Presented at SDG Short Course II on Exploration and Development of Geothermal Resources,
organized by UNU-GTP, GDC and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, Nov. 9-29, 2017.

GEOTHERMAL DEVELOPMENT IN TANZANIA

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ABSTRACT

Tanzania is among East African countries that are traversed by the East African Rift System. The geological settings for the occurrences of geothermal resource in Tanzania is variable and include potentials that are likely to be associated with typical young volcanic provinces in the north, intersection of eastern and western arms (triple junction) in the south west, faulted granites areas in central Tanzania (craton), and intrusive in young coastal sedimentary formation. This makes the occurrence of geothermal resource in Tanzania quite different from other countries. In addition the eastern arm and western arms tend to have different geological conditions that need to be differently considered during the exploration of geothermal energy resources in Tanzania.

Tanzania's power system has for decades relied on hydro and oil based generation mix. As a result, the power supply has been prone to variability and uncertainty due to frequent drought spells and oil price fluctuations. As a short term remedy, the government has resorted to emergency fuel oil based power plants to bridge the supply gap. This solution is not only expensive but also environmentally unfriendly. Tanzania's aspirations to reach the middle income status as enshrined in the country's Vision 2025 need to support the energy sector to access its agriculture and industrialization potential, and targets. Knowing that energy is vital for economic, social, and human development, Tanzania has determined to develop a sustainable energy mix that will ensure that households, communities, businesses and industries receive supply that is adequate, available when needed, reliable, convenient, healthy and safe for supporting the county's development agenda.

The country's current total grid installation capacity is 1,263 MW. This is from hydro (44.9%), natural gas (48.7%), disel (5.6%) and biomass (0.8%). Previously, the national power system was mostly relying on hydropower. Long and frequent periods of drought which might have been due to the climate change between 2003 and 2006; 2009 and 2010 lead to shortfalls in electricity supply from the hydropower stations; thus, the government of Tanzania resorted to thermal based generation sources as a short term solution. As a long term power development strategy the government intends to diversify the country's energy generation mix and is focusing on increasing the proportion of renewable energy generation, whereby geothermal development is ranked high on the list. Other renewable sources being considered are wind and solar.

Geothermal resource studies in Tanzania date back to 1949 but have been limited to surface studies mainly, measurements of surface temperature, water and gas sampling and analyses of the hot springs. To date, Ngozi geothermal prospect has gone beyond detailed surface study, where drilling of exploration testing wells is planned within one year time. Songwe, Kiejo-Mbaka and Luhoi geothermal fields are next rank to Ngozi. The detailed surface study in the support from ICEIDA/MFA is expected to complete by end of this year (2017). TGDC with ELC consultants undertaking geological, geochemical and geophysical investigations and culminated in locating three sites for drilling of test wells in Kieji-Mbaka and Luhoi geothermal fields.

This paper presents geothermal development in Tanzania covering the geology of geothermal potential sites, developments goals and strategies, institutional arrangements, new projects and future development plans for accelerating geothermal development and utilisation.

1. INTRODUCTION

The United Republic of Tanzania (Figure 1) is located between latitude 1°S an 11°45´ S and between longitude 29° 21´E and 40° 29´ E. It has a size of 945,087 km^2 and a population of 44.9 Million (2012 census). According to Tanzania Development Vision 2025 which is the main document that guides the general development, the country envisages to become a middle income country by 2025. By 2025, Tanzania envisions having transformed itself into a newly-industrializing, middle-income country, with a prosperous, globally competitive economy and a high quality of life in a clean and secure environment. In order to achieve this goal, the energy is one of the infrastructural sectors which have been accorded the high priority so as to support the envisaged social and economic development. It is anticipated that by 2025 the level of economic development will require about 10,000 MW. To attain this goal, sustainable, renewable, reliable and affordable energy technologies are needed to strengthening and increase energy security and diversity. Geothermal, being renewable energy source is expected to be one of the main contributor to the country's energy mix (MEM, 2014).

