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GEOTHERMAL DEVELOPMENT IN TANZANIA – AN UPDATE

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ABSTRACT

Tanzania's categorization into middle income economy is an indication that the country is progressing well with its efforts to achieve the goals set in the National Development Vision 2025 (TDV 2025). The sustainability of the achieved economic development requires to a large extent energy security by having adequate, reliable, modern and affordable energy supply. Such energy security can only be attained through diversified sources. Currently, Tanzania's grid power generation mix comprises: natural gas (57.3%); hydro (36.5%); liquid fuel (5.6%); and 0.7% biomass. Harnessing the country's geothermal resources, which are estimated to exceed 5,000 MW of electricity and 15,000 MWof thermal, will contribute to the country's energy security. Geothermal energy's value as a clean, renewable, base-load, indigenous and abundant energy source provides a unique opportunity to support the national future energy needs, in terms of energy security for industrialization and climate change concerns. The country's target is to connect to the grid 200 MW of electricity from geothermal by 2025 and several megawatts thermal for fuelling various direct use projects. Currently, five flagship geothermal projects are being implemented, out of which four (Ngozi, Songwe, Kiejo-Mbaka and Luhoi) have reached the phase of drilling deep exploratory wells (1,000-3,000m) to confirm the resource; whereas one project (Natron) is at the surface exploration stage. The consultant responsible for planning, supervising and managing the exploratory drilling programme for the Ngozi project is on site; while procurements of drilling equipment, tools and materials are proceeding. In order to put near surface geothermal resource in social and economic use, three (3) geothermal shallow wells (<300m) have been drilled in Kiejo-Mbaka geothermal field, where two out of them are discharging hot water (75°C) at a rate of 100 l/s. Several geothermal direct heat application technologies including drying of crops and vegetables, fish drying, chicken hatching, milk pasteurization, tea processing, balneotherapy and greenhouse heating are being considered for socio-economic use at Kiejo-Mbaka and Songwe. Among the developed geothermal technologies is a real-time hot spring logger technology which is being tested to fast-track data collection and minimize cost. This paper aims at presenting the status of the implementation of ongoing geothermal energy development projects, direct heat uses, and technologies development through ongoing research and innovation.

1. INTRODUCTION

Tanzania's vision 2025 has identified the energy sector as one of the driving forces in supporting economic growth and improving quality of livelihood of the people, as the country transforms into a middle income and semi-industrialized economy. Tanzania is replete with geothermal resources, which presents an opportunity for transformation of its energy sub-sector by diversify the power generation mix and increasing access of modern energy in a sustainable way. Geothermal direct heat utilization will stimulate directly economic and social development of communities around the projects and catalyze development of other sectors of the economy such agricultural, aquaculture, industrial, tourism, livestock and health. Such uses could include drying of crops, greenhouse farming, fish farming, poultry and husbandry, space heating, balneology, and recreation. The geothermal resource of Tanzania is estimated to exceed 5000 MW, which is expected to contribute 200 MW electricity to the national grid by 2025, as a short-term target as well as several megawatts thermal for fueling other sectors of the economy.

2. SET-UP AND ADMINISTRATION OF TANZANIA ENERGY SECTOR

The country energy sector is administered by the Ministry of Energy which is responsible for providing sectorial leadership and policy direction. The energy sector is branched into two arms: Electricity and Renewable Energy; and Petroleum and Gas. Geothermal development is under the electricity and renewable energy sub-sector, which further branches into three main arms, namely the Ministry, Regulator, and the Implementer (Generation, Transmission and Distribution).

