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Geothermal Development in Tanzania - a Country Update

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ABSTRACT

Tanzania envisages to achieve middle-income status stipulated in the Tanzania Development Vision (TDV) 2025. The government aims to expedite economic growth mainly through transformation of agricultural and industrial sectors of the economy. To realize this vision, infrastructure and specifically energy has been identified as one of the key ingredients for supporting economic growth through powering social services, industries, major infrastructure, and businesses. Thus, the country is taking transformative measures to ensure availability of adequate, reliable, affordable and environmentally clean energy supply. Harnessing the country's geothermal resource which is estimated to exceed 5000MW will not only contribute to economic development but also ensure increased low carbon economic growth path. The target is to generate at least 200MW from geothermal by year 2025. In order to attain this target, the Government has taken a number of measures including establishment of dedicated Geothermal Development Company (TGDC), mobilization of finance for project implementation, improving enabling business environment, and developing requisite local capabilities to implement projects. Four geothermal prospects namely; Ngozi, Songwe, Kiejo-Mbaka and Luhoi are ready for test drilling to confirm the resource. Mobilization of funds for test drilling is underway. Drilling of shallow wells at Songwe geothermal prospect is set to commence in the fiscal year 2018/2019 and drilling of slim well at Ngozi in fiscal year 2019/2020. This paper presents the progress of geothermal development and lessons learned since ARGEO –C6 in 2016 when the last Tanzania country update was presented. It also presents some important results of the surface exploration studies, geothermal development strategies, mobilization of funds and development of local capacity to implement geothermal projects.

1. Introduction

Tanzania is taking transformative measures to ensure availability of adequate, reliable, affordable and environmentally clean energy supply as a means of developing and modernizing its economy. Tanzania has traditionally depended on hydropower and fossil fuel to generate its power but this generation mix has been unsustainable largely due to persistent and frequent draught spells and fossil price fluctuations. Diversification of the energy portfolio to increase the ratio of renewable energy, especially geothermal sources in the generation mix seems to be viable approach to ensure security of supply.

Apart from electricity generation, the Government understands that geothermal will also offer a number of advantages over other renewable sources such as direct heat use in a multiple of applications and and geothermal by-products.

The Government of Tanzania believes that geothermal resources will not only diversify its power sources but also bring significant cost benefits to energy users in terms of the right energy sources for the right purposes including reductions in emissions. Such purposes could be direct heat uses as aquaculture, agriculture, industrial uses, drying of crops, and for recreational facilities like swimming pools in the respective prospect as it has been the case of other countries which have walked to a greater distance in terms of exploiting direct use opportunities.

This paper presents the current status of geothermal resources development in Tanzania including the level of resource assessment, study results, implementation strategies, investment opportunities, and local capacity development for supporting project implementation.

2. Power Sector Situation in Tanzania

Tanzania is endowed with diverse energy sources most of which are untapped; these include biomass, hydro, uranium, natural gas, coal, geothermal, solar and wind. The current primary energy supply includes biomass (85%) in the form of firewood and charcoal for cooking; petroleum products (9%); electricity (5%), and the remaining (1%) is contributed by coal and other renewable energy sources (NEP, 2015). More than 80% of energy delivered from biomass is consumed in rural areas thus there is heavy dependence on biomass as the main energy source. In 2010, the energy consumption composed of residential (73%); industry (14%); transport (6%); agriculture (4%) and others (3%) (NEP, 2015).

The country's electricity generation, transmission and distribution system is principally Government owned and operated by the Tanzania Electric Supply Company (TANESCO) which is a Public Utility Company. The current electricity generation mix in Tanzania consists of hydropower, natural gas and liquid fuel (HFO and diesel). As of April 2018, total installed generation capacity for the grid system is 1,435.56 MW; grid installed capacity is 1351.1 MW and off-grid plus the imports is 84.46 MW. Hydro power account for 567.7 MW (39.6%), natural gas power plants contributes 782.82 MW (54.5%) and liquid fuel power plants is 70.54 MW (5.2%) , and biomass is 10.5 MW (0.7%) (Figure 1). The imported power is from Uganda (10 MW), Zambia (5 MW) and Kenya (1MW) for cross boarder supply. Independent power producers (IPP) contributes 205.36 MW (16.3%) to the total grid installed capacity.