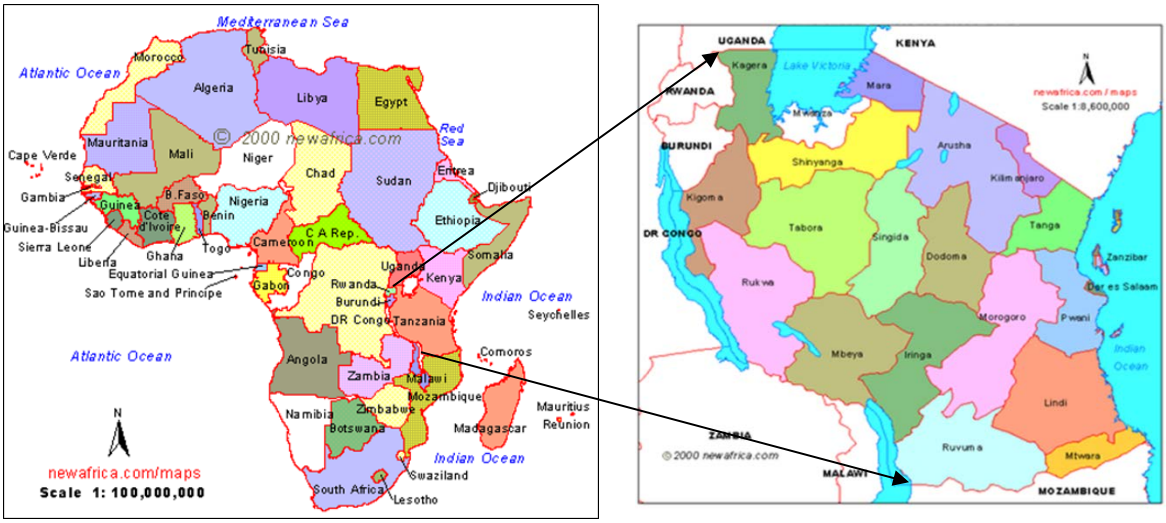

FIGURE 1: Map of Tanzania

Recognising the importance of geothermal energy in improving the country's energy mix, the Government of Tanzania is taking necessary measures to stimulate geothermal development. Recently, it has demonstrated its commitment towards geothermal development by establishing the Tanzania

Geothermal Development Company Limited (TGDC), which is a public company that exclusively deals with geothermal energy development and utilisation. The company was incorporated in December, 2013 and become operational July 2014. It is currently enhancing capacity development for staff, acquisition of equipment, solicit of funds and other resources to enable it to take up its responsibilities. In addition, the government under the Scaling Up Renewable Energy Program (SREP) is establishing enabling environment for geothermal development in Tanzania and geothermal projects have been prioritised with the target of realising 100 MW by 2025.

Under the long term plan (PSMP, 2009, 2012 update) diversification of generation mix is emphasised and geothermal is included in power generation sources. Both the Power Sector Master Plan (2010-2035) and Medium Term Strategic Plan (2012–16) envisage developing renewable energy sources as a measure of enhancing reliability of power supply. Key interventions under the Medium Term Strategic Plan are, (i) developing alternative and renewable energy sources mainly from solar, biomass and wind, and (ii) promoting energy efficiency and conservation. Regarding development of geothermal, the government is committed to reduce geothermal resource uncertainty, partly mitigate development risks, and improve sector governance and capacity to encourage the private sector participation in the development and supply of dependable and cost-competitive geothermal electricity. For that reason, the government has put emphasis on developing appropriate geothermal policy and legal and regulatory framework and support high-risk phases of geothermal project implementation, especially test drilling.

2. ELECTRICITY SUB-SECTOR OVERVIEW

From 1980's to 2000, the national power system was almost 100% relying on hydropower. Long and frequent periods of drought which could be linked to climate change have led to shortfalls in electricity supply from the hydropower stations. Under this situation, the government had to resort to contracted Emergency Power Projects (EPPs) which are thermal based generation sources, primarily because they have short implementation periods. These thermal power plants are expensive and depend on imported fuel. For medium term solution the government accelerated implementation of gas based generation. As a long term solution of ensuring reliability of power supply, diversification the country's energy generation mix including generation from gas, hydro, wind, solar, coal and geothermal is being pursued. Implementation of solar and wind projects is at various levels of development while for geothermal projects establishing of enabling environment and exploration studies are on-going with various stages of progress.

2.1 Sector governance

The Ministry of Energy and Minerals is responsible for formulation and articulation of policies that promote the supply of reliable, accessible and affordable power to economy to reach the middle income status by 2025. Other major government institutions in the sector include the Rural Energy Agency (REA), Tanzania Electric Supply Company (TANESCO), Energy and Water Utilities Regulatory Agency (EWURA) and the currently incorporated company, Tanzania Geothermal Development Company Limited (TGDC). In addition to the public sector, the private sector, development partners, NGOs and higher learning institution are key stakeholders in the sector.

The Rural Energy Agency (REA) is responsible for promoting improved access to modern energy services in the rural areas of mainland Tanzania. Tanzania Electric Supply Company (TANESCO) is the country's principal electricity generator, transmitter, and distributor. The Energy and Water Utilities Authority (EWURA) is empowered to (i) promote effective competition and economic efficiency; (ii) protect the interests of consumers; (iii) protect the financial viability of efficient suppliers; (iv) promote the availability of regulated services for all consumers, including low-income, rural, and disadvantaged groups; and (v) enhance public knowledge, awareness, and understanding of the regulated sectors. The structural relationship among the key players in the power subsector is as shown in Figure 2.

