Geothermal Development in Tanzania – A Country Update

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ABSTRACT

Tanzania is endowed with a huge geothermal potential which has not yet been used, and has only been explored to a limited extend. Geothermal power is a reliable, low-cost, environmental friendly, alternative energy supply and an indigenous, renewable energy source, suitable for electricity generation.

The total installation capacity is 1320 MW using hydro, gas and thermal. Currently, the national power system mostly relies on hydropower. A long period of drought between 2003 and 2006 as well as 2009 and 2010 lead to shortfalls in electricity supply from the hydropower stations; thus, the government of Tanzania intends to diversify the country's energy mix and is looking for alternative sources of energy.
The country power generation potential consists of hydro power, Heavy Fuel Oil (HFO), coal, wind energy, solar, sea waves, natural gas, geothermal and biomass. Most of the geothermal sites already identified with hot springs are located in areas transacted by the East African Rift System. Such areas include the northern volcanic provinces of Kilimanjaro, Meru and Ngorongoro and the Rungwe Volcanic Province in southwest Tanzania. In addition, some coastal areas also show surface manifestations of geothermal resources.

In Tanzania, several reconnaissance surveys and a few detailed studies of hot springs and geothermal sites have been carried out since 1949; some of these early studies in geothermal sites included measurements of surface temperature, water and gas flow as well as water and gas analyses of the hot springs. These studies on geothermal energy provide basic information for planning current geothermal projects. In 2006 and 2007, the Ministry of Energy and Minerals (MEM); the Division of Energy in collaboration with the Geological Survey Tanzania (GST) and the Federal Institute for Geosciences and Natural Resources (BGR) of Germany carried out geological, geochemical and geophysical investigations to assess the geothermal prospects as well as to locate a hydrothermal system and potential geothermal reservoirs. The results from the electromagnetic surveys (TEM, MT) conducted, show zones of low resistivity in the Ngozi area, which can possibly be correlated to alteration zones caused by geothermal activity and in turn indicate a potential geothermal reservoir (GEOTHERM, 2006). Further geophysical work was done in 2010 as a continuation of GEOTHERM. 2006.

1. INTRODUCTION

Tanzania is one of the East African countries with characteristics of geothermal energy resources. Most of the identified hot spring sites are located in areas transacted by the East African Rift System (Figure 1). Such areas include the northern volcanic provinces of Kilimanjaro, Meru and Ngorongoro and the Rungwe Volcanic Province in southwest Tanzania (Figure 2). In addition, some coastal areas show geothermal surface manifestations. Hot springs have been mapped in the Rufiji Basin, south of Dar -es – Salaam, Kisaki area in Morogoro region and to the north in the Tanga region. The hot springs in the coastal sedimentary basin are attributed to rifting and intrusions.

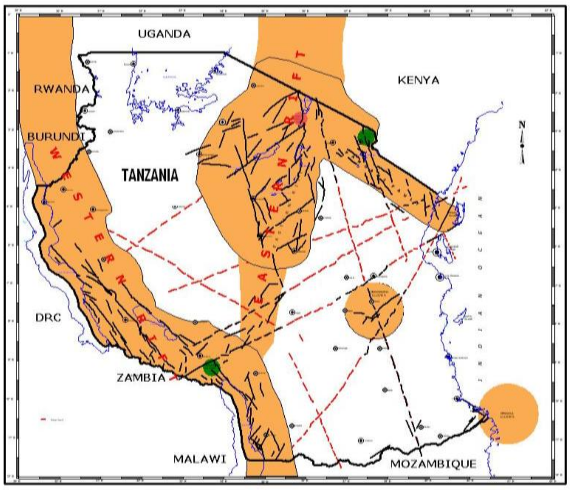

Figure 1: East African Rift System in Tanzania.

