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GEOTHERMAL DEVELOPMENT IN TANZANIA – 2023 UPDATE

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ABSTRACT

Tanzania is one of several countries that are favoured by being situated within the East African Rift system. It is endowed with an enormous geothermal potential that has not yet been tapped and has only been explored to a limited extent. It is estimated that Tanzania has a geothermal potential of more than 5000 MWe. Currently, Tanzania's energy mix is supported by natural gas (60.3%), hydro (33.9%), liquid fuel (5.2%), and 0.6% is from biomass. Harnessing the country's geothermal resource will contribute to the country's energy security. Geothermal energy's value as a clean, renewable, baseload, and abundant energy source provides a unique opportunity to support the national future energy needs in terms of achieving universal energy access along a low-carbon economic growth path.

The country's target is to connect to the national grid 200 MWe from geothermal sources and utilize more than 500 MWth for various direct heat applications in agricultural and industrial sectors by 2027. This paper aims to present the status of geothermal energy development in the country, as well as the amelioration of the enabling business environment for geothermal development and utilization.

1. INTRODUCTION

The economic and political changes that are taking place in Tanzania have greatly influenced the way the power industry is developing. The Tanzania Development Vision 2025 has identified the energy sector as one of the driving forces in supporting economic growth and high-quality livelihood as the country transforms into a middle-income and semi-industrialized economy. Currently, the power generation in Tanzania is based on gas and hydropower plants.

Tanzania is endowed with geothermal resources, which presents an opportunity for transformation of its energy sector by diversifying the power generation mix and increasing access to modern energy in a sustainable way while addressing climate change concerns. The geothermal resource of Tanzania is estimated to exceed 5000 MWe, and is expected to contribute 200 MW of electricity to the national grid by 2027 as a short-term target, as well as several megawatts of thermal energy for fuelling other sectors of the economy through direct heat applications.

Over 50 areas with geothermal potential have been identified in the country, occurring in different geological settings. Figure 1 illustrates the geothermal potential areas in Tanzania which are at different development phases. Among the identified potential sites, TGDC has selected five (5) priority projects which are promising for both electricity generation and direct use. These projects are Ngozi, Kiejo-Mbaka, Songwe, Luhoi and Natron.

Initiatives in realization of the initial 200 MWe target, among others, include the implementation of the five flagship geothermal projects, among which four (Ngozi, Songwe, Kiejo-Mbaka and Luhoi) have reached the stage of drilling deep exploratory wells. The following is a summary of each flagship geothermal project.

- The Ngozi project is the foremost geothermal project in the country in terms of development. It is a volcanic geothermal system hosting a high temperature reservoir with estimated temperature of 230±13°C. Resource confirmation drilling is underway where TGDC is currently commissioning the drilling rig and improving infrastructure to support drilling activities.
- The Kiejo-Mbaka project is in the preparatory stage for exploration drilling. TGDC is currently carrying out the procurement of services and materials to support exploration drilling in Kiejo-Mbaka which hosts a medium temperature reservoir of 140-150°C.
- Songwe project is also in the preparatory stage for exploration drilling. TGDC is currently mobilizing funds to undertake exploration drilling in Songwe which hosts a medium temperature geothermal reservoir with temperature <150°C.
- Luhoi project is also in the preparatory stage for exploration drilling. TGDC is currently mobilizing funds to undertake exploration drilling in Luhoi which hosts a low-medium temperature geothermal reservoir with temperature <120°C.
- The Natron project is in the early stage of development. TGDC is currently hiring a consultant to conduct the detailed surface study in Natron.

2. GEOTHERMAL RESOURCES IN TANZANIA

Tanzania is among the countries that are transected by the Eastern Africa Rift System (EARS), which hosts significant geothermal potential. Estimates using the theoretical approach indicate a potential exceeding 5,000 MWe but not yet exploited for commercial use. Most of the geothermal prospects in the country have distinct surface manifestations, mainly hot springs, mud pools, hot grounds, and altered grounds / hydrothermal alteration. The geothermal development efforts in Tanzania are outlined as follows:

- Started in the 1970s with several scientific studies along the EARS that were conducted by the Geological Survey of Tanzania (GST), Swedish Consultants (SWECO, 1978), and Virkir-Orkint Consulting Group.
- Then followed by other studies between the 1980s to 2005 by McNitt (1982), UNEP (1983), Hochstein et al. (2000), FEC (2004), and DECON, SWECO and Inter-Consult (2005). These studies generally identified potential geothermal areas where detailed geoscientific surface explorations should focus. The Rungwe Volcanic Province, SW Tanzania and the Northern Tanzania Volcanic Province were identified as among the prominent sites for further geothermal investigation.
- Between 2005 and 2013, BGR, the then Ministry of Energy and Minerals of Tanzania (MEM), TANESCO, and GST conducted surface explorations (geology, geochemistry and geophysics) in the Mbeya region under the GEOTHERM project (2006-2013) (BGR, 2006; 2013). The study concluded that the Mbeya area has two types of geothermal systems, the high and medium enthalpy geothermal systems to the north and south of Ngozi volcano, respectively.
- In 2015 TGDC in collaboration with GDC-Kenya conducted geological, geochemical and geophysical exploration in Ngozi, and proposed drilling targets following development of resource concept model (GDC, 2015).
- In 2015-2016 UNEP funded a detailed geothermal surface assessment which was conducted by high-level consultants. The main outcomes of this study were: Ngozi and Songwe are separate geothermal systems where Ngozi hosts a high temperature system confined around the Ngozi caldera while Songwe is medium temperature system (Alexander et al., 2016).
- In 2016-2017 detailed surface studies were conducted in Kiejo-Mbaka and Luhoi by ELC. The studies were funded by MFA-Iceland and Iceland Geosurvey (ÍSOR) was the supervising consultant. The studies identified these areas to host significant geothermal resources.

- In 2018-2019 detailed geological and geophysical studies were conducted in Songwe geothermal prospect and concluded that Songwe hosts a structurally controlled geothermal system where the reservoir could be located in the deeper part of the Songwe basin.
- To date, several geoscientific surface studies have been conducted in various potential areas and the results are promising for power generation and direct heat applications. Four prospects have been advanced to a level of confirming the resources as the measure to de-risking the fields for further investments by the Government and the Independent Power Producers (IPPs).

Mainly based on their occurrences, geothermal potential areas in Tanzania are divided into five (5) zones (Figure 1) which are:

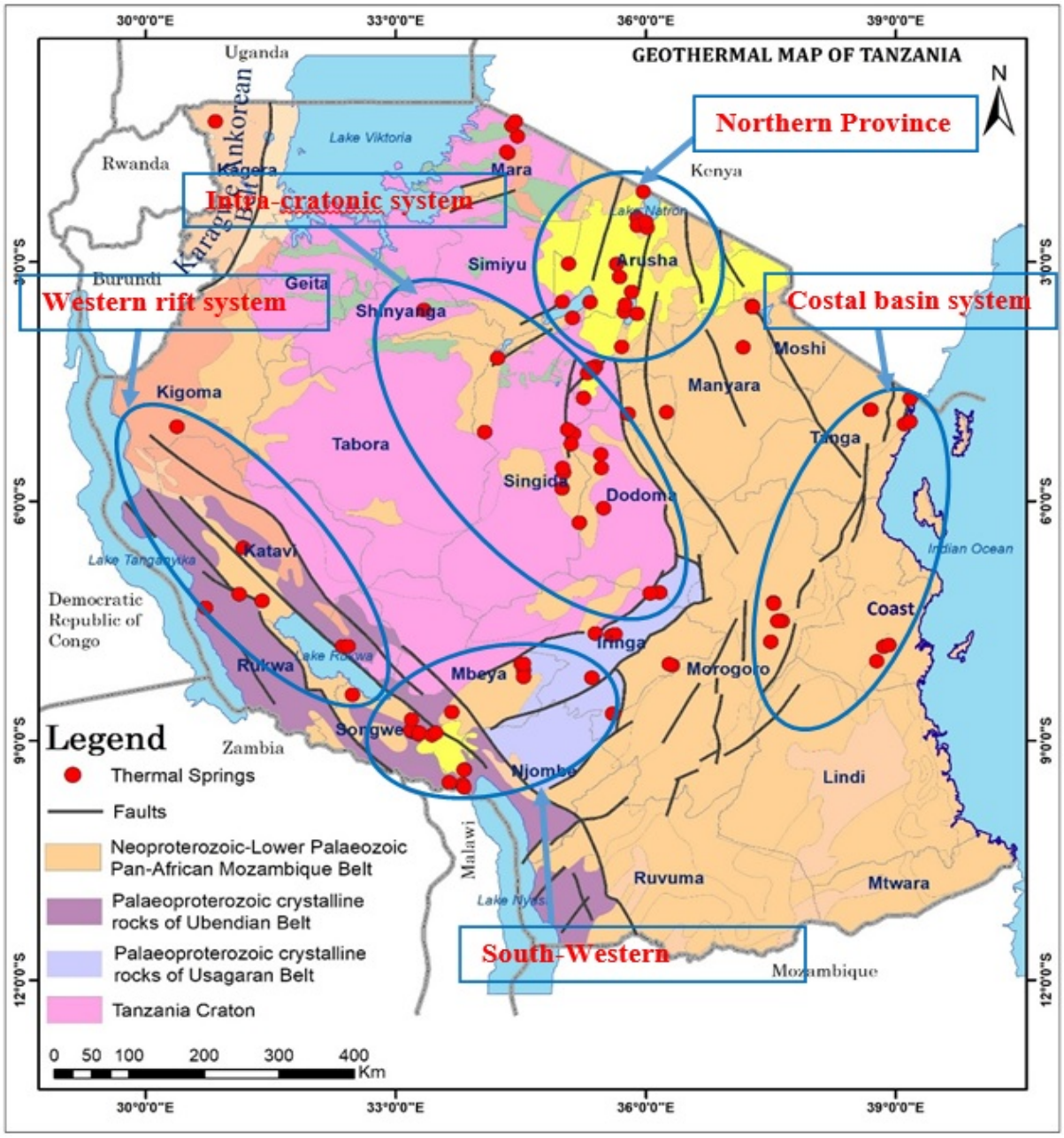

FIGURE 1: A simplified geological map of Tanzania showing the occurrences of geothermal resources in the country

(i) Southwestern Tanzania Volcanic Province: Comprises of geothermal area at the triple intersection of the eastern, western, and southern branches of the EARS. This area is dominated

by the Rungwe Volcanic Province which is characterized by young volcanoes including Ngozi, Rungwe, Tukuyu and several others which probably act as sources of heat for the geothermal systems in the area. The prospects in this province include Ngozi, Songwe, and Kiejo-Mbaka.

(ii) Northern Volcanic Provinces: Located in the eastern branch of the EARS and is both tectonically and volcanically active. This zone hosts a number of prominent young volcanoes including Kilimanjaro, Meru, Gelai, Oldonyo Lengai, Ngorongoro and several others, and is associated with rift spreading. This zone has huge potential for geothermal system resources and the prospects in the area include Eyasi, Natron, Manyara, Ngorongoro and Meru.

(iii) Coastal basin geothermal systems: Include geothermal resources in the costal sedimentary basins which are also associated with the eastern branch of the EARS. These systems could be mainly fault-hosted systems associated with some intrusives. Some of the geothermal prospects in this zone include Kisaki, Tagalala, Mtende, Luhoi, Utete, Bombo, Kidugalo and Amboni.

(iv) Intra-cratonic geothermal systems: Located in the Tanzanian craton, in the central part of the country and extending to the north to around Lake Victoria. These occur in the intra-cratonic rift basins of the Tanzanian craton and they could be fault-hosted, medium-temperature geothermal systems. Such prospects include Mponde, Takwa, Hika, Gonga, Msule, Isanja, Ibadakuli, Balangida, Kondoa, Balangidalalu, Mnanka, Nyamosi and Maji Moto-Mara.

(v) Western rift geothermal systems: Systems occurring in the western branch of the EARS, which is seismically active. These systems are likely structurally controlled without significant contribution of volcanic activities. Some of the geothermal prospects in this zone include Mtagata, Maji moto-Rukwa, Mapu, Ivuna and Rock of Hades.

3. IMPLEMENTATION OF GEOTHERMAL PROJECTS

Out of the over 50 identified potential sites, five (5) flagship geothermal projects have been earmarked as the priority for geothermal development in the country. As stated earlier, these projects are Ngozi, Songwe, Kiejo-Mbaka, Luhoi, and Natron. Four projects (Ngozi, Songwe, Kiejo-Mbaka and Luhoi) have advanced to resource confirmation stage by exploration drilling programme while Natron project is still under the surface exploration stage. The country is mobilizing the resources part of the efforts, among others, to make geothermal development a reality to accelerate socio-economic development. Briefly, the current status of each project is herewith highlighted under the subsections below.