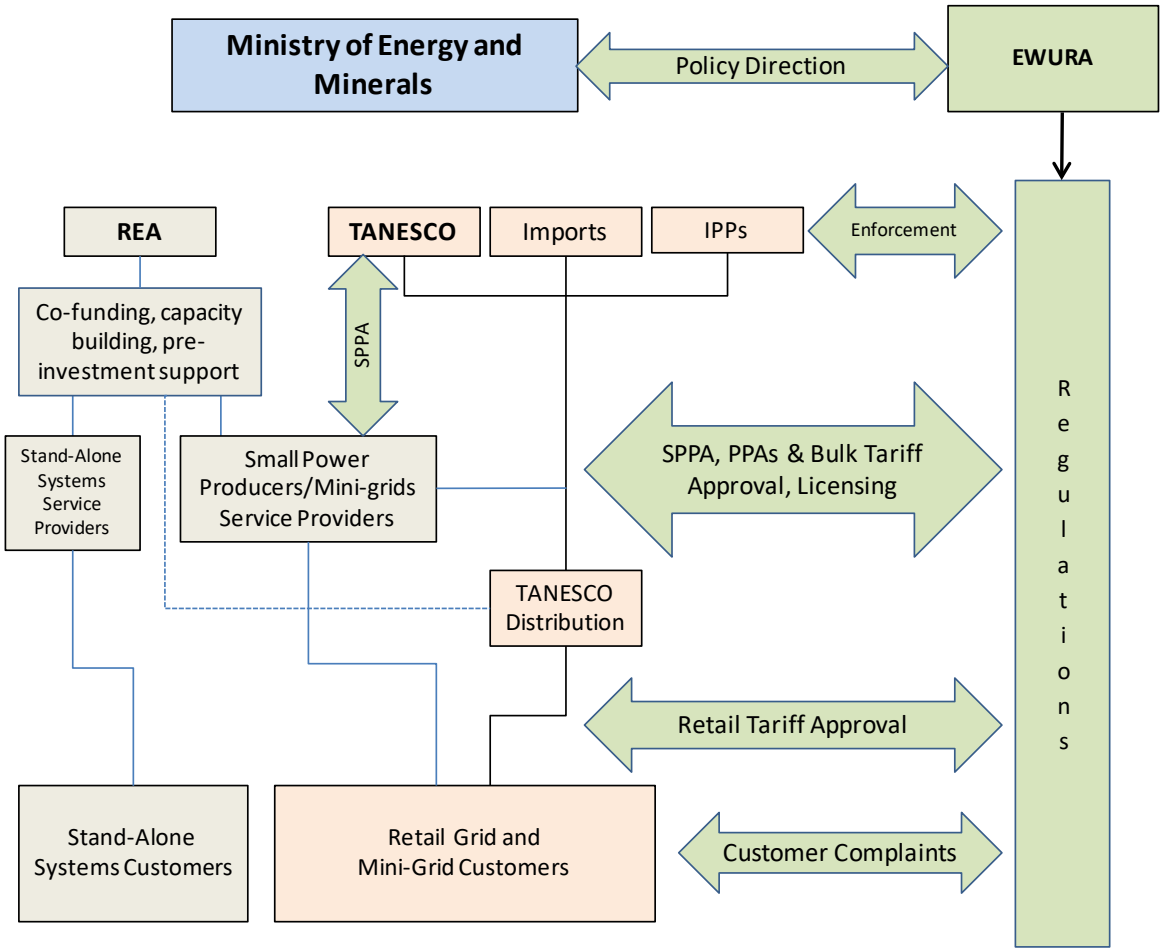

FIGURE 2: Institutional framework and market structure of the electricity sector

2.2 Policy, legal and regulatory frameworks

There are several published documents guiding the power sector since 2003 when the energy sector policy was published. Update on the policies, legislation and guidelines relevant for the Energy Sector including geothermal are as listed in Table 1 below:

TABLE 1: Published documents guiding the power sector

Document	**Current status and plans**
National Energy Policy 2003	Published in 2003, under review
Roadmap for Sector Reform	Published 30 June 2014.
PPP policy	Published in 2010
MEM Three Year Strategic Plan 2011/12-2015/16	Published Nov 2012
Public Procurement Act 2011	In place
Electricity Act 2008	In place
Rural Energy Act 2005	In place
Power System Master Plan	2012 Update, under review
Environmental Management Act 2004	In place
Geothermal development strategy, institutional legal and regulatory framework	Geothermal strategy, legal and regulatory framework has been developed. In the process to be enacted.

2.3 Current situation

The country's power system is mainly relaying on hydropower, gasoline and gas based generation. The country's current total grid installation capacity is 1,263 MW. This is from hydro (44.9%), natural gas (48.7%), diesel (5.6%) and biomass (0.8%). In October 2017, the total capacity was reduced by 16% from 1,516 MW to 1,263 MW by retiring fuel oil based emergency power plants. The annual electricity consumption per capita was 105 kWh in 2014, which is below acceptable global average per capita consumption of 500 kWh (Energy Qtly Digest, June 2016). The generation is from the national utility (TANESCO), independent power producers (IPPs), Emergency Power Producers (EPPs) and SPP-Small Power Producers. There is expected sharp increase in generation from gas due to implementation of BRN initiatives and Stiglers Gorge projects.

The plan is to double the current generation capacity through the Big Results Now Initiative (BRN), which aim at speeding up the processes necessary to fulfil Vision 2025. BRN focuses on key projects and a major structural change of the electricity sector. The time schedule and status for generation projects are as indicated in Table 2 and Figure 3.

