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Geothermal Development in Rwanda: An Alternative to the Energy Crisis

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ABSTRACT

The electrical energy in Rwanda is currently predominantly on diesel generation (60%) followed by hydropower (40%) as consequence of low rainfall and an increasing demand for electricity. The high prices of oil are putting a strain on the national budget and constitute presently a serious hurdle to the economic growth for a landlocked developing country such as Rwanda

Consequently, 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 the long term solution to this problem.

Rwanda is believed to have a geothermal potential which is estimated to be in excess of 300 MW and it presents a huge number of high, medium and low enthalpy geothermal zones of interest. The exploration of geothermal energy in Rwanda is still at an early stage.

Currently, the country is evaluating its high and medium enthalpy geothermal resources and the preliminary results from geology, geochemical data analyses and geophysical measurements indicate that medium to high temperature geothermal systems exist in the North-Western part of the country and possibility of drilling into a high temperature geothermal reservoir is high.

This paper gives an overview of Rwanda energy sector and presents the geothermal development update of the country.

1. INTRODUCTION

The Republic of Rwanda is a small landlocked country in east central Africa along the Western branch of the Great Rift Valley. The country is bordered by Tanzania (East), Uganda (North), Burundi (South) and the Democratic Republic of Congo (West) (Fig.1). The total area of the country is 26,338 km2 with a population of 9 million of inhabitants. Ninety percent of the population lives in rural areas with approximately one million people living in the capital city, Kigali.About 60% of the electricity production in Rwanda depends on imported diesel fuels and the electricity access to the population is only 6%.

The Government of Rwanda has set in its Economic Development and Poverty Reduction Strategy (EDPRS) the target to increase the electricity access rate to 16% by the year 2012, and by 35% by the year 2020. To reach these ambitious targets, the energy supply will be derived from all possible sources of energy available in Rwanda such as Hydropower, Lake Kivu Methane Gas, Geothermal, Solar, Wind, etc.

Rwanda is believed to have a potential for geothermal resources and this is proven by the surfaces manifestations discovered in the north-west and south west regions of the country. Currently, the Government of Rwanda is seriously assessing possibilities of using geothermal energy as the available data indicates a significant potential in this resource that could end the energy crisis and provide 100 percent of the electricity needs in Rwanda (Geothermal energy association, 1999).

Fig 1: Geographical setting of Rwanda in the regional context (Source Rwanda National Institute of statistics, 2005)

2. GEOLOGICAL BACKGROUND

The East African Rift (EARS) is a continental rift zone that appears to be a developing divergent tectonic plate boundary. The rift is a narrow zone in which the African Plate is in the process of splitting into two new plates called the Nubian and Somalian subplatesor protoplates. The East African Rift consists of two main branches called the Eastern Rift Valley and the Western Rift Valley.

Rwanda is part of the western arm of the East African Rift System, the Western Rift, also called the Albertine Rift (Fig. 2). The Western Rift is border by some of the highest mountains in Africa, including the Virunga Mountains, Mitumba Mountains, and Ruwenzori Range. It contains the Rift Valley lakes, which include some of the deepest lakes in the world (up to 1.470 m deep at Lake Tanganyika). Lake Victoria, the second largest area freshwater lake in the world, is considered part of the Rift Valley system although it actually lies between the two branches. All of the African Great Lakes were formed as the result of the rifting, and most lie within its rift valley.

The geology of Rwanda is similar to the geology of neighboring Burundi and southern Uganda. It consists into granite, migmatites, gneisses and micaschists of the

Paleoproterozoic Ruzizian basement overlain by the Mesoproterozoic Kibaran Belt. The Kibaran, composed of folded and metamorphosed sediments, mainly schists and quartzites intruded by granites, covers most of Rwanda. Cenozoic to Recent volcanic rocks occur in the northwest and southwest. Some of these volcanoes are highly alkaline and are extensions from the Birunga volcanic area of southwestern Uganda. From radiometric datations of migmatites and gneisses done so far and based on zircon element, the highest age determined was 2060 MY which corresponds to the paroxysm of the ubendian metamorphism (L. Cahen et al, 1984)

Except that area located inside the ubendian insular shelf and both NW and SW tertiary/quaternary lava fields, major geological formations of Rwanda are mid-Proterozoic (Burundian). They have been folded during the Kibaran – Burundian orogeny. Laterite and thick alluvium cover directly overlying the Precambrian rocks. Those Precambrian rocks include a granitic/gneissic basement complex of Paleo - Proterozoic period which is intruded by subsequent granites, pegmatites, metabasics, migmatites and a deformed sequence of meta sediments, which is essentially mid-proterozoic in age.

