Fact sheet for geothermal development to promote Public Private Partnerships in East Africa

United Republic of Tanzania

Overview of electricity sector status

The total electricity generation capacity in Tanzania as of June 2022 was 1,732.16 MW out of which, 1,694.55 MW was from the main grid (TANESCO - 1,482.27 MW, SONGAS – IPP -189 MW, SPP-23 MW) and 37 MW off-grid (TANESCO-35 MW, IPPs-2,176 MW) sources (Energy and Water Utilities Regulatory Authority , 2022). As of end of 2021, natural gas was the main source of electricity generation in Tanzania by 60%, followed by hydropower at 9.12% and finally by heavy fuel oil and biomass at 0.15% and 0.18% respectively (Energy and Water Utilities Regulatory Authority, 2021). There are 13 national utility owned hydropower plants, while there are 19 thermal power plants owned either by TANESCO or IPPs that are connected to the national grid. Of these thermal plants 8 are gas-fired, 2 are biomass plants, 7 are diesel-fired, 1 is industrial diesel oil (IDO) and 1 is heavy fuel oil (HFO) plant. TANESCO's diesel, IDO and HFO plants which are connected to the grid are currently operated as reserve capacity (Ministry of Energy, 2020). Figure 1 shows grid-connected installed electricity capacity trends in Tanzania by source from 2010 to 2020. Electricity capacity in Tanzania has increased significantly from 1,590 MW in 2010 to 1,898 MW in 2020. Of this, fossil fuels, mainly natural gas, contributed about 1,276 MW which accounts for 63% of total installed capacity. Meanwhile, hydropower and biomass account for 30% and 2% of total installed capacity, respectively. Small portion of solar panels and onshore wind were also installed with a capacity of 2 MW, respectively. None of Geothermal is installed in Tanzania.

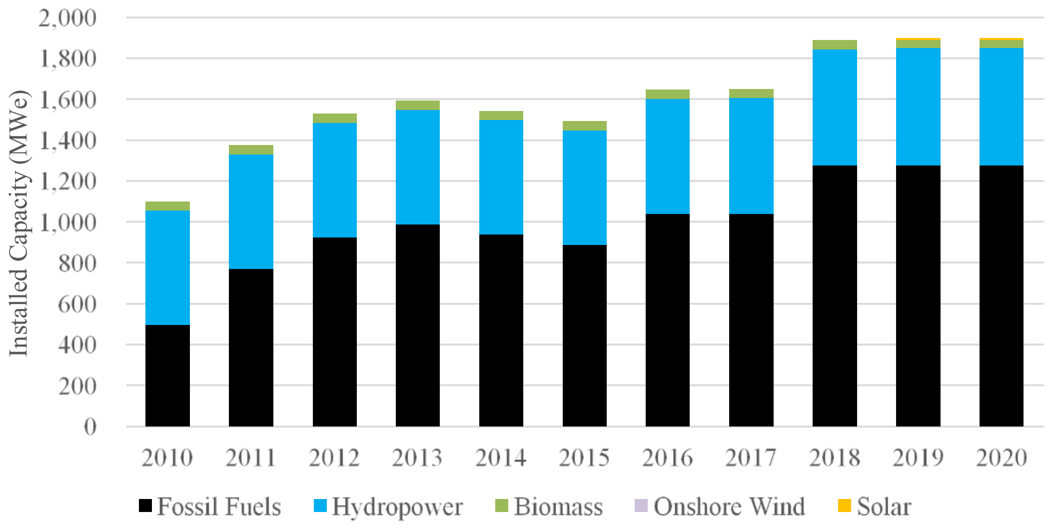

Figure 1: Grid-connected installed electricity capacity trends in Tanzania by source

Data Source: (IRENA, 2022)

Electricity generation in Tanzania was mainly by fossil fuels and hydropower. Electricity generated by fossil fuels, mainly natural gas, has increased significantly since 2015 as shown in Fig 2. This growth is attributed to expanded capacity to utilize natural gas extracted from the Rufiji basin (IRENA, 2020). In 2019, the share of electricity generated from fossil fuels, mainly natural gas, was 67%, hydropower 32%, and biomass 1%.

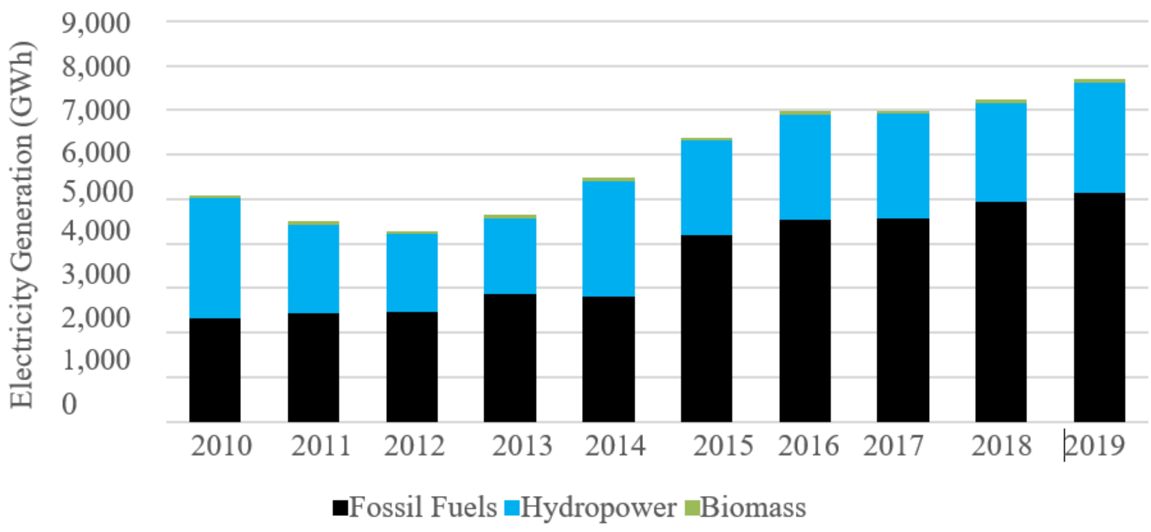

Figure 2: Grid-connected electricity generation trends in Tanzania by source

Data Source: (IRENA, 2022)