TABLE 2: Planned project under BRN initiative

Generation project		**Planned commission date**	**Current status**	
	PSMP		**BRN**	
Mwanza,	60 MW HFO	2013	-	In operation.
Kinyerezi I	150 MW, NG GT	2014	Sep 2014	Construction completed. Extension of 185 MW under construction.
Kinyerezi II	240 MW, NG CC	2015	Jan 2016	Construction in advanced stages.
Kinyerezi III	300 MW, NG GT	2016	Jan 2015	Negotiations on PPA.
Kinyerezi IV	300 MW, NG GT	-	Jan 2015	Feasibility study.
Singida Geo Wind Phase 1	50 MW	2016	Dec 2014	Negotiations on financing, settling land issues.
Kilwa Energy Phase 1	210 MW, NG GT	2014	June 2015	Seeking project guarantee.
Stiglers Gorge	2,000 MW	2020		Tendering

As shown in Figure 3, geothermal is one of prioritized under BRN initiative. This calls for deliberate efforts to accelerate geothermal development to meet the national targets. It is planned that geothermal projects will add 100 MW to the grid in 2025, 500 MW in 2033 and 800 MW in 2035.

3. GEOLOGY BACKGROUND

Tanzania lies on the African Plate, which is one of the Earth's largest slabs of continental crust. The African Plate contains Archean cratons which are over 2.5 billion years old, which preserve evidence of rock-forming events shortly after solidification of the earth's crust. The geological framework of Tanzania reflects the history of this part of the African continent and elucidates the setting of the mineralization. Tanzania's present form is the result of a series of events which began with the evolution of the ancient Archean craton shield that was subsequently modified by metamorphic re-working and accretion of other continental matter, and later covered with continentally-derived sediments of the Karoo sequence and, most recently, began the process of sundering of the craton along the East African Rifts.

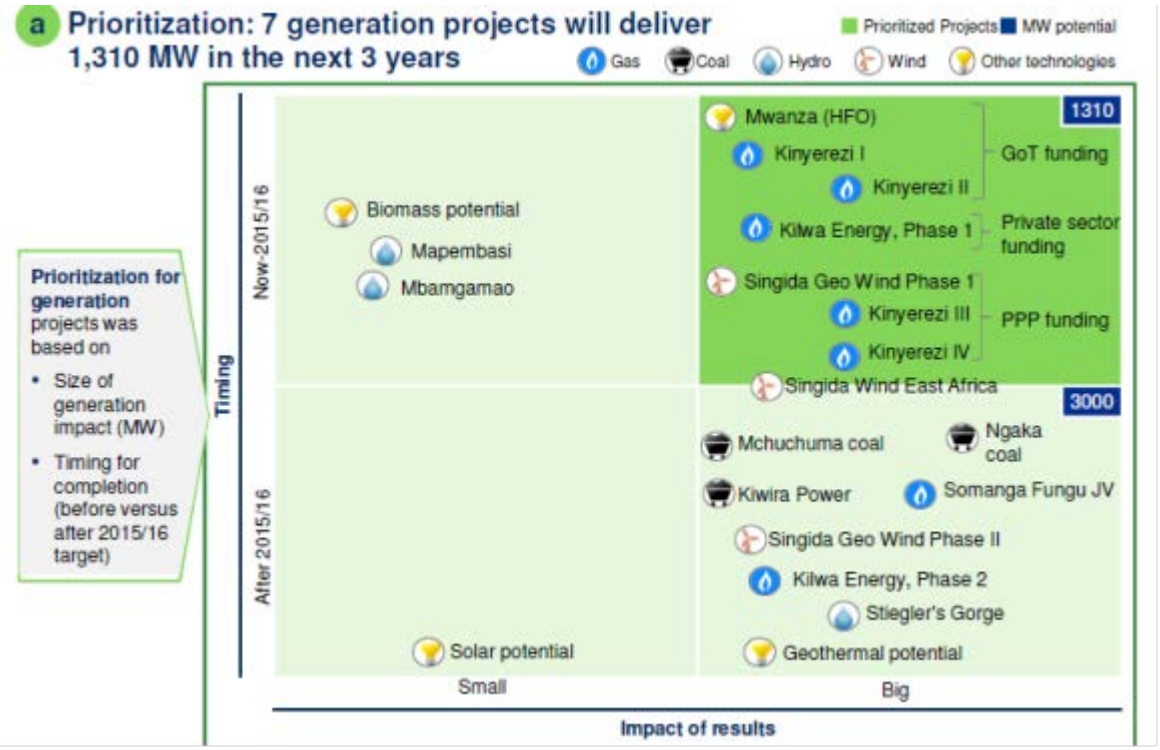

FIGURE 3: Prioritized projects under Big Results Now (BRN) Initiative

Tanzania craton is composed of granites and zones of schist and gneiss containing greenstone belts. The craton is rimmed by Proterozoic crystalline rocks (Figure 4). Proterozoic formations distributed in the west and the south consists mainly of gneiss and schist associated with a small amount of amphibolites. Schist, gneiss, granite and a small amount of marble are distributed in the eastern region, and a series of Karoo group formations is distributed in the southwestern region where continental meta-sediments and marine sediments have accumulated successively over the basement. Younger sediments and volcanoclastics of recent times occupy the rifted graben, coastal plains and inland basins. There are many intrusive rocks ranging from old to young in age showing ultramafic to felsic composition such as gabroo, dolerite, kimberlite, carbonatite granite, syenite and so forth.