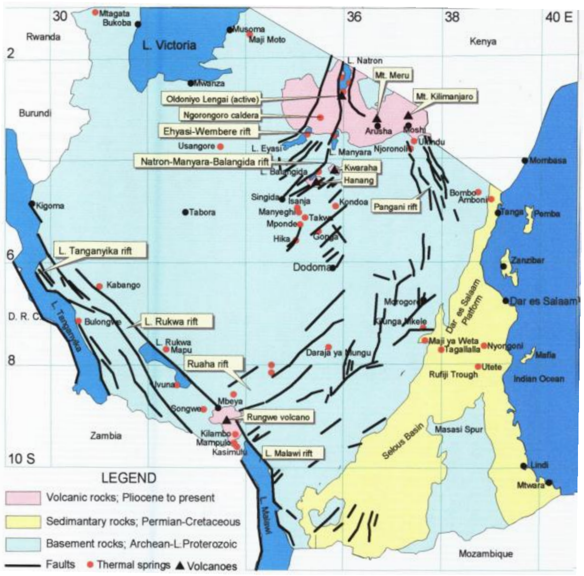

FIGURE 2: Geothermal sites in Tanzania

In Tanzania, several reconnaissance surveys and a few detailed studies on geothermal energy have provided basic information for planning current geothermal projects. Existence of thermal energy is indicated by the presence of hot springs, volcanic activities and geological structures. Hochstein et al. (2000) argue that the geothermal resources of Tanzania appear to be rather small and limited in terms of existing technology. Estimates by McNitt (1982-UNDP), concluded by analogy method, indicate that the geothermal potential of Tanzania could be as high as 650 MW. Based on this result, the potential was refined to be in the order of 140 MW to 380 MW. This value is based on the natural heat flow discharge from hot springs. Provided that geothermal reservoirs do exist, the potential could be even higher. The challenge is to locate the present reservoirs by integrating the geophysical, geochemical and geological techniques.

Despite the fact that Tanzania has an estimated geothermal energy potential; it has not been given due attention in the energy policy of Tanzania until recently, (UNEP, 2003). The geothermal energy (as an alternative energy source for Tanzania) project conducted by MEM, GST and BGR in May and November 2006, and also further work in August 2010 at Lake Ngozi area give promising results for further surveys which might lead to the location of geothermal reservoirs.

The demand for electrical energy which is solely dependant on hydropower, gasoline and gas turbines has been increasing since its first production in 1908 by Germany for railway workshops in the Tanganyika territory. The country experiences long periods of droughts, rising imported oil prices and sedimentary infilling of dams, which hamper its energy security. While it is in an energy crisis, Tanzania is endowed with abundant, inexhaustible and less polluting geothermal potential, which has not yet been explored.

In 2002, about 11% of 34.6 Million people had access to reliable electricity (http://www.tanzania.go.tz/energyf.html). The forecast of the energy peak demand is estimated to increase from 2,540 GWh in year 2000 to 11,548 GWh in year 2026 with a growth from 426 MW in year 2000 to 727 MW in year 2005 and to 1,994 MW in year 2026. In order to overcome the rate of increased demand, a total of 1,053 MW will be required between 2002 and 2021 (Mwihava et al, 2004). DECON, SWECO and Inter-Consult (2005) suggest that geothermal energy amongst others, as an indigenous, environmental friendly, renewable energy source, is suitable for future electricity supply.

2. STATUS OF ELECTRIC PRODUCTION.

The organization responsible for electricity generation, transmission and distribution in Tanzania is known as TANESCO (Tanzania Electric Supply Company). The company is wholly government-owned and is responsible for 98 % of the country's electricity supply. The country's power generation system encompasses the use of hydro, thermal and gas power. Hydropower contributes the most to Tanzania's electrical power generation. The total capacity of hydropower generation is 561 MW.

Tanzania's interconnected grid system has an installed capacity of 1320MW. The largest hydropower complexes are the Mtera and Kidatu Dams and they are situated on the Great Ruaha River. The Mtera Dam is the most important reservoir in the power system providing over-year storage capability. It also regulates the outflows to maintain the water level for the downstream Kidatu Hydropower Plant. Thermal generation in Tanzania currently relies on imported Heavy Fuel Oil (HFO), Jet A (aviation) fuel and diesel.