The electricity and renewable energy sub-sector is regulated by Energy and Water Utilities Regulatory Agency (EWURA) established under the EWURA Act Cap 414 of the laws of Tanzania. It is responsible for technical and economic regulation of the electricity, petroleum, natural gas and water sectors in Tanzania. In the line of electricity supply industry, EWURA regulates the whole supply chain from generation, transmission and distribution to supply and cross-border electricity trading activities. It is responsible for licensing and registrations, providing regulatory tools (Rules, Codes, Guidelines, Manuals and Declarations), power purchase agreements, compliances as well as promoting efficiency and effectiveness electricity services and supplies (Electricity Act, 2008; EWURA Act, 2006). The key players in the implementation of the electricity and renewable sub-sector are Tanzania Electric Supply Company Limited (TANESCO), Tanzania Geothermal Development Company Limited (TGDC), Rural Energy Agency (REA) and Independent Power Producers (IPP). TANESCO is the national power utility responsible for electricity generation, transmission, and distribution and is the main off-taker. TGDC is wholly owned by the government through TANESCO and is solely mandated with spearheading geothermal resources development in the country. REA, established under the Rural Energy Act (2005), is responsible for the promotion of improved access to modern energy services in the rural areas. In addition to its generation, Tanzania through TANESCO buys electricity in bulk from Independent Power Producers (IPP) and from cross-border trade. Figure 1 illustrates the administration set-up of the electricity and renewable energy sub-sector.

2.1 Electricity and renewable energy sub-sector

Tanzania has an installed capacity of 1,601.8 MW of which 1,565.7 MW is connected to the national grid. The main sources are hydropower, which contributes 36.6%, natural gas contributing 57.0%, liquid fuel (HFO and diesel) 5.7%, and 0.7% biomass (Figure 2). TANESCO generation accounts for 86.5% of the total generation while 13.5% comes from the IPPs. TANESCO also owns off-grid generation which provides power of about 36.1 MW to the isolated areas.

The electricity demand in Tanzania is growing in the range of 10% to 15% per annum and is expected to increase even more due to ongoing countrywide rural electrification program, rapid growth of new

industries and implementation of major infrastructure. The renewable, reliable and affordable energy contribution is vital in counteracting the situation, geothermal being among the potential sources. The national generation target is to generate 10,000 MW by 2025 and geothermal will contribute 200 MW in arching the national target (MEM, 2020).