Tanzania is traversed by both eastern and western branches of the rift system. The western branch of the rift runs along the western side of Lake Victoria and along the edge of the East African plateau. The western branch is composed typically of half-grabens characterized by high-angle normal rift faults. Eastern branch runs from the southern extreme of the Kenya segment through northern Tanzania segment, where both segments are dominated by alkaline and carbonatitic volcanism of which Ol Doinyo Lengai is well-known example. The prevalence of the carbonatites in the region is attributed to the deep source of the lavas occasioned by the thick cratonic crust in the region. Alkaline lavas are predominant in the areas around Kilimanjaro, where micro-rift graben occur near Arusha and further south.

4. GEOTHERMAL POTENTIALS OF TANZANIA

Reconnaissance surveys and a few detailed studies of hot springs on geothermal sites have been carried out since 1949. Some of these early studies are referenced in Walker (1969), (SWECO, 1978). The recent study was by JICA (2013). The geothermal potentials of Tanzania are shown in Figure 5. Existence of thermal energy is inferred from the presence of hot springs, volcanic activities and associated fault structures. Hochstein et al. (2000) argue that the geothermal resources of Tanzania appear to be rather small and limited in terms of existing technology. McNitt (1982), based on analogy

methods concluded that the geothermal potential of Tanzania could be as high as 650 MW. Today, the potential is estimated to be over 5000 MW. This value is based on the natural heat flow discharge from hot springs. The estimates are based on integrated the geophysical, geochemical and geological techniques without test drilling.