The installed capacity of the thermal power facilities are: the Tegeta power station which is privately owned and operated by Independent Power Tanzania Limited (IPTL), the Ubungo power station, was owned by TANESCO, but, operated by Songas until its privatization in June 2004. Tanzania also has other thermal generation in isolated areas that are not connected to the grid. It also imports electric power for Kagera Region from Masaka substation in Uganda while Sumbawanga, Tunduma and Mbozi districts receive about 3 MW from neighbouring Zambia. Bulk supply of electricity is made to Zanzibar from Ras Kilomoni substation at the Indian Ocean coast in Dar es Salaam.

There are several diesel generating stations connected to the national grid in Dar es Salaam, Mwanza, Tabora, Dodoma, Musoma and Mbeya. Some regions, districts and townships are dependent on isolated diesel - run generators (Kigoma, Mtwara, Lindi, Njombe, Mafia, Mpanda, Tunduru, Songea, Liwale, Ikwiriri, Masasi and Kilwa Masoko.

Majority of the population that receives electricity live in urban areas. The country faces a major challenge of providing 90% of the remaining population with access to electricity. This requires huge investments, hence the need for both international and local investors to participate in expanding the country's power sector. As the country is becoming more and more focused on providing electrical power, the need for new capacity is increasing rapidly. The country power generation potential consists of hydro power, coal, wind energy, solar, geothermal and biomass, but until today no electricity generation is from geothermal source. There are a number of projects that the country is pursuing in order to maximize its electrical power supply, among which geothermal energy is being considered.

3. GEOTHERMAL EXPLORATION

3.1 Geothermal studies in Tanzania.

In Tanzania, several reconnaissance surveys and a few detailed studies of hot springs and geothermal sites have been carried out since 1949. Some of these early studies are referenced in Walker (1969). A detailed overview and table including the location, temperature, water and gas flow as well as water and gas analyses of the hot springs in Tanzania has been given in the studies carried out. However, the geothermal resource assessment in Tanzania is still limited to preliminary surface studies. These studies on geothermal energy provide basic information on planning current geothermal projects.

Between the years 1976 and 1979 geothermal exploration was carried out under the direction of SWECO, a Swedish consultant group, in cooperation with VIRKIR, Iceland. Financial support was provided by the Swedish International Development Cooperation Agency (SIDA). The objective of the reconnaissance studies was to study the possibility of exploiting geothermal recourses in Tanzania. For this purpose, 50 hot springs mainly in northern Tanzania and in the Mbeya region have been investigated and terms of reference for future investigations elaborated (SWECO 1978). The study included measurement of surface temperatures of hot springs. Tests conducted have indicated high temperature sources in Lake Manyara, Lake Natron, Ngorongoro Crater and the Mbeya region, while lower temperatures were recorded around Lake Eyasi, and the Musoma area (Maji Moto). Based on this study, SWECO recommended further studies on hot springs occurring in the Rungwe Volcanic Province in the Mbeya region, Ngorongoro, and Manyara which appeared to have higher subsurface temperatures compared to the others. The results of the reconnaissance survey carried out by the Swedish Consultant Group (SWECO-VIRKIR, 1978) were favourable, indicating a good possibility of encountering high, intermediate and low temperature reservoirs, in northern and southern Tanzania within the Neogine volcanic areas in the East African rift system.

In 1995, Hochstein et al. (2000) made a reconnaissance study of the major geothermal prospects in Tanzania to assess their geothermal potential and the natural discharge rate, under financial support from TANESCO. Since all the water samples were lost in transit, the authors had to use chemical analyses from SWECO (1978) for their study. From this study it was concluded that the geothermal resources of Tanzania appear to be rather small.

The First Energy Company Limited (FEC, Dar es Salaam) has the license for detailed geothermal exploration and development of the Luhoi Geothermal Prospect in the Lower Rufiji Basin. FEC compiled studies, which are mainly based on results and data from petroleum exploration, to assess the prospect. FEC estimated the geothermal potential at Luhoi to be in the order of 100 MW. The reports and data of the studies are not available yet.

In 2004 and 2005, the Tanzanian Rural Electrification Study (TRES) was conducted by Deutsche Energie-Consult Ingenieurgesellschaft mbH (DECON), a German company, SWECO and Inter-Consult. TANESCO was the implementing institution on the client's side. The African Development Bank (ADB) was the funding organisation of the TRES. In the study, geothermal energy, among others, was regarded as an indigenous, renewable energy source suitable for future electricity supply in Tanzania.