3.1 Ngozi Project – Southwestern Tanzania

The Ngozi project is ranked as one of the most promising fields and therefore stands as a flagship project. It is located within Rungwe Volcanic Province (RVP), southwestern Tanzania, at the triple junction of the eastern, western and southern (Malawi) branches of the Eastern African Rift Valley. The primary geothermal features are thermal water discharges (up to 89°C) at the bottom of the Ngozi caldera lake. The estimated reservoir temperature of the Ngozi field is 232 ± 13°C, which is classified as a high-temperature volcanic system suitable for both power generation and direct heat projects. The project is currently under the exploration drilling phase, which will see TGDC drilling its first three (3) geothermal slim wells.

The exploration drilling program is co-financed by the Government of the United Republic of Tanzania and the Geothermal Risk Mitigation Facility (GRMF). The program implementation is underway whereby the drilling consultant who is responsible for managing the drilling program is already in place. Relevant permits such as the EIA certificate, water rights, and way leave accesses have been granted. Processes for the development of infrastructure (access roads, water supply) are in the final phase.

3.2 Songwe Project - Southwestern Tanzania

Songwe geothermal field is located about 50 km northwest of the Ngozi field. It is characterized by magnificent surface thermal discharges with a maximum recorded discharge temperature in the hot

springs of 82°C. Findings from the geoscientific surface studies suggest that Songwe is a fault-controlled system with a medium temperature resource (112 ± 16°C) (Alexander et al., 2016); hence could be more suitable for binary power plants and direct heat use projects. Because of the natural high flow rate of thermal water in Songwe, several pilot direct heat applications have been developed for demonstration purposes (Figure 2).

FIGURE 2: Photos showing greenhouse and geo-spa at Songwe

Implementation of Songwe project is in the preparatory stage for exploration drilling where TGDC is currently mobilizing funds to undertake exploration drilling. The exploration drilling program in Songwe is co-financed by the Government of the United Republic of Tanzania and the Geothermal Risk Mitigation Facility for Eastern Africa (GRMF).

3.3 Kiejo-Mbaka Project – Southwestern Tanzania

The Kiejo-Mbaka geothermal field is in the southern part of the Rungwe Volcanic Province (RVP), which hosts Ngozi, Rungwe, and Kiejo volcanoes in the southwest of Tanzania. Notable geothermal surface manifestations include hydrothermal alterations and hot springs with recorded temperature of 64°C. It is a medium-temperature system with an estimated reservoir temperature of around 150°C, which is suitable for power generation and direct heat applications.

To increase confidence in the results of the geoscientific surface studies and obtain subsurface data, shallow wells were drilled in 2021. Stratigraphy was obtained to the total drilled depth and currently one of the drilled wells is discharging hot water (Figure 3) at a flow rate of 100 l/s and temperature of 75°C, intersected at a depth of 70 m.

FIGURE 3: Photos showing a successful discharging shallow well drilled at Kiejo-Mbaka geothermal field

Implementation of the Kiejo-Mbaka project is in the preparatory stage for exploration drilling, with TGDC currently procuring the services and materials to support the drilling. The exploration drilling program in Kiejo-Mbaka is co-financed by the Government of the United Republic of Tanzania and the Geothermal Risk Mitigation Facility for Eastern Africa (GRMF).

3.4 Luhoi Project – Eastern Tanzania

The Luhoi geothermal field is in the coastal sedimentary basin on the western shore of the Indian Ocean. It is situated along the southeast extension of the East African Rift System (EARS) in central Tanzania. The prominent geothermal surface manifestation is several hot springs with a maximum measured temperature of 74°C which discharge along the Luhoi River over a stretch of about 600 meters. From the detailed surface exploration conducted in 2017 (ELC, 2017), the results indicated that the Luhoi field hosts a low to medium-temperature geothermal system (95-145°C) and is suitable for direct uses and power generation using binary technology.

TGDC is currently mobilizing funds for the exploration drilling program which is co-financed by the Government of the United Republic of Tanzania and the Geothermal Risk Mitigation Facility for Eastern Africa (GRMF).

3.5 Natron Project – Northern Tanzania

Natron geothermal prospect is in the Northern Tanzania Volcanic Zone, within the eastern arm (Gregorian rift) of the East African Rift System. It is in the southern extension of the Kenyan rift in the Natron-Magadi basin. The prominent surface geothermal manifestations in Natron are the hot springs (Figure 4) and the maximum measured temperature is 53°C. Preliminary surface exploration has been done, and TGDC is currently procuring a consultant to conduct a detailed surface exploration with the aim of confirming the nature of a geothermal system, developing a resource conceptual model, and proposing the locations of the exploration wells.