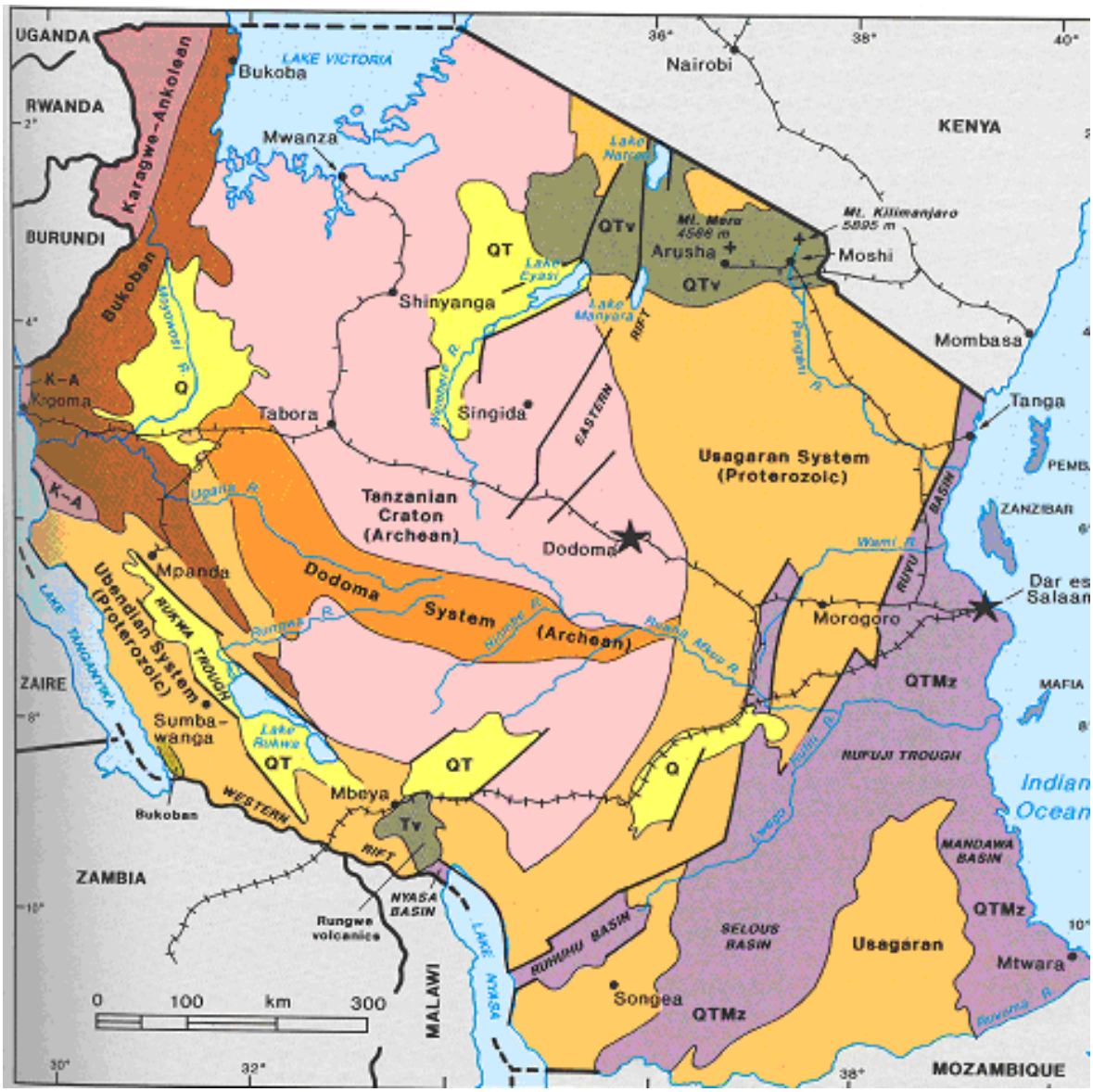

FIGURE 4: A simplified geological map of Tanzania (Source: GST)

The areas with features of geothermal energy resources are mostly located in the Gregory (Eastern) and Albert (western) arms of the great East African Rift Valley. The most common surface manifestations are hot spring sites. However, there are many areas outside the main rift valley with indications of geothermal resources. It is therefore possible to categorise the occurrences of geothermal energy resources based on geological settings into five distinct geological areas:

a) The volcanic provinces of Kilimanjaro, Meru and associated with the eastern arm. This type is found in Northern Tanzania close to the border with Kenya (Lake Natron, Lake Manyara, Ngorongoro Crater).
b) The volcanic province of Rungwe and associated with the triple junction in the south western Tanzania, near the border with Malawi and Zambia. This is the junction of the western and eastern

arms of the Eastern Africa rift valley. This zone is CO2 dominated system and travertine deposits where the outflow reaches the surface at Mbeya area.

c) Granite dominated craton of central Tanzania. These areas are dominated with discontinuous faults associated with rifting (Singida, Dodoma and Shinyanga).
d) Coastal belt geothermal resource potentials. These are linked with young intrusive in sedimentary formations, attributed to rifting and intrusions (Luhoi, Kisaki, Utete and Tanga).
e) The western arm- The occurrence of geothermal resources in the western arm is not well studied but there are hot rings extending from Mtagata in Karagwe near the border with Uganda, Uvinza in Kigoma and Majimoto in Mpanda near the border with DRC and Zambia.

There are also scattered hot springs throughout the country with no clear faulting or volcanism.

TGDC's contribution to sustainable development and poverty reduction in line with the Tanzania National Development Vision 2025 is to realize about 100 MWe by 2025, 500 MWe by 2033 and 800 MWe by 2035 from geothermal generation.