Ongoing & Planned Power Generation Projects

The ongoing and /planned power generation projects in Tanzania are projected to contribute additional generation of 5,197 MW from hydro power plants with Julius Nyerere HPP of 2115 MW being the largest project. Gas fired power plants of 6,700 MW are also included in the plan. All the gas will be from local sources. Coal plants totaling 5,300 MW are also planned. Solar is planned to contribute about 720 MW while wind energy is expected to provide about 1,000 MW. The plan also targets 200 MW from geothermal sources by 2025.

Electricity Access

The national household electricity access in Tanzania was 30.0% by 2020. The government planned to raise this level to 50% by 2025 and to 96.1% by 2044. In order to achieve these set targets, a five-year plan of connecting 290,000 people annually was put in place in 2020 (Ministry of Energy, 2020).

Demand forecast and Generation Expansion Plan

According to the Tanzania power system master plan designed in 2020, the projected growth in average peak demand including both grid and islanded systems will be 2,677 MW in 2025, 4,878 MW in 2030, and 17,611 MW by 2044. The demand growth rate was projected at 11.7 annually. The generation system loss was 16.19% in 2020 and is planned to drop to 12% by 2026. In order to realize the ambitious target of planned generation, the planned total generation for the short term is projected at 3,971.4 MW while that for the mid-term and long-term are 12,255.7 MW and 20,200.6 MW respectively (Ministry of Energy, 2020).

Overview of geothermal development status

Geological setting

Tanzania is transected by both eastern and western branches of East African Rift System. The eastern branch extends from the Natron basin in the north through Ol'doinyo Lengai volcano with a bifurcation into the Lake Eyasi basin and southeastward forming the Pangani basin (Fig. 3). The western branch of EARS extends Virunga volcanic complex in Rwanda and DRC through Burundi into Lake Tanganyika, Rukwa and Nyasa/Malawi rifts. At Mbeya occurs a triple junction between Rukwa-Tanganyika rift and the Usangu rift (Figure 3). Most of the geothermal areas in Tanzania are associated with the EARS and the Permian rift in the Rufiji basin. Geothermal resources in Tanzania fall in various tectonic regimes that include volcanic systems in the south at Rungwe volcanic field; rifted and faulted terrains at Songwe and Kiejo-Mbaka; faulted terrains around Lake Natron and the geothermal systems associated with the Rufiji basin. Four broad potential target areas for geothermal exploration singled out so far are: (a) Natron region near the Kenyan border in the North; and (b) Mbeya region between Lake Rukwa and Lake Nyasa in the southwest and (c) Rufiji basin in the east and (d) central Tanzania region. In northern Tanzania, geothermal activity occurs mainly along the southern extension of the Kenya rift into Lake Eyasi, Ngorongoro, Lake Natron, Ol'doinyo Lengai and Arusha areas. The prospects in the Mbeya region are associated with the Rungwe volcanic complex and include Ngozi, Songwe, and Kiejo-Mbaka geothermal areas. In the Rufiji basin in eastern Tanzania occur Luhoi, Kisaki and Utete sites. Other geothermal areas are in central Tanzania and include Singida, Kondoa, Dodoma and Shinyanga areas. As part of this study, the prospects that will be evaluated are Natron, Ngozi, Songwe, Luhoi and Kiejo-Mbaka geothermal prospects. These prospects were targeted to provide 200 MW by 2025.