In addition to the SWECO study, a number of other studies have been conducted as shown in Table 1.

TABLE 1: Studies conducted during the period 1976-2010

Year	Institution	Study	Results	Area
1976 to 1979	SWECO through Sida	Reconnaissance exploration	50 hot springs sampled	Lake Natron, Manyara, Utete, Mbeya, Musoma
1983	UNDP funded geothermal mission	Reconnaissance exploration	Mbeya considered a good prospect	South Mbeya
1997 to 2004	First Energy Company Ltd	Reconnaissance Exploration, Power project pre feasibility study	Samples collected and analyzed, good results, (promising site)	Luhoi - Coast region
2004 to 2005	DECON through African Development Bank (ADB)	Rural electrification study Magnetometric, gravity and resistivity surveys	Recommended detailed assessment of Mbeya area.	Lake Natron, Manyara and Mbeya (Songwe, Kasumulo, Mampulo)
2004 to 2005	Regional Consultant for Geothermal in East Africa	Status of geothermal resource development in Tanzania	Recommended further studies on Songwe, Luhoi and Lake Natron	Lake Natron, Songwe River, Luhoi (Coast region)
2006 to 2007	MEM in collaboration with Geological Survey of Tanzania (GST)and Federal Institute for Geosciences and Natural Resources (BGR) German	Reconnaissance study on geophysics method of exploration by using Transient Electro Magnetic (TEM) and Vertical Electric Sounding (VES)	One site for detailed assessment identified	Songwe River and Lake Ngozi in Mbeya region
2010	MEM in collaboration with Geological Survey of Tanzania (GST)and Federal Institute for Geosciences and Natural Resources (BGR) German	Reconnaissance study by using electromagnetic surveys - Transient Electro Magnetic (TEM) and Magnetotellurics (MT).	Low resistive layers encountered in the subsurface	Lake Ngozi area in Mbeya region

In June, 2006 the Ministry of Energy and Minerals; the Division of Energy in collaboration with the Geological Survey Tanzania (GST) and the Federal Institute for Geosciences and Natural Resources (BGR) of German conducted a project on "Geothermal as an alternative Source of Energy for Tanzania". The project is part of the GEOTHERM programme; which is a technical cooperation programme of the German government. It promotes the use of geothermal energy in partner countries by kicking off development at promising sites. Songwe in the Mbeya region has been selected as a project site (Figure 2). The project's aim is to initiate a successive expansion of the geothermal sector in the country.

The objective of the GEOTHERM project in Tanzania is that "Tanzanian institutions move further on evaluating the country's geothermal potential". One project component is planned to prove the existence of a hydrothermal system and to recommend potential locations for a geothermal exploration borehole on the basis of modern geothermal exploration methods in the project area. Other project components include; training Tanzanian experts in acquiring, analysing and interpreting exploration data, thus enabling MEM and GST to continue with geothermal exploration works, dissemination of information about possibilities of geothermal energy use in Tanzania among decision makers and search for funds for shallow drilling in Songwe.

3.2 Methods employed in exploration

Geothermal resource assessment in Tanzania is still limited to preliminary surface studies; that is, geological and geochemical surveys. In 2006 and 2007, MEM, GST and BGR carried out geological, geochemical and geophysical investigation to assess the geothermal prospect as well as to locate a hydrothermal system and potential geothermal reservoirs. Field visits to Songwe (November, 2006) involved the following activities:

- Sampling of rocks and collecting water samples for analyzing cations, anions, noble gases (helium) and carbon dioxide;
- Measuring Total Dissolved Solids, water temperature and conductivity;
- Analyzing geological structures such as fracture, fault and tectonic fissures;
- Exploration by using geophysics methods Transient Electro Magnetic and Vertical Electric Sounding; and
- Finding new geothermal manifestations in the Rungwe area.

Geo-electric Soundings (VES – Schlumberger array) and Transient Electromagnetic (TEM) were the geophysical methods selected. Low resistive layers encountered in the subsurface, together with promising geochemical results indicated possible geothermal activity encouraging further surveys. Due to these first results, later in June/July 2007, and August 2010 ("Geothermal as an alternative Source of Energy for Tanzania" Phase II) additional integrated surveys were carried out and the results have encouraged the project to move further to locate a potential geothermal reservoir. Transient Electromagnetic (TEM) and additional Magnetotellurics (MT) were applied this time.