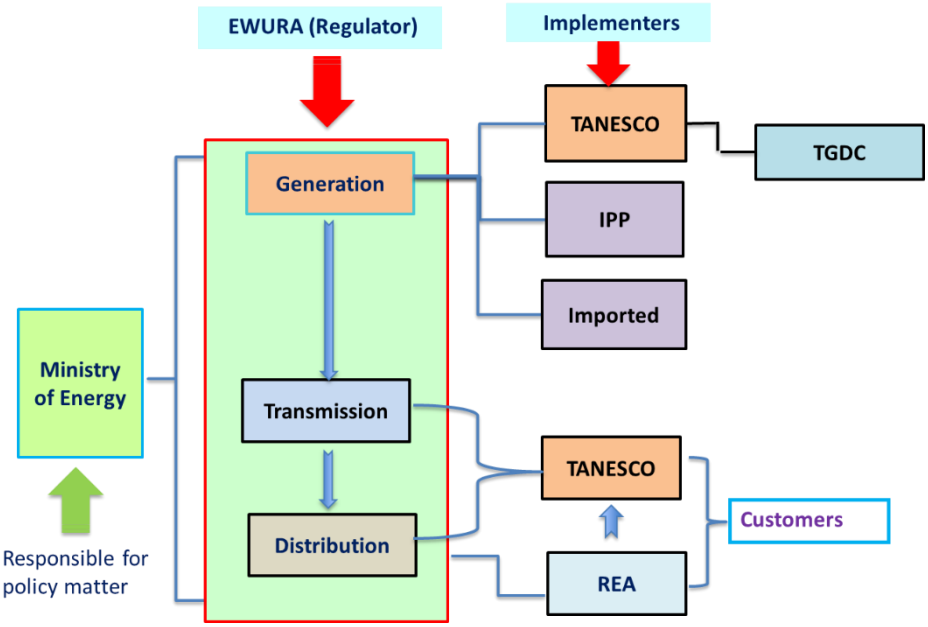

FIGURE 1: Set-up of the Electricity and Renewable Energy Sub-Sector in Tanzania

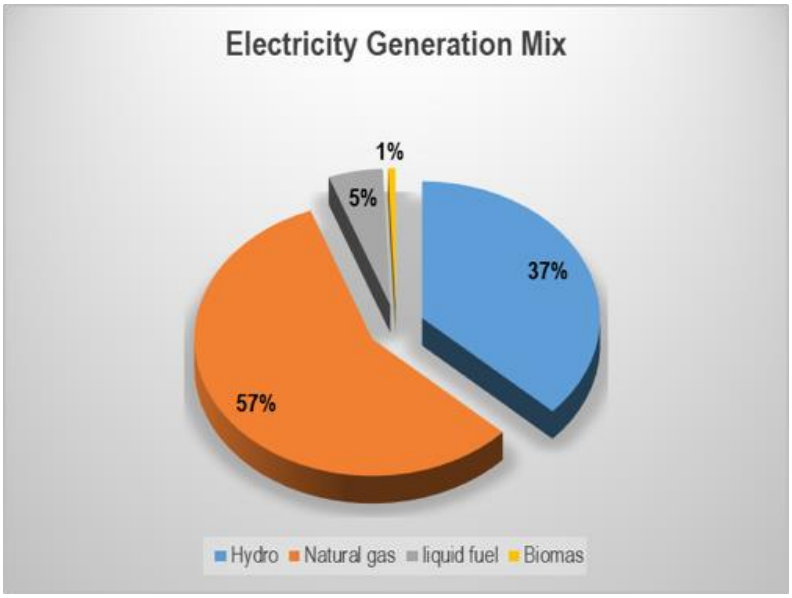

FIGURE 2: Electricity generation mix

3. GEOTHERMAL DEVELOPMENT JOURNEY IN TANZANIA

The geothermal development journey in Tanzania started in the 1970s with several scientific studies along the East Africa Rift System (EARS) conducted by Geological Survey of Tanzania. In 1976 to 1979 Swedish International Development Agency (SIDA) funded reconnaissance exploration for geothermal in Tanzania which was conducted jointly by Sweden Consulting Group (SWECO) and

Virkir-Orkint Consulting Group. In the study 50 hot springs from Northern Tanzania and Mbeya were investigated whereby high and low temperature hot springs were identified for further studies.

Based on previous study recommendations, several other reconnaissance studies were conducted across the country between 1983 and 2004 (McNitt, 1982; Hochstein et al., 2000) which generally identified potential geothermal areas for detailed surface explorations. The SW Tanzania (Mbeya region) which belong to the Rungwe volcanic province being among the prominent sites for geothermal. The studies also identified Luhoi in Rufiji basin along Coast Region, about 150 km from Dar es Salaam.

DECON (2005) under funds from African Development Bank (AfDB) through rural electrification study undertook a survey in Mbeya and Natron which suggested Mbeya areas for further geothermal investigations while geothermal energy was regarded as among the most suitable indigenous source of power which could supply the rural communities. Between 2006 and 2013, jointly BGR (Federal Institute for Geosciences and Natural Resources of Germany), TANESCO, the then Ministry of Energy and Minerals of Tanzania (MEM), and GST (Geological Survey of Tanzania) conducted surface explorations (geology, geochemistry and geophysics) in Mbeya region under the GEOTHERM project. The study concluded that Mbeya area has two types of geothermal systems. High and medium enthalpy geothermal systems to the North and South of Ngozi volcano respectively. Further study by UNEP, 2017 revealed that Ngozi and Songwe (grouped to northern system) are separate geothermal systems which further proposed drilling of three temperature gradient holes to study the temperature pattern while increasing confidence of the developed geothermal conceptual model. The study also extended to hot springs in the Southern part of Rungwe Volcanic Province at Kiejo.