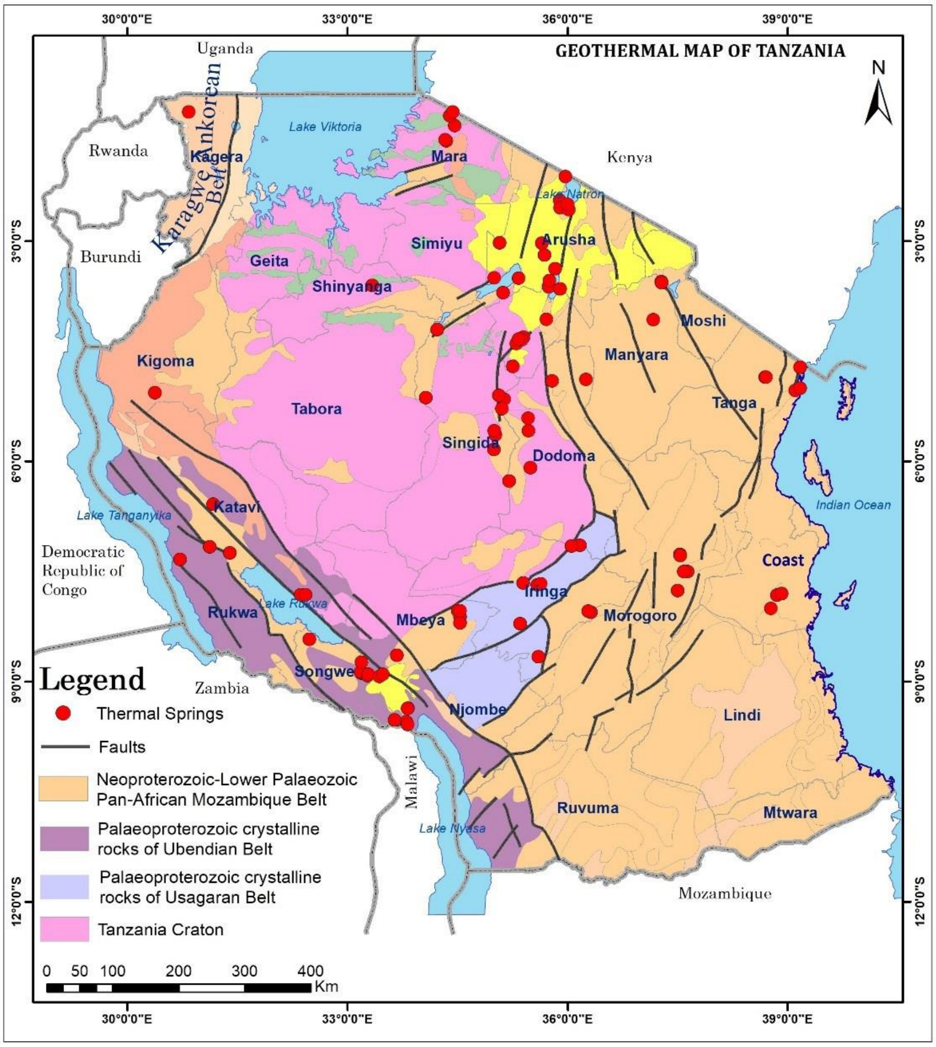

Figure 3: Geological map of Tanzania showing geothermal areas

Geothermal fields and prospects

- **Ngozi Geothermal prospect**

Ngozi volcano is part of the Rungwe volcanic complex. Ngozi is part of the Poroto Mountain ridge thought to be largely made up of basalt, phonolite and trachyte lava flow deposits erupted from numerous centres (Fontijn, Williamson, Mbede, & Ernest, 2012). The Ngozi collapse caldera measures ca. 3 km across. The Rungwe Volcanic Province developed at the intersection between the eastern and the western branches of the East African rift system in the SW highlands of Tanzania. In particular, it forms a triple junction with the NW-SE trending Songwe basin (southern extremity of Rukwa rift, the Livingstone basin (northern extremity of the Nyasa rift) and the NE-SW trending Usangu basin (4). Volcanism started 8-9 Ma years ago concomitantly with normal faulting activation of the major rift border faults. The triple junction is seismically active, has many active hot springs and the last volcanic eruption happened about 200 years ago (Fig. 4).

Ngozi has known at least two major, regional-scale eruptions in the Holocene, that are both thought to have contributed to the formation of the present-day caldera: the ca. 10–12 ka Kitulo Pumice and the Ngozi Tuff. The Ngozi trachytic tuff is thought to correlate with the 1674 ± 13 AD ash layer found in Lake Malawi cores (Fontijn, Williamson, Mbede, & Ernest, 2012). The tuff deposits define caldera forming episodes. Studies revealed the presence of a resurgent cone under Ngozi Caldera Lake which is related to the youngest activity in the area. The rocks associated with Ngozi volcano include basanite, alkali basalt, phonolite and trachyte. Trachytic pumice fall deposits were also erupted during the Holocene. Presence of trachytes suggests that a shallow magma body exists under Ngozi. Studies indicated that the Rungwe volcanic complex have a different melt generation model than the other volcanoes in western branch and thus likely to have shallow magma chambers from trachytic magma bodies. The other volcanoes are explained by "lithospheric drip magmatism" generating melt, which do not stall in crustal levels to form magma chambers. (Alexander, Cumming, & Marini, 2016) modeled the magma chamber to occur between 5 and 7 km depths. Other evidence for shallow magma body includes silicic volcanism, tuff and pyroclastics, associated to the development of the caldera at Ngozi.

TGDC has undertaken details surface studies including geological and structural studies, geochemistry and geophysical studies to confirm the modeled geothermal system at Ngozi volcano to allow for development. Three deep slim holes have been sited to confirm the existence of the geothermal system. To this end, the Government of Tanzania has procured a drilling rig to be used for the exploration programme. TGDC has further obtained funds from Geothermal Risk Mitigation Facility (GRMF) and drilling is expected to commence in August 2023. Studies within the entire Rungwe volcanic field indicate that an anomaly could be present within the Rungwe volcano (Figure). The heat source has been modeled as a trachytic magma chamber located about 5-7 km depth within the basement rocks. This, however, is deeper than recorded at Menengai (~2.2km) and modeled for Olkaria geothermal field (~4km). There is therefore a high chance that a high temperature (>230°C) geothermal system exists under Ngozi volcano and that lack of manifestations on the surface is due to blanketing by thick pumice fall from the Rungwe volcanic complex (Alexander et al., 2016).