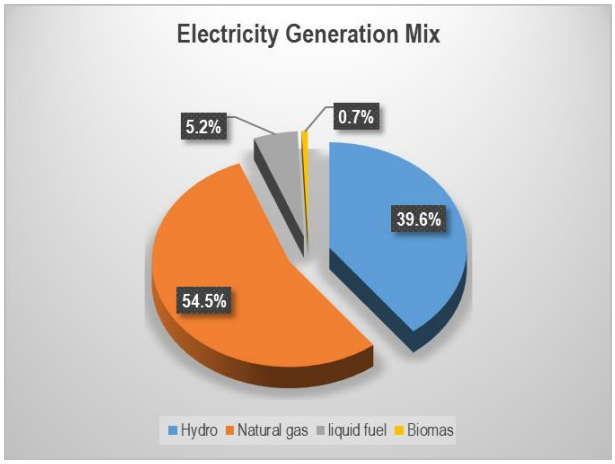

Figure 1: Electricity Generation Mix

The 2016 Energy Access Situation Survey showed that about 67.5 percent of the Tanzania Mainland population had access to grid electricity. The Demand for electricity is growing at a

pace of between 10% and 15% per annum and is forecasted to increase more due to growing energy requirements in transport, mining and industry sectors. The annual electricity consumption per capita is about 133 kWh, but the government vision is to become a middle income country by 2025 with electricity consumption of at least 490kWh/capita (PSMP, 2016). Tanzania aims to increasing connection level to 50% by 2025 and 75% by 2033 using renewable energy generation mix and geothermal energy is one of the target mix.

So far, there is no contribution from geothermal generation, but according PSMP (2016 update), geothermal energy is expected to contribute 200 MW to the national grid by 2025.

3. Geothermal Resources in Tanzania

Tanzania in one of the EARS countries with significant geothermal potential that has not yet been fully utilized. Estimates using theoretical approach indicate a potential exceeding 5,000 MW but not yet exploited neither for power generation nor for commercial direct use applications. Most of geothermal prospects have been identified by their on-surface manifestations, mainly hot springs. Surface assessments started in 1976 and, to date, there are over 50 clusters of hot springs identified in the country occurring in different geological settings which are divided mainly in four zones (Figure 2):

3.1. South-Western Volcanic Province

The south western part of Tanzania is geologically distinct due to presence of the Rungwe Volcanic Province (RVP) which comprise four young volcanoes of Ngozi, Rungwe, Kyejo and Tukuyu. This region is located at the southern triple junction of the East African Rift System (EARS) where the NW-SE Rukwa-Tanganyika rift, the NE-SW Mtera-Ruaha and the N-S Nyasa (Karonga) rift intersect (Fontijn et al., 2010), which is characterized by complex tectonics and volcanism. Some of the geothermal systems in this zone include; Ngozi, Songwe, Kasimulu, Kiejo- Mbaka, Mbarali and Daraja la Mungu. The last documented eruption of Ngozi volcano which is the heat source for Ngozi geothermal system was around 1 ka.

3.2. Northern Volcanic Province

This province is located in the northern part of Tanzania and is characterized by young and active volcanoes. It is situated in the eastern branch of the East Africa Rift System (EARS) just south of the Kenyan Rift. Prominent volcanoes in this area include Kilimanjaro, Meru which last erupted in 1990's while Oldoinyo Lengai is still active. Structurally the area is located at the northern Tanzania divergence which comprise of the N-S trending Natron-Mayara-Balangida which is the dominant neogene rift structure, NE-SW trending Eyasi-Wembere and the NW-SE trending Pangani rift (Hahne, 2017). Considering the high and complex network of structures, the area is highly permeable for fluids migration. Therefore, this zone has a huge potential of geothermal resource. Some of the geothermal systems in this area include Eyasi, Natron, Manyara, Mount Meru and Masware.

3.3. Coastal basin geothermal systems

This zone includes geothermal systems in Morogoro, Costal and Tanga regions. They occur in coastal sedimentary basins of Tanzania and are mainly fault hosted geothermal systems that are possibly associated with magmatic intrusions which act as heat source. Propagation of the eastern branch of EARS extend toward the Kisaki and Tanga areas, so the coastal geothermal systems can also be linked to the eastern branch of EARS. Some of the geothermal prospects

occurring in the Tanzanian coastal sedimentary basins are Kisaki, Tagalala, Mtendde, Luhoi, Utete, Bombo, Kidugalo and Amboni.