3.3 Results

The principal objective of geochemical surveys during geothermal exploration is to predict subsurface temperatures, to obtain information on the origin of the geothermal fluid and to understand subsurface flow directions (Arnorsson, 2000a). The conditions for high-enthalpy resources are principally favourable in the Mbeya region due to the presence of active faults - allowing fluid flow, a young volcanic heat source which is sparse in other parts of the western branch of East African Rift System and surface manifestations of hot springs indicating geothermal activity in the subsurface. The geochemical study of hot spring waters in the Mbeya geothermal sites essentially involved three steps, namely: sampling, analysis and data interpretation.

Geophysical signatures were studied in order to demarcate the extent and depth to the reservoir; to ascertain stored anomalous heat, potential usable heat, heat loss and power potential of the study area and to develop a model, which will form a basis for the prospect model to be refined during drilling and exploitation.

3.3.1 Geochemical Data

The interpretation of thermal fluids is supported by the presentation of data in triangular diagrams, binary plots, and modelling plots. The interpretation of chemical data obtained in the November 2006 field campaign shows waters with low B/Cl ratios, which suggest that they belong to the old hydrothermal system. Some hot springs plots in areas of immature water and others in areas of partially equilibrated water. The detailed information on chemical and geological investigation which comprises the findings of assessment of geothermal sites in Mbeya, including results for fields where investigations were conducted by GEOTHERM during June/July 2007, is in a Technical report (GEOTHERM, 2006).

3.3.2 Geophysical Data

The results from the electromagnetic surveys (TEM, MT) conducted, show zones of low resistivity in the Ngozi area, which can possibly be correlated to alteration zones formed by geothermal activity. This might be an indication of a potential geothermal reservoir (GEOTHERM, 2006). The results and findings from the geophysical surveys and the final report of the GEOTHERM, 2006 suggested a continuation with the project "Geothermal as an alternative Source of Energy for Tanzania" Phase II which was conducted in August 2010.

4. INVESTMENT OPPORTUNITIES.

Tanzania's energy sector today is attracting major interest from companies around the world. The government strongly encourages foreign investment. Major assets in the energy sector include coal reserves, wind energy, solar, gas reserves, and geothermal resource.

Tanzania has introduced new policies creating a highly attractive climate for foreign investment – trade liberalization, financial sector reform, privatization, and special tax incentives.

5. WAY FORWAD

- Additional measurements at sites with promising results have to be performed in order to narrow down the potential location of the geothermal reservoir. Nevertheless, no one method can stand alone. Geology, geochemistry, geophysics and later on drilling must be integrated into a single model to resolve the nature of the subsurface geothermal system.
- A more detailed study should be carried out to prove the commercial viability of geothermal energy and to identify and remove the barriers to the widespread commercial development of geothermal energy in Tanzania.
- To develop a comprehensive institution set up and organizational framework that manages geothermal energy development.
- To assess the existing scientific geothermal resources information and plan for wells drilling.

6. CONCLUSIONS.

- A detailed exploration plan and associated budget is needed for further assessment of the geothermal site(s) with the greatest potential for the near term development of an economically viable power generation project and by doing so to become eligible for risk mitigation programs designed to minimize the financial risk of exploratory drilling.
- Tanzania, among East African countries, has a large potential of geothermal energy, which is significant for exploration and exploitation. Electricity can be produced domestically, thus providing jobs for rural communities and reducing security concerns associated with dependence on firewood or foreign sources of oil.
- So far from the data available, the highest potential for geothermal power exploration is in south-western Tanzania (the Rungwe Volcanics and the Rukwa Basin) while the second highest is at the northern zone (Lake Natron and Arusha - Kilimanjaro area). Developing geothermal renewable energy resources will contribute to a stable and reliable supply of energy and also stable tariffs.

- Training is needed in different kinds of geothermal disciplines to build geothermal capacity in Tanzania and to create awareness on geothermal in the country.

- Appraisal studies and field development should be initialized for more promising sites.

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