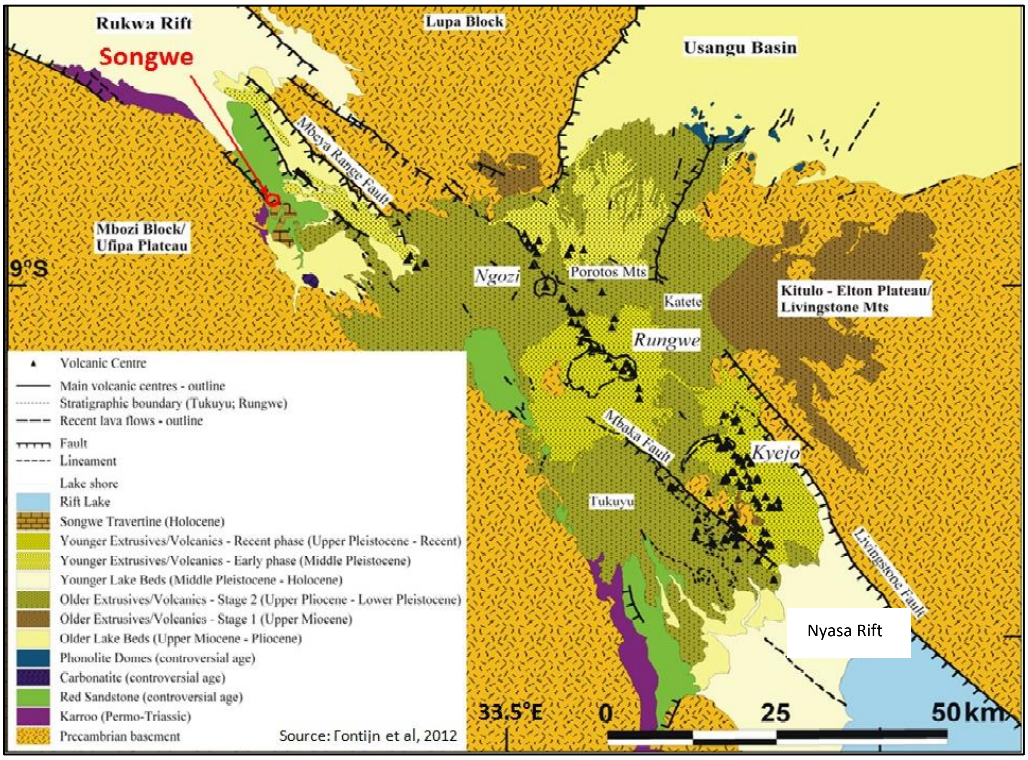

Figure 4: Geological map of Rungwe volcanic complex and the surrounding areas

- **Songwe Geothermal Project**

Songwe geothermal area is located within the Rukwa rift basin along the western fault scarps. Songwe is within a micro graben defined by NW trending faults. Songwe hot springs occur on the western fault that dips in NE direction (Figure). At Songwe, travertine deposits overlie Limestone beds, Red sandstone, and Karoo conglomerates. There are Cretaceous carbonatite intrusive in the southern Songwe basin. However no recent volcanic activity present in the area. Differing from Ngozi, this geothermal site should be considered as amagmatic (hydrothermal convective system along faults without magmatic heat source).

The geology of Songwe area is dominated by Pan African metamorphics, travertine deposits, Cretaceous carbonatite intrusive in the south, Karoo Supergroup conglomerates, Cretaceous Red Sandstone Group, Lake beds, volcanics and Quaternary travertine deposits. U-Th dating shows that travertine deposits at Songwe have been active since 400 ka. The Songwe basin evolved as a complex, northeast-tilted half graben. The evolution of the antithetic normal fault on the southeast side of the basin has led to the development of an accommodation zone in this basin between oppositely dipping normal faults (Alexander, Cumming, & Marini, 2016). Therefore, the Songwe geothermal system is attributed to deep circulation of surface water along faults. This has been confirmed by geophysical studies that imaged shallow anomalies. TGDC has set up plans to drill deep slim holes at Songwe geothermal area as part of testing for the geothermal reservoir at the prospect. In the interim, TGDC has set up pilot direct use facilities that include hot bath, hatchery, and greenhouse.