3.4. Intra-cratonic geothermal systems

These are geothermal systems located in the Tanzanian craton which occur in the central part of the country and extend to the north to around Lake Victoria. This zone includes all geothermal systems occurring in the intracratonic rift basins of the Tanzanian craton. They are likely fault hosted geothermal systems and are viable for both power production and direct use application. Some of the geothermal prospects in this zone include Mponde, Takwa, Hika, Gonga, Msule, Isanja, Ibadakuli, Balangida, Kondoa, Balangidalalu, Mnanka, Nyamosi and Maji moto-Mara.

3.5. Western rift geothermal systems

These are geothermal systems occurring in the western branch of the EARS. In Tanzania the western branch passes from the north-western, western and the south western part of the country. Some prominent features in the western rift includes Lake Tanganyika which is the deepest lake in Africa. The western rift is more seismically active. Some of the geothermal prospects in the western rift are Mtagata, Maji moto-Rukwa, Mapu, Ivuna and Rock of Hades.

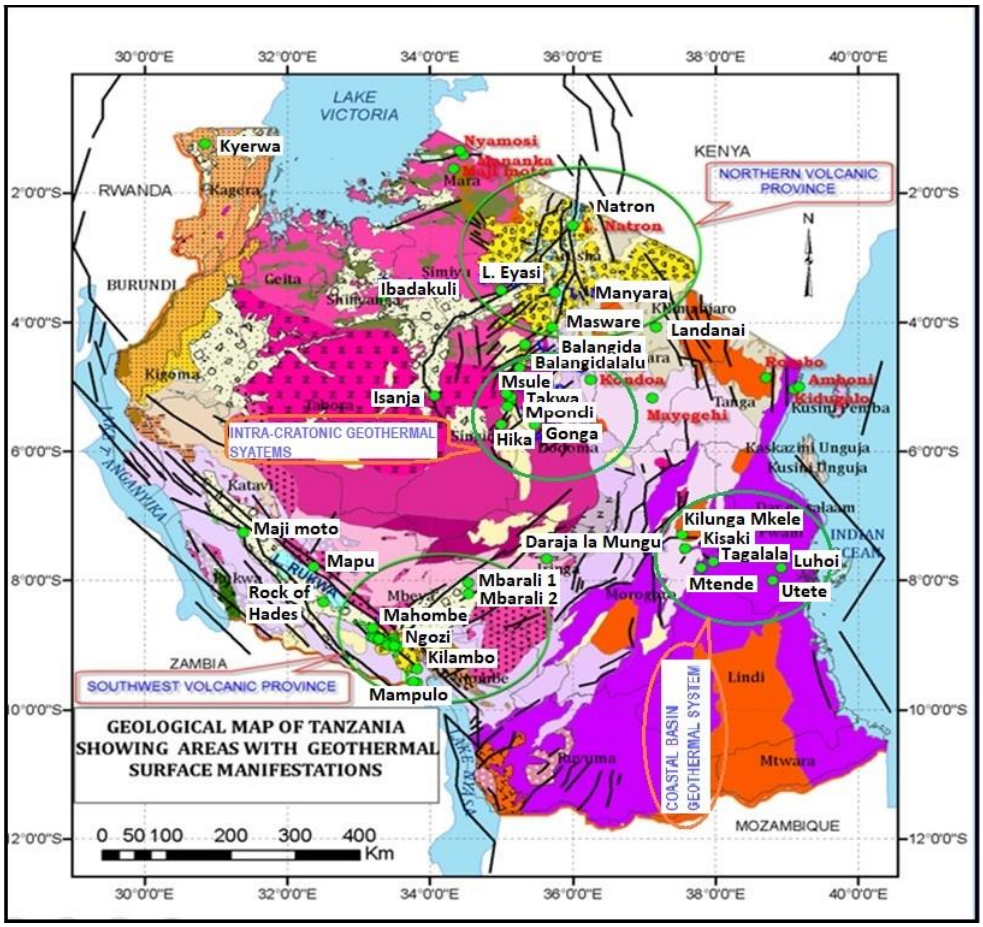

Figure 2: Tanzania geological map showing geothermal occurrence zones.