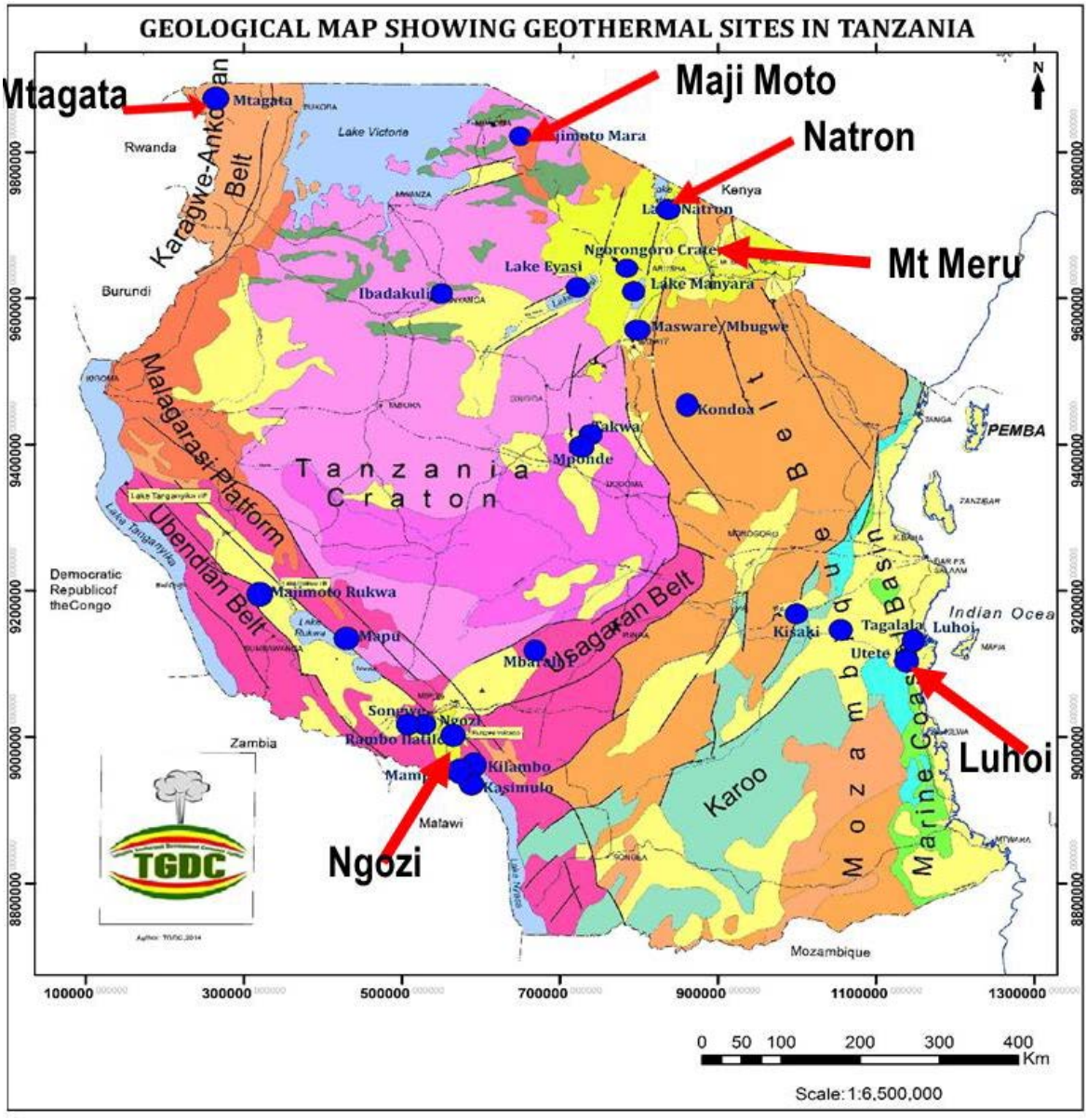

FIGURE 5: Map for geothermal potential areas in Tanzania

5. GEOTHERMAL UTILIZATION

In Tanzania there is no formal geothermal utilization but local uses of sinters for feeding animals, washings and skin bathing are quite common. The oldest document use of geothermal for skin bathing was in 1876 when Mtagata hot spring in Karagwe district, Northwest Tanzania was visited by Henry Morton Stanley in 1876. He reports the temperature as 129.0 F (54.0C)and that the water had healing properties for sick people around and that the water tasted pure, that a bath had a very invigorating and refreshing effect, and that the water burst out in a tolerably strong jet. The skin bathing is practicing at Mtagata. There are no commercial usages of geothermal water but there are various opportunities ranging from domestic to industrial heating and the like once the resource is brought to the surface. The exploration for geothermal resources in plan is going in parallel with evaluating the direct use in the respective project areas.

6. NEW DEVELOPMENTS IN ACCESSING GEOTHERMAL EXPLOITATION SINCE 2012

There have been positive developments since 2012 when the Tanzania geothermal country update was presented in ARGeo-C4. Among the notable new developments are establishing the National Geothermal Task Force in 2012, prioritizing geothermal as one of the SREP project components and establishing the geothermal development company. Accordingly, geothermal is expected to be one of the main contributors to the country's energy mix.

6.1 Establishment of the National Geothermal Task Force in 2012

The National Geothermal Taskforce was formed in 2012 with the mandate of strategizing and advising the Government on how to accelerate geothermal development. The composition of the Task Force was multidisciplinary and multi-sectorial drawing members from government institutions, academia and the civil societies. Among others, the Task Force advised the Government to establish a dedicated company for spearheading development of geothermal resources in the country. The advice was taken by the government and implemented after consultation with other stakeholders, including development partners, and the geothermal company was established in December 2013.

6.2 Creation of enabling environment

Presently, there is no specific law governing geothermal development. However, with the intention of speeding-up geothermal power development, the government under SREP is formulating a legal and regulatory framework for geothermal. A tender has been advertised in 2016 for hiring a consultant for preparation of "geothermal strategy, legal, institutional and regulatory framework and risk mitigation and guarantee scheme". It is expected that private-sector will provide technical know-how and financing for development of geothermal power. The project is targeting to achieve 100 MW by 2020. The geothermal strategy, legal, institutional and regulatory framework, as well as the risk mitigation and guarantee scheme has been developed by September 2017. The documents are to be reviewed and subjected to government process enacted for practice.

6.3 Establishment of Tanzania Geothermal Development Company Limited (TGDC) in 2013

Tanzania Geothermal Development Company Limited (TGDC) was incorporated on 19th December 2013 as a public company, 100% owned by the government of Tanzania with the mandate of spearheading geothermal resources development in the country. Its duties among others include:

a) To undertake upstream geothermal resource assessment;
b) To sell steam to state and private owned generation companies;
c) To promote direct uses of geothermal energy;
d) To solicit financing for geothermal resources development; and

e) To cooperate with local, regional and international geothermal stakeholders.

TGDC has taken over the all duties that were previously under the National Geothermal Task Force but has much broader mandates including ability to collaborate or partnership with other entities or organizations that have technological, professional and financial capabilities to undertake capacity development, research, training and knowledge and skills transfer.

TGDC became operational in July 2014 by recruiting technical staff from the Ministry of Energy and Minerals, TANESCO and Geological Survey of Tanzania.

Among the priority areas TGDC is working on:

a) Developing a strategic plan (25 years horizon) that aligns TGDC plans with much broader national development plan;
b) Preparation of the 5 year business plan and action plan that guide the company performance and growth in 5 years;
c) Development of project pipelines according to the geothermal potential sites ranking.
d) Human Capacity development through formal training, on the job training, attachments to required skills and expertise;
e) Acquisition of equipment and tools, more importantly drilling rigs; and
f) Establishing relationships and cooperation with local, regional and international geothermal communities.

