located in the southern province of Rwanda (Figure 1). The geothermal manifestations in this area are hot and warm springs and travertine deposits, which is being mined as feedstock for a nearby cement factory. The highest temperature for the springs is about 55^{o}C. This prospect probably extends into Burundi and the Democratic Republic of Congo.

A regional geothermal exploration study funded by EU has started in November 2013 for the three countries, Democratic Republic of Congo, Burundi and Rwanda. The consultancy firm hired for this project is Reykjavik Geothermal (RG). Great Lakes Energy Agency (EGL) is mandated for the implementation of this regional project. Detailed geo-scientific surveys for the three countries have just been completed in this area. The exploration study shall identify the most feasible site for drilling a deep exploration well.

4. OTHER INITIATIVES

A detailed Geothermal Strategy and Geothermal Act have been developed which will both be formally approved early 2015. The existing geothermal strategy is being reviewed through the support of EU Energy Initiative Partnership Dialogue Facility (EUEI-PDF). This study will consider the existing geothermal data and develop a new strategy for geothermal exploration that will define the approach to private sector involvement in geothermal exploration and development of the country.

Furthermore, JICA is supporting the development of a master plan for geothermal energy development. The study is expected to be finalized in February 2015 and is executed by West Japan Engineering Consultants (West JEC). The master plan will provide potential estimates of each geothermal prospect area and a clear plan of priorities for the exploration of the identified potential sites. Preliminary findings have estimated Rwanda geothermal potential at 47- 90 MW

Technical assistance and capacity building are provided and financed by several institutions; JICA, ICEIDA, the United Nations University Geothermal Training Programme (UNU-GTP), GDC, the African Rift Geothermal Development Facility (ARGeo), EUEI and others.

5. CONCLUSIONS AND RECOMMENDATIONS

Rwanda has very positive indicators of geothermal potential but the resource still need to be confirmed. Four potential geothermal prospects have been identified and two exploration wells were drilled in one prospect, Karisimbi. There is however need to carry out a thorough assessment of the data to minimise the risks of sinking unproductive wells. A criterion for sitting wells therefore needs to be established.

Existing data need to be reviewed in order to define a clear way forward and strategy for future geothermal exploration in Rwanda. A careful approach will be utilised in the exploration program to increase the success rates in future. The western branch of the Rift needs to be deeply investigated to

understand the geothermal system of this part of the rift. This will help in designing an appropriate strategy for geothermal exploration of countries lying along the western rift including Rwanda.

Considering the high risk for exploration drilling, the GoR should involve development partners and potential investors to assist for the exploration and development of Rwanda geothermal resources. Capacity building is required from the first stage of reconnaissance to the implementation of the project. There is a lack of appropriately trained local graduates from Rwandan Universities in some fields related to earth sciences (geology mainly). On job training is needed for young graduate scientists and engineers to understand the steps for geothermal exploration and development. The establishment of a legal and regulatory framework as well as an updated geothermal exploration strategy are urgently required.

REFERENCE

Chevron, 2006: *Preliminary assessment of Rwanda's Geothermal Energy Development Potential*. Report for Government of Rwanda.

Demange, J., Fabriol, R., Rançon, J.Ph. and Verzier, P., 1983: *Reconnaissance Géothermique de la République du Rwanda: Rapport de synthèse*. Bureau de Recherches Géologiques et Minières, Orléans, France, 36 pp.

Egbert, J., Gloaguen R., Wameyo P., Armannsson H., and Perez P .A. H, 2009. *Geothermal Potential Assessment in the Virunga Prospect, Northern Rwanda*. Report – GEOTHERM 1 for the Rwandese Ministry of Infrastructure by Federal Institute of Geosciences and Natural Resources of Germany

Energy Sector Strategic Plan (ESSP), 2013: *Energy Sector Strategic Plan 2013-2018 (ESSP).*

EWSA, 2012: *Proceedings Validation and Peer Review Geothermal Workshop, Kigali, Rwanda 2nd – 4th April, 2012,* 54 pp.

EWSA, 2013: *Data and Final Report Validation Workshop. Golden Hills Hotel, Kigali Rwanda, 9th – 10th January 2013,* 19 pp.

GDU, 2013: *Map of locations of wells, Karisimbi prospects.* Map by Geothermal Development Unit, EWSA.

GDU, 2014: *Location of Rwanda geothermal prospects.* Map by Geothermal Development Unit, Energy Development Corporation Limited.

GEA (Geothermal Energy Association), 1999: *Preliminary report: Geothermal Energy, The potential from clean power to Earth*, Washington DC, USA, 15 pp.

ISOR, 2014: *Geothermal Resources of Rwanda: Assessment of Geoscientific Data and Conceptual Models;* Report prepared for Government of Rwanda

KenGen, 2009: *MT survey of Virunga geothermal prospect, Rwanda*. The Kenya Electricity Generating Company (KenGen), report prepared for the Federal Institute for Geosciences and Natural Resources (BGR), 48 pp.

KenGen, 2010: *Geothermal potential of the Karisimbi Prospect*, Rwanda

Mariita, N.O., Wanjohi, A., Opondo, K., Kemboi, E. and Gachau, E., 2010: *Geothermal Potential Appraisal of Karisimbi Prospect, Rwanda (Combined Report),* 178 pp. incl. appendixes.