4. Status of Geothermal Development in Tanzania

Geothermal energy is a clean, indigenous strategic energy resource for supporting development of the country's economic growth. In this respect, the Government of Tanzania formed a dedicated geothermal company Tanzania Geothermal Development Company Ltd (TGDC). The Government through TGDC has already developed a Strategic and Business Plan that will guide the company business decisions, processes and growth for a horizon of 25 years. The country's target is to generate 200MW from geothermal by year 2025 (PSMP, 2016 Update) which is firmly supported by TGDC 25 years Strategic Plan (2017).

The TGDC 25 years Strategic Plan (2017) has identified four (4) flagship projects that will help in achieving the 2025 target (200 MW), namely Ngozi, Songwe, Kiejo-Mbaka and Luhoi. To date, all four (4) flagship prospects ready test drilling to confirm the resources. Mobilization of funds for carrying out of test drilling is underway.

The following section presents detail descriptions, important results of the surface exploration studies, development strategies and current status of each site;

4.1. Ngozi geothermal prospect

Ngozi geothermal prospect is located within the Rungwe Volcanic Province (RVP), southwest Tanzania. The prospect is at the Mbeya triple rift intersection of the Western, Eastern and Southern Branches of the East African Rift System. It has been studied by many workers since 1950's mainly regional geology, geophysical, and geochemistry without going further for geothermal energy exploration (GST, 1958 and Harkin, 1960, DECON, 2005). The Ngozi and Songwe prospects were once believed to be one system and hence combine studied.

GEOTHERM Phase I (2006-09) carried a study in the Mbeya region and concluded that Rungwe and Ngozi are two different systems. Based on that conclusion, GEOTHERM Phase II (2009-13) concentrated on Ngozi only.

TGDC with technical support from UNEP/ARGEO and MFA/ICEIDA has carried out gap filling studies in the area with the intention of defining the geothermal system model and selecting drilling targets to confirm the resource potential and characteristics. The study was completed in September 2016, concluding that Ngozi and Songwe are two distinct systems. For Ngozi prospects, the geothermal reservoir is beneath Ngozi with estimated temperature of 232 ± 13 °C, TDS of 15,800 ± 2300 mg/kg (Na-Cl composition), and a PCO2 of 15 ± 4 bar.

Geologically, the Ngozi is the major eruptive centre of the Rungwe Volcanic Province (RVP). It is characterized by young volcanic deposits of Plio-Pleistocene to Holocene age that are mainly composed of pyroclastics, basalts, phonolites and trachytes. The early phase of volcanism that dates ~12 ka produced mainly phonolites while the second phase lasted <1ka and mainly involved basalts and phonolites/ignimbrites (Fontijn et al., 2012). The later eruption is related to the formation of the Ngozi caldera which is about 2.5 km long and 1.6 km wide with a surface area of 3 km^2. The primary geothermal features are thermal water discharges (up to 89°C) at the bottom of the Ngozi Crater Lake. The heat source is likely a trachytic magma chamber, perhaps 5 to 7 km deep, which was replenished after the Ngozi Tuff eruption less than 1,000 years ago. The reservoir temperature is estimated at 232± 13ºC based on the observed outflow temperature on the lake bed of 89ºC (UNEP/ARGeo 2016). Figure 3 is the possible conceptual model of Ngozi geothermal system.