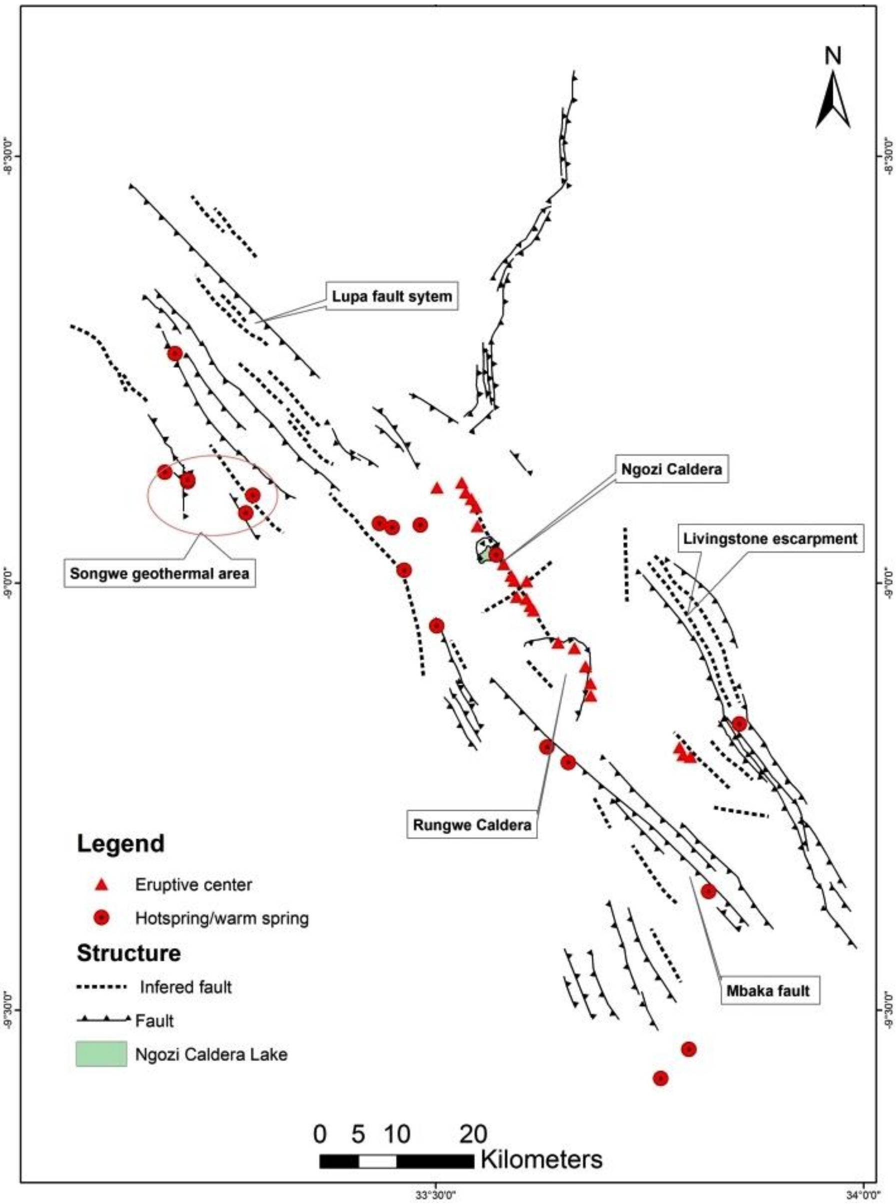

Figure 5: Thermal manifestation map of Rungwe volcanic province

- **Kiejo-Mbaka Geothermal prospect**

The Kiejo-Mbaka area is situated between Lake Nyasa and Mbeya town in SW Tanzania. It is a part of the northernmost sub-basin of the Nyasa rift at a triple junction of the East African rift. The permeable intra-basin Mbaka fault and Livingstone border fault allow for the ascent of deep hot water along the Mbaka fault (Figure 6). The northernmost sub-basin of the Nyasa rift, the Karonga basin is an asymmetric down-to-the-east half-graben, which is characterized by the prominent NW-SE trending Livingstone border fault and the parallel major intra-basin Mbaka fault (both seismically active). Especially the latter of the two deep-reaching structures is highly permeable allowing for ascent of hot water from the floor of the ca. 5 km deep rift basin. Several hot springs emanate along Mbaka fault. Kiejo is the third largest volcano after Ngozi and Rungwe in the RVP. It is thought to consist dominantly of lava flow units with (alkali) basalt–basanite–tephrite and phonolitic trachyte–trachyandesite compositions. Magmatic activity in the Rungwe volcanic field started in Miocene times and continued to the Recent with the latest eruption at Kiejo volcano ca 200 years ago.

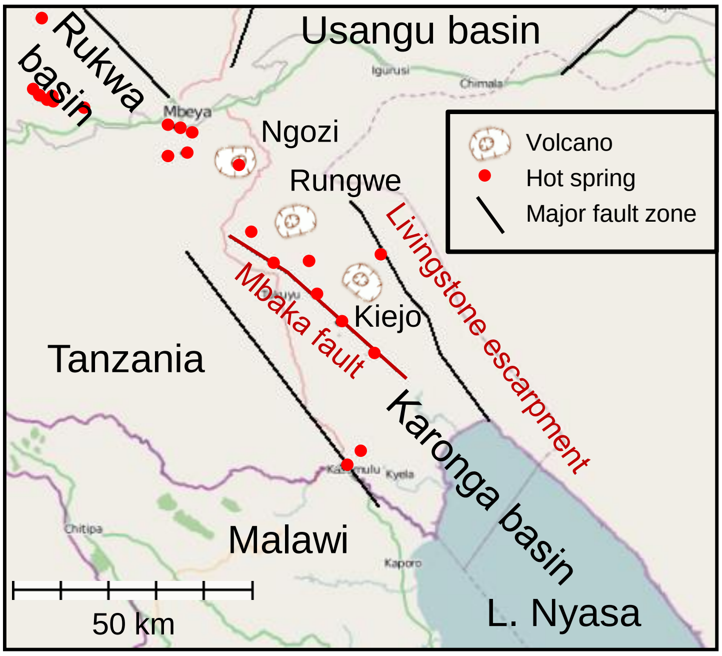

Figure 6: Structural map of Rungwe volcanic field showing Mbaka fault and associated fault systems (Kraml et al. 2012)

Hot springs along Mbaka fault discharge along the main fault structure with the main areas of activity being at the intersection between the NW-SE and NNE-SSW structures (Figure 66). The springs discharge at temperatures of up to 70ºC and deposit travertine on the surface along the fault line to a maximum distance of 40 m from the fault trace. During previous studies, it was estimated that the reservoir temperature of Mbaka fluids is more than 160 °C (Kraml, Kreuter, & Robertson, 2012). Other studies estimated that between 3.5 and 7 MWt is discharged by the springs along Mbaka fault (Hochstein, Temu, & Moshy, 2000). TGDC drilled a thermal gradient hole along the Mbaka fault which discharged hot water at 70ºC (Figure 7). The model for Kiejo-Mbaka geothermal system is explained by fault-controlled model for the resources associated with the Mbaka fault. TGDC plans to drill slim holes to confirm the resource characteristics which would if successfully lead to the development of staged 10 MWe power plant in the initial phase.