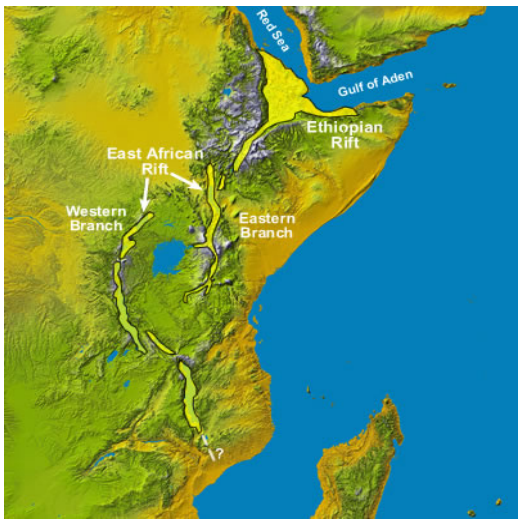

Fig 2: East African Rift system

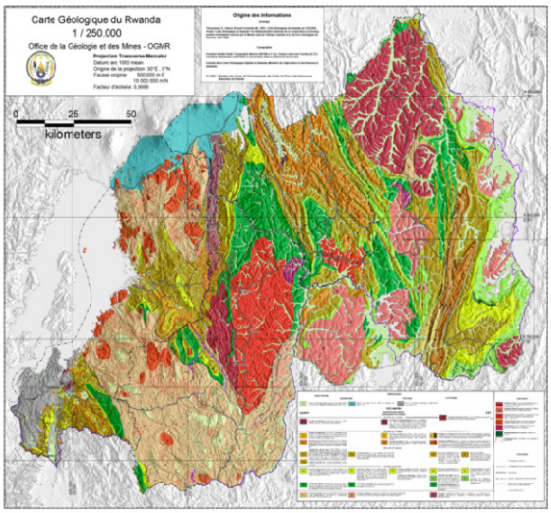

Fig 3: Geological Map of Rwanda 1/250 000 (OGMR, 2008)

3. ENERGY STATUS

Rwanda is currently confronted to an energy supply problem. 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 90% of the population. Imported petroleum fuels on the other hand dominate the local industries energy supply. In the third level is electricity, which is used by only 6% of the population. Production of electricity in Rwanda was mainly from hydro resources but since 2004, the capacity of hydroelectric power plant has lowered significantly as a consequence of low reservoir levels. Thermal power is currently use to ensure stable power supply and constitutes half of the electricity production in the country. This situation is regarded by the Government of Rwanda as a short-term solution, since importation of fuel puts a further strain on the national budget.

Rwanda has currently an installed total electricity generating capacity of 72.5 MW however only 54.6 MW is consumed. The bulk of the capacity is derived from hydro (20 MW domestic, 11.5 MW imported) and thermal plant (22.8 MW), with only 0.33 MW from micro- hydro and solar sources (0.6% of the total). This capacity satisfies slightly less than half the national demand, the total available power is still very low with a peak load of about 100 MW (Table 1). The average cost of electricity for domestic consumers is about 0.22 US$ per Kilowatt hour. This high cost is principally due to use of expensive imported diesel fuel to feed the thermal plants.

Given the dependency on the oil imports and in the line of long term development of the country, the Government of Rwanda has set ambitious targets for extending electricity access under the Economic Development and Poverty Reduction Strategy (EDPRS). The EDPRS which covers the period 2008-2012 is the medium term programmatic framework for achieving the country's long term development aspirations as embodied in Rwanda Vision 2020, as well as the intermediate targets in the 2015 Millennium Development Goals (MDGs). In the targets, the Government of Rwanda has planned to increase the electricity access rate to 16% by the year 2012, and by 35% by the year 2020. The energy supply will be derived from all possible sources of energy in Rwanda.

To reach those targets, the Government of Rwanda has elaborated the national energy strategy and policy.

The national energy policy contains policy statements on issues such as energy pricing and subsidies, energy sector governance and regulation, and the financing of energy sector investments. The policy also contains a separate policy statement on the electricity sub-sector, which confirms the policy commitment to enhancing access to electricity, particularly in rural areas.

The national energy strategy sets out how the energy transition in Rwanda will be achieved given the macroeconomic impacts of consuming more petroleum products and electricity. The strategy highlights that the Government's priorities to develop a knowledge-based economy and exploit indigenous energy resources will help to ensure that modern energy consumption is consistent with sustainable increases in national income levels.