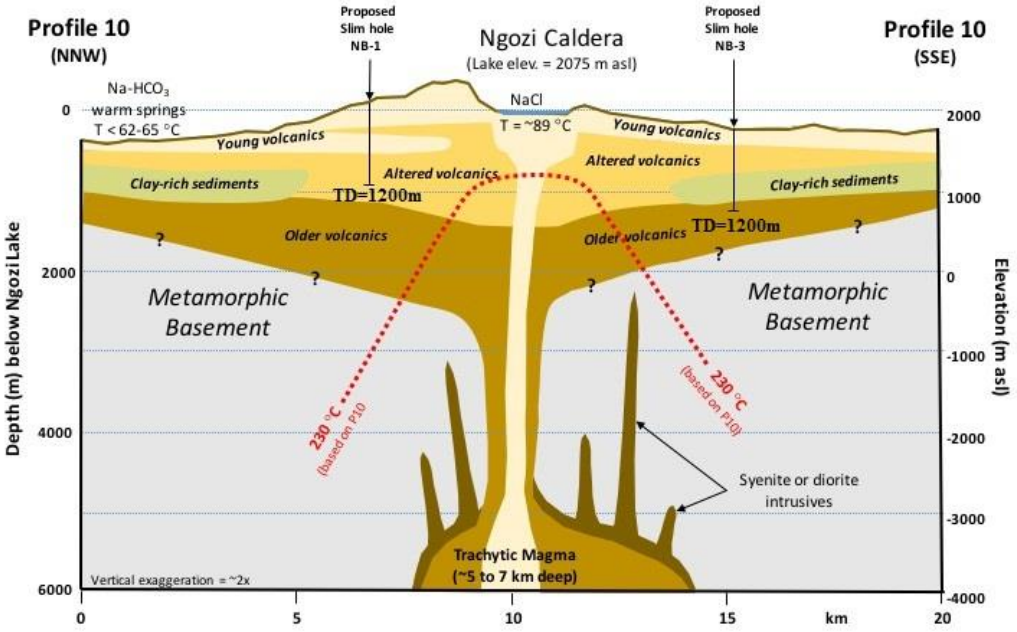

Figure 3: Conceptual model for Ngozi geothermal system.

The study identified five (5) locations for test drilling around Ngozi; TGDC is planning to start with three (3) slim wells drilling in fiscal year 2019/2020. The Geothermal Risk Mitigation Facility (GRMF) has approved co-financing the drilling programme. Currently, procurement process of the drilling consultant is in progress. Environmental permit for test drilling has already been obtained from the Government.

4.2. Kiejo-Mbaka geothermal prospect

Kiejo-Mbaka geothermal prospect is located in the Southern part of the Rungwe Volcanic Province (RVP) which host Ngozi, Rungwe and Kiejo volcanoes in the south west of Tanzania, in Mbeya Region (Figure 4). The prospect is located south of the Mbeya triple junction of the East African Rift System (EARS) where the N-S Nyasa basin split into the NE-SW trending Ruaha-Mtera segment and the NW-SE trending Rukwa-Tanganyika basin (Fontijin et al., 2012). Different studies have been undertaken in the prospect area either for geothermal assessment and/or for general geo-scientific academic researches. The most prominent studies include those by ELC, 2017, Ochman and Garofalo, 2013, Fontijn, et al., 2012, de Moor, et al., 2012, Delalande, et al., 2011 and Ebinger, et al., 1989. The recent study is by (ELC, 2017) which concluded that Kiejo-Mbaka is a medium temperature geothermal system based on both water and gas geothermometric assessments with estimated reservoir temperature around 140 °C. Further, the system is manifested on the surface by hot springs which discharge in the areas of Kilambo, Kajala and Ilwalilo with temperature ranging 59 – 64 °C and are recharged by meteoric water as confirmed by the isotopic studies.