Figure 7: Discharging temperature gradient hole in Mbaka prospect

- **Natron Geothermal Prospect**

The Lake Natron Basin in northern Tanzania forms part of the East African Rift System. Rifting began ~30 Ma in Ethiopia and has moved southwards, with rifting beginning in northern Tanzania ~ 8 Ma. The Lake Natron Basin is part of the Kenya Rift segment at the southern end of the EARS, and records a complex history of volcanism, sedimentation and faulting during the last 2 Myr. Ol'Doinyo Lengai, the world's only active carbonatite volcano, rises up from the basin floor and forms a prominent stratocone that dominates the landscape (Sherrod et al., 2013). Lake Natron salt-lake (Figure 8) is the dominant physiographic area in the area aside from the Ol'Doinyo Lengai active volcano.

Figure 8: Photo facing north showing Natron fault on the west and hot springs on the downthrow side

Lake Natron basin lies within the southern extension of the Kenya rift and forms the lowest point at about 600m asl. The area is one of the most tectonically, seismically and volcanically active portions of the eastern branch of the Kenya rift. The rift segment is bound by major rift fault on the west side and less prominent structures on the eastern side which may reflect half graben structural features and with Gelai volcano as the most important feature (Figure 9). At the latitude of Ol'doinyo Lengai, the rift bifurcates into SW part that beyond Lake Eyasi and the eastern branch that extends through Mt. Meru and Pangani graben. The western part of the Lake Natron Basin is defined by a major escarpment caused by faulting along the Natron Fault. This escarpment comprises a complex sequence of lavas interbedded with a variety of volcaniclastic rocks. This sequence is cut by a series of N-S trending rift-related faults. In the eastern part of the basin a similar sequence of rocks is preserved, but with NE-SW trending faults. Preliminary studies indicate that a geothermal resource exists associated with fault zones to the west and east of Lake Natron and exhibited by hot springs. It has also been suggested that a resource could be present under Gelai volcano and shown by intense, shallow seismic activity at the volcano (Lee, et al., 2016), (Albaric, Déverchère, Perrot, Jakovlev, & Deschamps, 2013). Detailed studies are planned by TGDC to evaluate potential geothermal occurrence in the Lake Natron basin.