Rwanda has a large range of renewable resources that can improve its energy situation, such as geothermal energy, solar energy, wind energy, micro hydro and methane gas. Currently two big hydro projects are being developed by the Government of Rwanda, Rukarara 9.5MW and Nyabarongo 27.5 MW. The methane gas project is expected to deliver more electricity by the year 2010 (30-350 MW). Studies for micro hydro and geothermal projects are being carried out.

Therefore, the priority of the Government of Rwanda is presently to develop other indigenous energy resources of the country in order to meet the increasing energy demand and reduce polluting thermal stations.

Table 1: Rwanda electricity situation

Category	Name	Installed Capacity (in MW)	Available Capacity (in MW)
In house Hydro Power	Ntaruka	11.75	6
	Mukungwa	12.5	11
	Gihira	1.8	1.8
	Gisenyi	1.2	1.2
Imported Hydro Power	Rusizi 1 (SNEL)	3.5	3.5
	Rusizi 2 (SENELAC)	12	8
Micro Hydro Power	Nyamyotsi	0.075	0.075
In house Thermal Power	Jabana	7.8	7.8
	Gatsata2	4.77	0
	Gatsata1	1.8	0
Rental Thermal Power	Aggreko 1 (Gikondo)	10	10
	Aggreko 2 (Mukungwa)	5	5
Solar Power	Kigali Solar	0.25	0.25
Total		**72.445**	**54.625**

4. GEOTHERMAL POTENTIAL

The geothermal potential of Rwanda is estimated between 170 and 300 MW (Geothermal Energy Associates, 1999). Rwanda hosts two prospective areas for geothermal potential; the Volcanoes National Park and the faults associated with the Western Branch of the East African Rift near the Lake Kivu. Following preliminary reconnaissance studies (BRGM, 1982), three important zones presenting a geothermal potential interest for electricity production can be selected:

- The National Volcanoes zone in the Northern part of Kivu Lake with the eight big volcanic structures. Five of them are situated in Rwanda (Muhabura-Gahinga-Sabyinyo-Bisoke-Karisimbi) (Fig. 4).
- The Cyangugu Zone in the Southern part of Kivu Lake. It is situated in the Eastern part of the Graben. The hydrothermal manifestations (hot springs and the travertine deposit) are linked to this type of structure (Fig.5).
- Hot springs of Gisenyi (Fig.6)

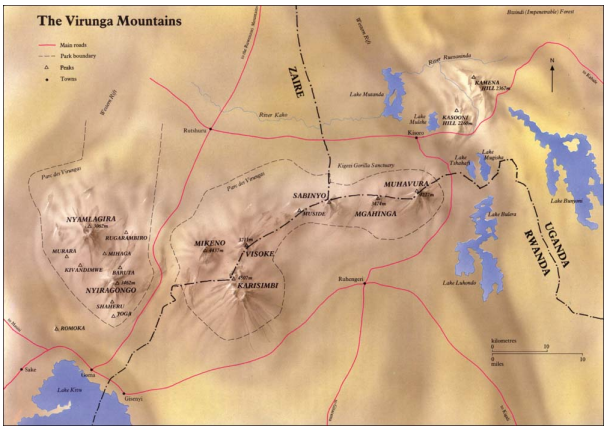

Fig. 4: Rwanda volcanoes in National Park

Fig. 5: Thermal area in Mashyuza (Temperature: 54°C)

Fig. 6: Thermal area in Gisenyi (Temperature: 74°C)

5. GEOTHERMAL DEVELOPMENT

5.1 History

Rwanda does not have a long history of geothermal resources development. Geothermal exploration started in 1982 with the French Bureau of geology and mining research (BRGM). Reconnaissance missions and limited surface exploration works with a focus on hydro geological data collection were carried out in the Western, Northern and Southern parts of the country. Eighteen hydrothermal springs of the country were identified and analyzed for the study (Fig. 7). The hottest spring was located at the NE shores of the Lake Kivu.

The major areas which have been investigated in the country are:

- In the Western province, Mashyuza (Rusizi district), Gisenyi (Rubavu district) and Kibuye (Karongi district);
- In the Southern province, Ntaresi (Karaba district);
- In the Northern Province (Musanze district)

According to existing studies, most favorable conditions appear to exist in N-W of the country, in the vicinity of the National volcanoes Park. Additionally to the W-E ranging volcanic system between Rwanda, DRC and Uganda, the Cyangugu area also hosts a geothermal system with surface manifestations.