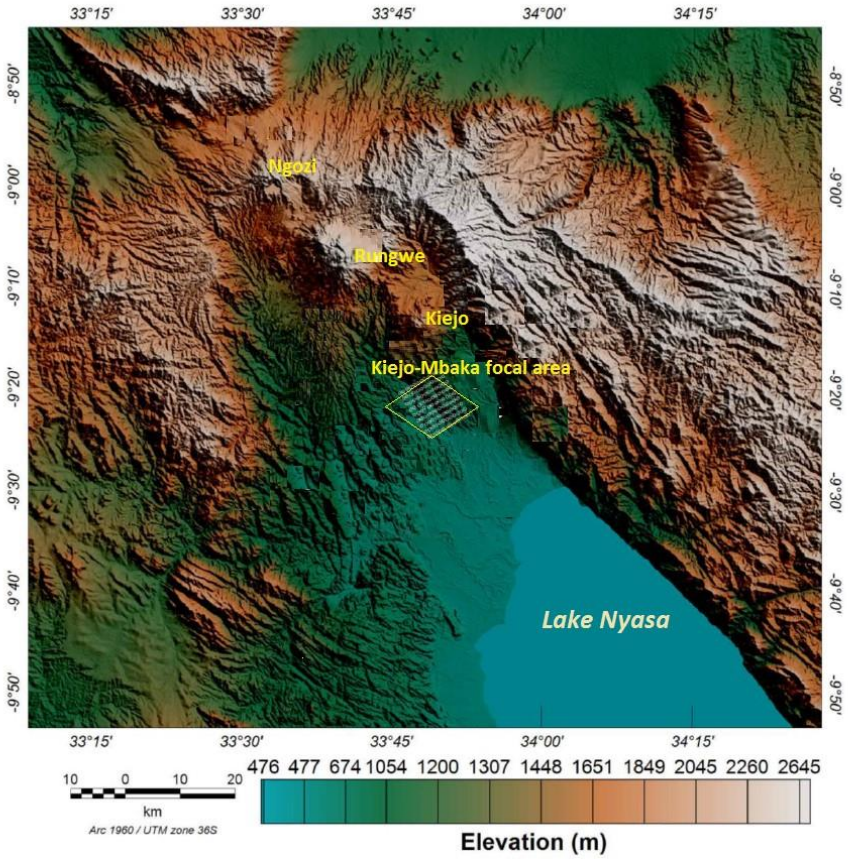

Figure 4: 3D topography view of Kiejo-Mbaka volcano in Rungwe Volcanic Province (RVP)

The study by ELC (2017) has recommend resource confirmation by test drilling and seven (7) possible locations have been identified. TGDC is planning to start with four wells (4), three of them being slim wells and one (1) full size well. The test well drilling programme is planned for in the fiscal year 2019/20. Funds mobilization from different sources for carrying out of test drilling is underway.

4.3. Songwe geothermal prospect

Songwe prospect is located in Songwe Region, just North West of Ngozi prospect. Detailed surface study for this prospect was completed in 2016 by UNEP/ARGeo technical consultants and was carried out together with Ngozi prospect. The study shows that Songwe is a low to medium temperature resource (112 ± 16 ^{0}C) more suitable for direct use applications and binary power plant. The study further recommended to undertake a gap filling study for Songwe prospect to determine appropriate locations and number of wells prior to embarking on test drilling.

TGDC in collaboration with East Africa Geothermal Facility (EAGER) carried out additional gap filling study in in the area between October, 2017 and June 2018. The study recommended Temperature Gradient Holes (TGH) drilling programme comprising fourteen (14) drilling locations to increase the knowledge about the system before undertaking actual test drilling programme for resource confirmation and suitability for direct use applications and power generation (Figure 5).