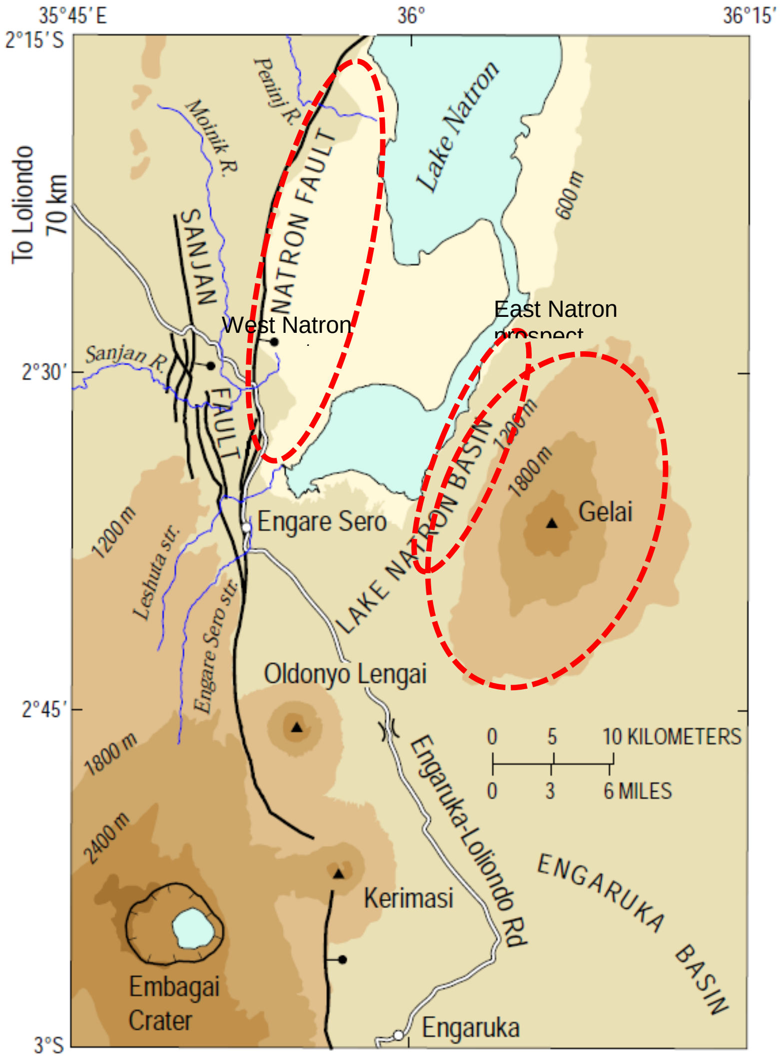

Figure 9: Map of the Lake Natron Basin, northern Tanzania

- **Luhoi geothermal project**

Luhoi geothermal prospect is situated about 150 km SSW of Dar es Salaam between Kibiti Town in the North and Luhoi River (a tributary of Rufiji River) in the South. It lies within a graben defined by the E-W oriented Jurassic rift superimposed on repeatedly rejuvenated Permian rift oriented in the NE–SW direction. The sediments are reported to be more than 10 km thick. The Luhoi area is characterized by a thick sequence of Cretaceous to Tertiary marine sediments comprising of unconsolidated sediments, sandstones, travertine, limestone, siltstone and conglomerates. The area consists of NW-SE and NE-SE intersecting structural lineaments. No young volcanic activity has been reported in this region and the latest volcanism has been dated at Carboniferous to Permo-Triassic. Several hot springs have been recorded with hot water outflows forming extensive warm wetlands in some places (Nyongoni hot springs). The main geothermal surface manifestations comprise of gas bubbles, surface alteration and travertine which are scattered within the Rufiji basin at temperatures of up to 71.5°C. The heat source for the geothermal system is deep circulation along the intersecting fault systems. Recent studies estimated power generation potential of 30 MWe from a reservoir of about 140°C (JICA, 2014).

Direct use applications

There are currently no commercial-scale direct use applications in Tanzania. However, small-scale applications are found in the Arusha and Kilimanjaro areas, Songwe, Mbaka fault, Luhoi and Lake Natron (Figure 10). The main direct use application in these localities is bathing, especially for tourism. The facilities are used in the elementary form with minimal marketing. At Songwe, the main attraction has been the beautiful landscape produced by the carbonate springs but lately TGDC has built demonstration facilities comprising hot pool, greenhouse and hatchery. The springs produce carbonate sinters which are used as feed supplement for cattle (Mnjokava, Kabaka, & Mayalla, 2015). The travertine deposits discharge at temperatures of as high as 79ºC. TGDC has made an effort to promote direct use in Tanzania by undertaking prefeasibility studies for Luhoi and Songwe geothermal areas by examining the potential applications.

Figure 10: Direct use demonstration facilities at Songwe geothermal area

Policy, regulatory and institutional framework for development of geothermal resources

Institutional framework

- **Ministry of Energy**

The Ministry was formed in 2017 after the preceding ministry, the Ministry of Energy and Minerals was split to improve supervision (Figure 11). The Ministry formulates and monitors implementation of policies on energy, oil, and gas in the country. It is also responsible for energy and petroleum resource management; value addition in petroleum; oil and gas infrastructure development; bulk procurement of oil; urban and rural electricity programs; local content in energy and petroleum; renewable and non-renewable sources of energy; performance improvement and development of human resources; extra-ministerial departments, parastatal organizations, agencies, programs and projects under the Ministry (Ministry of Energy, 2022). Ministry of Energy developed the Power System Master Plan (PSMP), which will guide the next 25 years of Tanzania's power development, including generation planning of geothermal energy. Geothermal development projects in Tanzania are under the control of the Division of Renewable Energy, Department of Energy and Oil, Ministry of Energy.

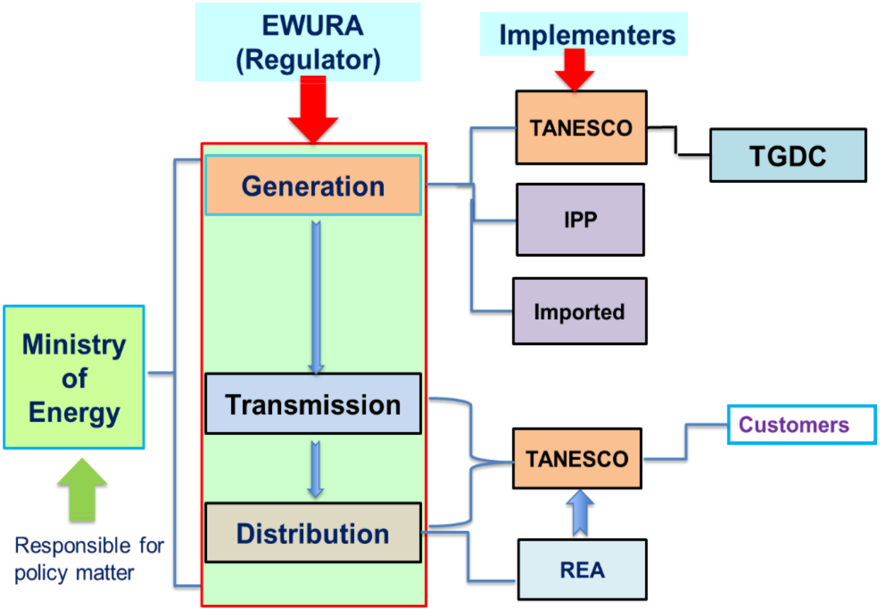

Figure 11: Institutional Setup in Tanzania[1]

- **Ministry of Finance and Planning**

Government of Tanzania through Ministry of Finance and Planning provides partial funds for drilling tests at Ngozi site. In 2021, The government has announced to allocate TZS 20 billion (over U$8.5m) to finance the initial stage of the Ngozi geothermal project.