FIGURE 4: Photo showing geothermal surface manifestations in Natron (left) and Manyara (right) geothermal prospect

4. GEOTHERMAL LEGAL AND REGULATORY ENVIRONMENT

The legal and regulatory environment is among the key enabling factors for sustainable geothermal development and utilization. Geothermal is widely recognized for its advantages and unique characteristics, which differentiate it from other sources of energy, including other renewable sources. These include, among others, resource identification and ownership, accessibilities, investment risks as well as resource uncertainty, which require sufficiently accurate resource assessment and evaluations to

reduce risks and uncertainties. Another unique feature is the inability to access the global market as a commodity in comparison with oil, minerals, and gas.

These unique features require the creation of a suitable legal and regulatory environment for the sustainable development of geothermal resources. The aim is to strike a balance between resource owners' (public) benefits, investment risks, environmental management, and community impacts.

The Government of the United Republic of Tanzania is curretly evaluating alternative options for the geothermal regulatory environment, whether by the enactment of specific geothermal laws or reforming/amending the existing laws to accommodate geothermal resources development and utilization. Among other issues, the legislation is expected to address the current licensing challenges for geothermal resource development and utilization.

5. INVESTMENT OPPORTUNITIES

The country's electricity demand is growing at an average rate of 10 to 15% per annum. This requires significant investment in the power generation, transmission, and distribution systems. In this regard, the development of geothermal resources in Tanzania is crucial for the transformation of the country's energy sector into a balanced, diversified, and sustainable one. The country is also transforming its economy into industrialization which implies that much power demand can be expected. In addition, geothermal can provide heat for various industrial processes. These factors indicate great opportunity in the development of geothermal resources in the country.

The country is currently working on a legal framework to attract investments in the geothermal industry. The Government of Tanzania offers some incentives to strategic investors through the Tanzania Investment Centre (TIC), which is the Primary Government Agency that is responsible for the coordination, encouragement, promotion, and facilitation of investment in Tanzania. The Government recognizes the role of the private sector in bringing about socio-economic development through investments, so the Public-Private Partnership (PPP) frameworks have been developed to provide important instruments for attracting investments.

6. DISCUSSION

There have been significant advancements in geothermal development in Tanzania since the establishment of the dedicated company to spearhead geothermal development in the country, TGDC. Substantial advances have been made in the areas of exploration, direct heat applications, research and innovations, project development, and the establishment of an enabling environment.

TGDC has made significant steps in developing geothermal resources in the country where detailed surface exploration studies have been completed in four (4) priority projects and preparations for exploration drilling are at different stages in different projects. Preliminary exploration studies have also been conducted in several other potential areas. TGDC has obtained relevant permits such as prospecting licenses, environmental certificates, water extraction permits, and way leave access have been obtained, thus providing the rights for infrastructure development (access roads and water supply) for exploration drilling activities.

TGDC has implemented several direct heat application pilot projects for technology testing and demonstration. Pilot projects (geo-spa, greenhouse, fish pond, egg hatchery) have been developed using existing hot water from the natural flow of hot springs in the Songwe prospect area. Thus, Songwe is being developed as a demonstration site for non-electrical geothermal utilization as well as a Geo-Tech Hub.

TGDC is currently assessing the viability of such applications technically, financially, economically, environmentally, and socially for commercialization into large-scale projects. However, scaling up of direct heat use projects is envisaged to be feasible when combined with power generation, i.e. cascading use of geothermal heat.

Innovation is being promoted in the country for the purpose of generating appropriate solutions and technologies that will enable geothermal to contribute to national development by stimulating other sectors of the economy, such as agriculture, animal husbandry, aquaculture, tourism, and recreation.

The significance of establishing a favourable legal and regulatory environment for sustainable geothermal development has been recognized, and various options for improving the environment for geothermal development and utilization are being considered. In order to maximize the benefits of geothermal development, there are deliberate efforts by the Government to develop local capacity in terms of human skills, capacity for the supply of goods and services, and confidence in taking part in the geothermal industry.

7. CONCLUSION

The geothermal development journey in Tanzania has taken a huge milestone since the establishment of the Tanzania Geothermal Development Company. Many achievements have been registered, and many initiatives are ongoing to ensure the realization of the year 2027 target of connecting 200 MWe to the national power grid. The country acknowledges the support and contribution from local, regional, and international stakeholders towards the development and utilization of geothermal resources in Tanzania.

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