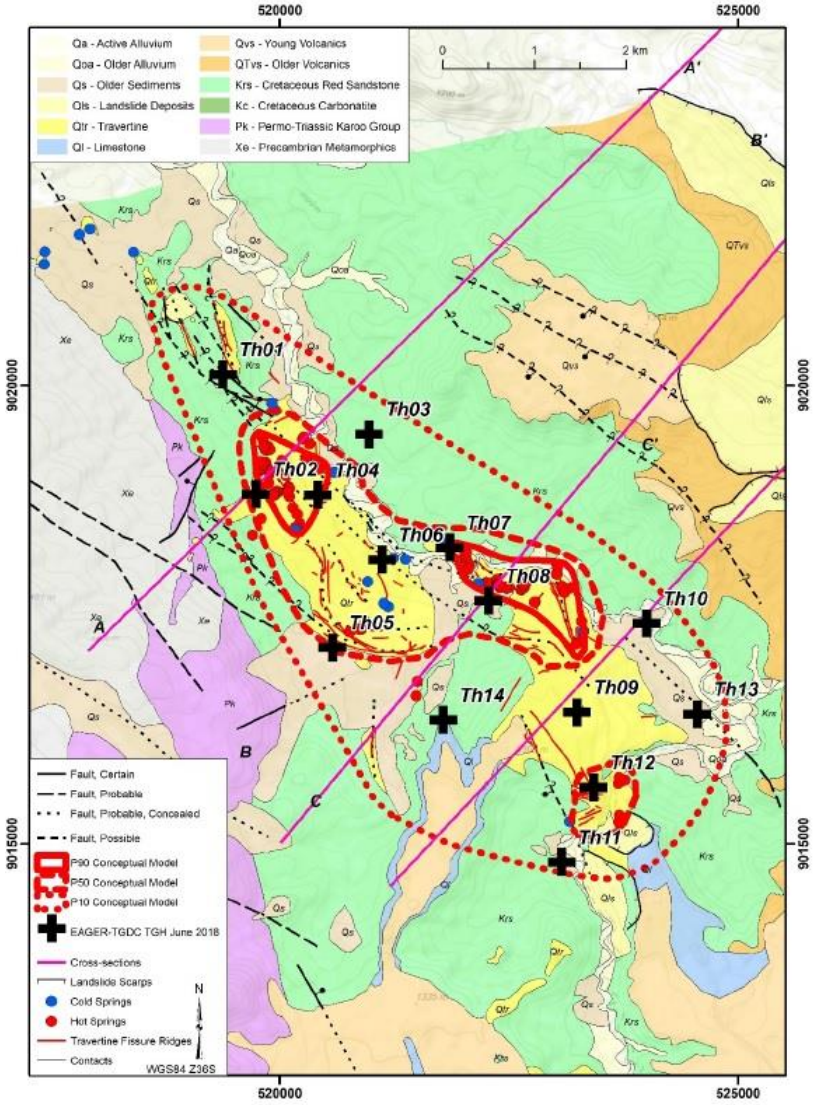

Figure 5: Map showing Songwe conceptual model and TGH locations.

TGDC in collaboration with EAGER has conducted a pre-feasibility study for direct uses applications for Songwe prospect. The study shows that the prospect is suitable for a number of multi direct utilization mini projects such as aquaculture, drying agricultural crops, and recreational (tourism). With consideration that Songwe region is famous in agricultural activities like growing of coffee, pyrethrum, tea, beans and the like, TGDC believes that, introducing agri-processing technology such as drying of crops and fish farming to the farmers and developing tourism can have significant economic effect and benefits not only to the local community but also to the regional and national economy.

4.4. Luhoi geothermal prospect

Luhoi geothermal prospect is located in Coast Region, about 150 km from Dar es Salaam. It is situated along the southern extension of the East African Rift System (EARS), "Coastal Basin", which formed mainly in response to progressive fragmentation through time of the super continent of Gondwana. The detailed surface study was finalized by a consultant (ELC 2017) from Italy in 2017 in the joint project framework with Kiejo-Mbaka under technical support from the MFA Iceland/ ICEIDA. The results from the technical report show that Luhoi geothermal prospect host a low temperature geothermal system (95-145°C) and is suitable for direct uses and power generation using binary technology.

Geologically, Luhoi is located on the southern extension of the EARS in the south eastern coastal basin of Tanzania which split into the NNE-SSW trending Selous sub-basin and NNW-SSE trending Mandawa sub-basin where the two are separated by a spur of Pre-Cambrian basement (Figure 6). The prospect area occurs the northern intersection of the two sub-basins within Rufiji trough. This is the E-W trending basin which is covered by the sedimentary sequence which become thicker and younger toward the Indian Ocean in the east. The coastal basin of Tanzania was formed in response to progressive fragmentation of Gondwana where a series tensional regime and spreading events split the continental crust creating sedimentary basins along the eastern coast of the continent. The prospect is manifested by several hot springs (about 72 °C and 20-30 l/s flow) along the Luhoi River over a stretch of about 600 m and large amounts of accumulated travertine.