- **Energy & Water Utility Regulatory Authority (EWURA)**

The Energy and Water Utilities Regulatory Authority (EWURA) is an autonomous multisectoral regulatory authority established by the EWURA Act Cap 414-2006 of the laws of Tanzania and its amendments EWURA Act (Amendments No. 6 of 2019). It is responsible for technical and economic regulation of the electricity, petroleum, natural gas, and water sectors in Tanzania pursuant to Cap 414 and sector legislation. Geothermal projects in the country must have permission/license for power projects from EWURA. Licensing is done by filling in the application form (form No. 100), which can be downloaded from the EWURA website (www.ewura.go.tz), and providing the supporting documents, such as a letter showing support for the initiative from the Ministry of Energy, EIA certificate, feasibility study (Energy and Water Utilities Regulatory Authority, 2022). EWURA also has developed Model Power Purchase Agreements for power projects for seven power generation energy resources, which include geothermal power generation above 10 MW, to provide guidance to parties when negotiating for PPAs. EWURA determines PPA tariff based on the cost of generation of electricity, cost of investment and operations. And this is also based on specific technology (technology specific tariff).

- **National Environment Management Council (NEMC)**

Tanzania Environmental Management Act (2004) and the Environmental Impact Assessment and Audit Regulations of 2005 require mandatory environment impact assessment (EIA) before the implementation of any development project, including geothermal exploration and development project. National Environment Management Council (NEMC) is the main EIA authority in Tanzania with

[1] TGDC Team (2023). Geothermal Development in Tanzania: an overview. Presented at UNIDO meeting in Naivasha, Kenya

institutional mandate to undertake the review, monitoring, enforcement, and compliance activities for EIA and facilitates public participation. The environmental impact assessment and audit regulation has highlighted key steps to embark on and satisfy the awarding of an environmental certificate. In the case of geothermal development project, TGDC shall, in the first place, register the project to NEMC for screening, undertake scooping exercises, and conduct impact analysis, and finally, implementation of mitigation and impact management.

- **TANESCO**

Tanzania Electric Supply Company Limited (TANESCO) is a parastatal organization established by Memorandum and Articles of Association incorporated in 1931, which established Tanzania Electric Supply Company Limited (the then Tanganyika Electric Supply Company Limited -TANESCO). The company generates, purchases, transmits, distributes, and sells electricity to Tanzania Mainland and sells bulk power to the Zanzibar Electricity Corporation (ZECO).

- **Tanzania Geothermal Development Company (TGDC)**

TGDC is a subsidiary company of Tanzania Electric Supply Company Limited (TANESCO); 100% owned by the government of Tanzania, incorporated in December 2013 for the purpose of spearheading development of geothermal resources in Tanzania. It commenced its business in the July 2014 with the mandate amongst others to explore, drill, and harness geothermal resources for power generation and direct applications.

Policy and regulatory framework

- **National Energy Policy 2015**

The National Energy Policy (NEP) was updated in December 2015 by the Ministry of Energy. It aims at sustainably providing adequate, reliable, and affordable energy to the Tanzanians. The NEP notably aims at scaling up the utilization of renewable energy per se and to diversify the country's energy mix, using solar, biomass, wind, small-scale hydro, and geothermal, including in buildings and industrial designs. According to NEP, Feed-in Tariffs should be established, and renewable energy integrated into both the national and isolated grids. The policy also describes fiscal, legal, and regulatory frameworks for energy sector in general. In terms of fiscal framework, the Government strives to put in place policy guidelines for Standardized Power Purchase Agreements and Tariff as well as Model Power Purchase Agreements in electricity subsector. In terms of legal and regulatory framework, the current framework for energy resource management and development is governed by various instruments, including: The Constitution; the Local Government Act (1982); the Land Act (1999); the Energy and Water Utilities Regulatory Authority (2001), the Atomic Energy Act (2003), the Fair Competition Act (2003), the Environmental Management Act (2004); the Rural Energy Act (2005); the Electricity Act (2008); the Water Resources Management Act (2009), the Public Procurement Act (2011); Petroleum Act (2015); and the Public Private Partnership Policy of 2009 and Act of 2014. However, there is no specific legal and regulatory framework for geothermal development until now.

- **The Environmental Management Act 2004**

It provides for legal and institutional framework for sustainable management of environment; to outline principles for management, impact and risk assessments, prevention and control of pollution, waste management, environmental quality standards, public participation, compliance, and enforcement; to provide a basis for implementation of international instruments of environment; to provide for implementation of the National Environment Policy, etc. To implement this act, the detail rules and procedures for carrying out of environmental impact studies and environmental audits are regulated in Environmental Impact Assessment and Audit Regulations, 2005. This act prohibits the carrying out of projects without an environmental impact assessment required under the Environmental Management Act and defines the contents and form of an environmental impact assessment and the basic principles of an environmental audit.

- **Public Private Partnership Act №. 18 of 2010 and its Policy of 2009**

This Act establishes a Coordination Unit within the Tanzania Investment Authority. The Coordination Unit deals with promotion and co-ordination of all matters relating to public-private partnership projects in various sectors of the economy, including (a) agriculture; (b) infrastructure; (c) industry and manufacturing; (d) exploration and mining; and (e) environment and waste management. The public sector shall facilitate the implementation of the public-private partnership projects by (a) identifying projects, (b) carrying out feasibility studies, (c) monitoring and evaluation, (d) risk sharing, and (e) putting in place an appropriate enabling environment. Where the project requires an environmental impact assessment (EIA) is required under the Environmental Management Act, the contracting authority shall ensure that the environmental impact assessment certificate is obtained by the private party before undertaking the project. The agreement shall contain conditions ensuring, among other things, that the environmental impact assessment certificate has been issued in respect of the project.