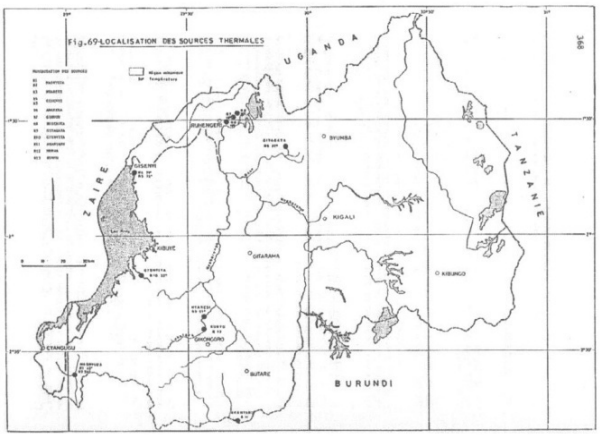

Fig. 7: Location of hot and/or mineralized springs in Rwanda (BRGM, 1982)

In 2006, serious initiative to begin developing geothermal project started in the country. Preliminary assessment of two geothermal prospects (Gisenyi and Mashyuza) was carried out by the American company Chevron and it indicated that the reservoir temperature of the Gisenyi hot springs could be between 150°C and 210°C

5.2 Present exploration

In November 2007, an Implementation agreement concerning the technical cooperation project "Geothermal Potential Assessment and Capacity Building in Rwanda" between the Germany Federal Institute of Geosciences and Natural Resources (BGR), the Ministry of Infrastructure and the Ministry of Natural Resources both Rwandan ministries.

A selection of one of the two prospective areas was done for detailed surface exploration and the area from Gisenyi to the volcanoes was therefore investigated within the project.

Geological surveys (remote sensing), geochemical sampling (water and soil gas analysis) as well as geophysical measurements (magneto telluric MT and Transient electromagnetic TEM) were carried out.

Detailed temperature and gas (CO2 flux, Radon, etc.) surveys with the objective to get information on the temperature distribution and degassing processes within the study area was also conducted.

Preliminary results indicated a low resistivity anomaly and there is a possibility of the existence of medium to high temperature geothermal system(s) of more than 210°C on the southern slopes of Karisimbi volcano in Rwanda and of a medium temperature geothermal system(s) probably exist along the NE trending accommodation zone west of Mukamira. (MT survey of Virunga Geothermal Prospect, Rwanda; Kenya electricity Generating Company).

Detailed surveys are recommended in the area where anomalies were detected and exploratory drilling is planned to start by 2010.

6. FUTURE DEVELOPMENT

Detailed assessment of Rwanda geothermal resources is urgently needed in order to properly evaluate the country geothermal prospects. It is in that view that the Government of Rwanda is currently working with the German Federal Institute for Geosciences and Natural Resources (BGR) for the geothermal resource assessment and capacity building in the Northern part of the country. The exploration drilling is planned for 2010.

Surface exploration of the SW geothermal field of the country is planned to start end of year 2009.

The Government of Rwanda has in parallel started to develop the geothermal capability within the country. Successful contacts were made with the United Nations University Geothermal Training Program for its assistance in capacity building of Rwandans and three Rwandans have been trained for six months in the UNU-GTP those last two years, 2008 and 2009.

7. CONCLUSION

Given the frequent drought that affect the national hydropower, fluctuations in fossil fuel prices in the world and the rapid demand for more power, geothermal energy offers an indigenous environmental friendly alternative source of energy for Rwanda. The deficiency in Rwanda geothermal resource development has been due to the availability of cheap hydropower however due to the existing energy context, the development of this resource is now fundamental. The volcanoes area, the geological context and the hydrothermal manifestations of Rwanda indicate the existence of potential geothermal system. The Government of Rwanda in collaboration with its partners has started to carry out investigations of its geothermal resources and build its human capacity within the sector. However, private sector involvement for the development of the Rwanda Geothermal Resources is highly needed.

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APPENDIX – STANDARD COUNTRY UPDATE TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (Methane gas)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2009	0	0	35.3	304.992	31.5	272.16	0	0	1.8	15.552	68.6	592.704
Under construction in December 2009	0	0	0		50	432	0	0	45	388.8	95	820.8
Funds committed, but not yet under construction in December 2009	0	0	0	0	0	0	0	0	100	864	100	864
Total projected use by 2015	15	129.6	0	0	20	172.8	0	0	120	1036.8	155	1339.2

TABLE 7. 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 Progra
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2005	0					
2006	1					
2007	3				1	
2008	2					
2009						
Total	6				1	

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1995-1999	0					
2000-2004	0					
2005-2009	1					