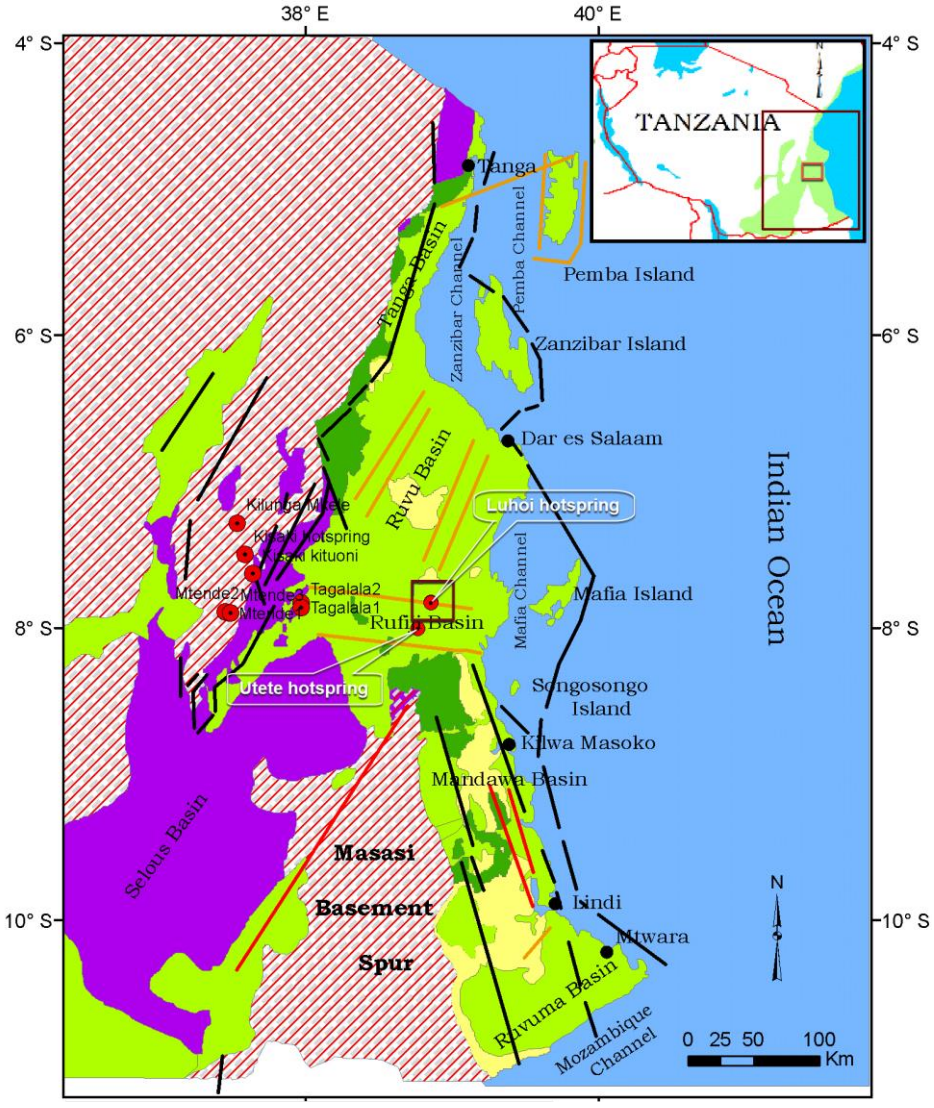

Figure 6: Luhoi geological map

5. Investment Opportunities

Country's electricity demand is on average growing between 10 and 15 % per annum. This requires significant investment in generation, transmission and distribution systems. In this regard development of geothermal resources in Tanzania is essential so as to transform the country's energy sector to balanced, diversified and sustainable.

Development of the geothermal energy resources requires investment catalysts which among others are to establish enabling environment, legal and policy framework, financial sustainability for geothermal projects and developing requisite local capabilities. The country is currently working attracting and creating suitable environments investments which there are number of opportunities in geothermal developments.

At present, there is no specific law governing geothermal development. However, the Government is putting efforts in formulating a legal and regulatory framework for geothermal development. The draft bill for regulatory framework and institutional set up have already been prepared and completed in September, 2017. The draft was developed under support from Scale up Renewable Energy Programme (SREP) is formulating a legal and regulatory framework for geothermal. The draft bill takes into consideration and addresses the challenges surrounding geothermal development in the country including current licensing and regulatory mechanism. Also, it is anticipated that the legal and regulatory framework will encourage private investments in power generation and direct use applications.

The country has already conducted a number of surveys on the direct use opportunities in areas around geothermal potential areas. The surveys conducted in Mbeya, Songwe, Coast and Shinyanga regions identified several direct use opportunities. The identified opportunities include agricultural uses, industrial uses, recreational and geo-tourism. Specifically, the agricultural uses may include greenhouse farming, drying of crops, aquaculture, and chicken hatching.

The Government of Tanzania offer some investors 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 private sector in bringing about socio-economic development through investments, so Public-Private Partnership (PPP) frameworks have been developed to provide important instrument for attracting investments.

6. Conclusions

The short term target is to inject 200 MW in the country's energy portfolio by 2025. Four geothermal prospects (Ngozi, Songwe, Kiejo-Mbaka and Luhoi) have been identified to flagship the geothermal development so as to meet the target; and as of to date, generally all the four prospects are ready for test drilling to confirm the resource. Mobilization of funds for carrying of test drilling is underway.

The main challenges encountered during the development of geothermal resources in Tanzania include high upstream cost with associated risks, inadequate human capacity and equipment, absence of geothermal law and lack of sufficient awareness to some of the key stakeholders.

As a measure to address these challenges, the country is now formulating a specific legal and regulatory framework for geothermal development and a strategy for soliciting external and internal financing from various sources. Adequate and highly trained professionals are needed and the Government is continue to train the staffs in order to strengthen the institutional capacity to develop and manage geothermal projects. For sustainability of geothermal development, TGDC and the Government have established a number partnerships locally and abroad to support geothermal development and utilization.

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