Currently, the company is owning prospecting rights over several sites countrywide, the main ones being Ngozi, Songwe, Natron, Kusaki, Natron, Luhoi and Mbaka-Kiejo.

7. PLANNED GEOTHERMAL DEVELOPMENT ACTIVITIES IN THE COMING 5 YEARS

7.1 Enabling environment for geothermal development

This work, which is funded under SREP, comprises development of geothermal development road map, legislation, and associated regulations for geothermal development; supporting institutional development planning. Terms of reference for engaging a consultant to undertake these works were completed in 2016 under AfDB support. The consultant has completed the work and submitted the required reports to the government.

7.2 Geothermal resource assessment and feasibility studies

7.2.1 Phase 1: Preliminary studies and preparation of geothermal Atlas

Surface studies on various geothermal sites include Luhoi, Natron, Ibadakuli, Takwa and Eyasi. These studies will appraise the sites for detailed studies. The geothermal Atlas has been prepared to guide the ranking and selection of suitable sites for detailed investigations. It is expected that the Atlas will be updated as new information become available.

7.2.1 Phase 2: Detailed exploration

These activities will comprise resource identification of high priority sites to select from 3 to 5 projects for further in-depth investigation. Ngozi prospect is the first priority project. TGDC has completed detailed surface study in Ngozi and Songwe prospects. The well targets have been identified in Ngozi geothermal prospect. TGDC is about to negotiate grant support from GRMF for undertaking drilling on Ngozi prospect and Songwe by other development partner. The surface study has been undertaken in

Kiejo-Mbaka and Luhoi with support from MFA/NDF. The next project is to package Kiejo-Mbaka for GRMF drilling program support, followed by Mt. Meru using BGR support.

7.3 Capacity building

Capacity building in terms of human skills and equipment is the cornerstone of sustainable geothermal development in the country. Tanzania is progressively developing strategic local capacity in terms of specific knowledge and skills relevant to exploration, development and utilization for supporting the geothermal development. As such, TGDC accords high priority to capacity building and it is currently preparing a grand plan for acquiring the required skills and equipment to enable it to execute its mandates.

8. DISCUSSION AND CONCLUSION

Recognising the potential contribution of renewable energy to the country's future energy mix, the Government of the United Republic of Tanzania is ambitious to foster the development of low-carbon energy initiatives through harnessing its renewable-energy resource base. Renewable energy, which is environmentally benign, can improve access to sustainable modern and cleaner energy services with the potential for contributing to job creation, income generation, and improved livelihoods of marginalised social groups, particularly women and children in rural areas. As one measure of climate change mitigation and adaptation, the government has developed the National Adaptation Plan for Action 2007 and the Sector Environmental Action Plan 2011–2016.

About legal and regulatory framework, the government has realised this set-back and has embarked on policy changes and creation of enabling environment including establishing legal and regulatory framework and streamlining institution framework. Among the results of these efforts is the formation of Tanzania Geothermal Development Company Limited (TGDC). The establishment of TGDC as a government vehicle has increased the pace toward making geothermal a reality in Tanzania. Within two to three years of existence, TGDC has completed detailed surface studies of geothermal projects (Ngozi, Songwe, Kiejo-Mbaka, and Luhoi) and is about to negotiate for GRMF grant for Ngozi drilling program; also intending to submit EoI for AR5 to GRMF for financing for Kiejo-Mbaka (DP) and Natron (SS). Presently, the government has short listed the consultant firms for test drilling at Ngozi and Songwe to confirm the availably of commercial geothermal resource for power generation and direct use.

There are still challenges in developing geothermal resources in the country, the main ones being inadequate human capacity and equipment. There are few people in Tanzania with formal training in geothermal energy. The immediate solution is to utilise all available experts locally and hire expertise from outside while extensive training programs are underway to develop the required people.

At present, absence of appropriate legal and regulatory framework that addresses specific geothermal peculiarities is a challenge but under the SREP this challenge will be solved and the private sector risk averseness will be addressed in order to attract them in investing in the development of geothermal energy projects.

The government is and has been improving the conditions catalysing geothermal development. But it is known that initial exploration phase for geothermal energy, before confirming the potential by well drilling, is perceived to be risky and capital intensive, thus unattractive to the private investors. That is why the government has stepped in to form a public company that will take care of the upstream exploration works. The government alone can support the preliminary exploration works which include drilling of exploratory wells to confirm the resource. It is expected that the current practice where public funds from the government, development partners and concessional loans will unlock geothermal development by taking part to finance the initial phases of geothermal projects. Given the above plans, strategies, programs and efforts, the future of geothermal development and utilization seems to be bright in Tanzania.

ACKNOWLEDGMENTS

The author would like thank the UNU-GTP for organizing this useful training and support given to TGDC in attending this course. Also thank GDC and KenGen organizers for their tireless capacity knowledge transfer to trainees.

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