In 2013, the Government underlie the strategy of energy mix by diversifying energy sources of which renewable energy has a significant role to play. Releasing this, the development of geothermal resources was inevitable and demand for a purely dedicated entity to spearhead the development aroused. Tanzania Geothermal Development Company Limited (TGDC) was finally established in December 2013 and operationalized in July 2014. Since its establishment, TGDC has been working to appraise most of the geothermal prospects to a level of confirming the resources as the measure to de-risking the fields for further investments. Four (4) flagship prospects (Ngozi, Songwe, Luhoi and Kiejo-Mbaka) have advanced to resources confirmations through test drilling with current implementation of drilling programme in Ngozi project. TGDC is also undertaking several direct use pilot projects in Songwe and Kiejo-Mbaka as well as innovations of technologies to support other economic sectors. Figure 3 below summarizes the geothermal development journey in Tanzania highlighting the major milestones.

3.1 Geological settings of geothermal resources in Tanzania

Tanzania is among the countries that belong to the Eastern Africa Rift System (EARS), with significant geothermal potentials. Estimates using theoretical approach indicate a potential exceeding 5,000 MW but not yet exploited commercial use. Most of geothermal prospects have distinct surface manifestations, mainly hot springs. Geothermal explorations in the country have identified and grouped four main geological settings where the geothermal resources are hosted (Figure 4).

(i) South-Western and Northern volcanic provinces: comprises young volcanos situated along the EARS at the southern trip junction where the eastern and western branches converge. The Northern Province is located in the eastern branch of the EARS. The zones have huge potential of medium to high temperature geothermal systems that includes Ngozi, Songwe, Kasimulu, Kiejo- Mbaka, Eyasi, Natron, Manyara, and Meru.

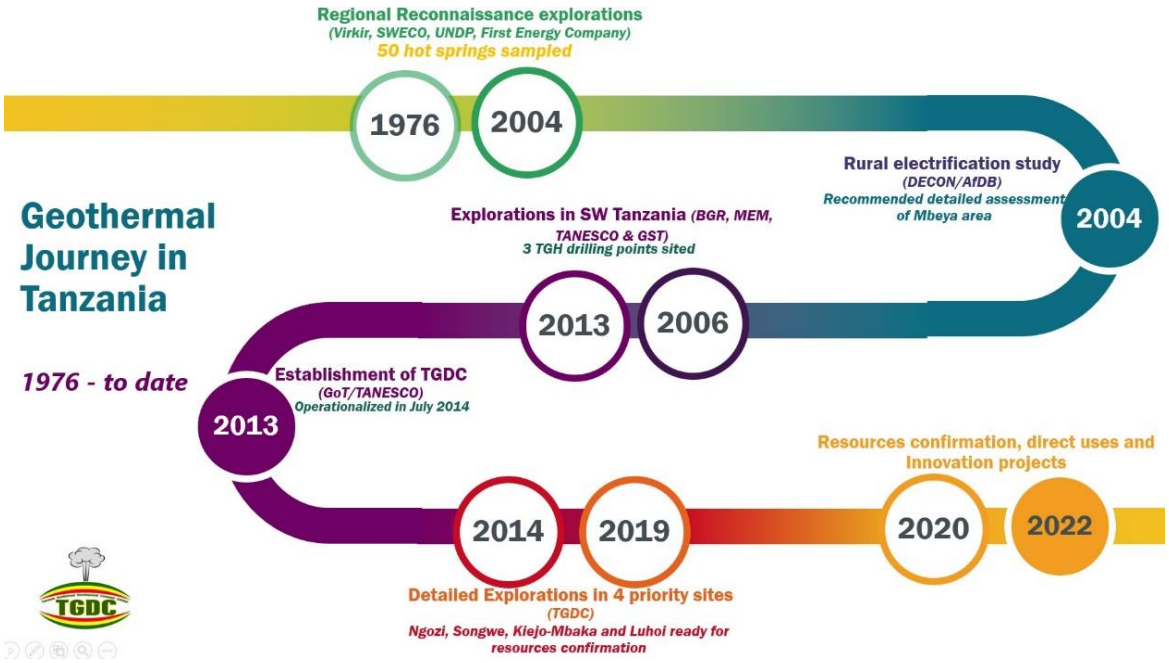

FIGURE 3: Geothermal development journey in Tanzania

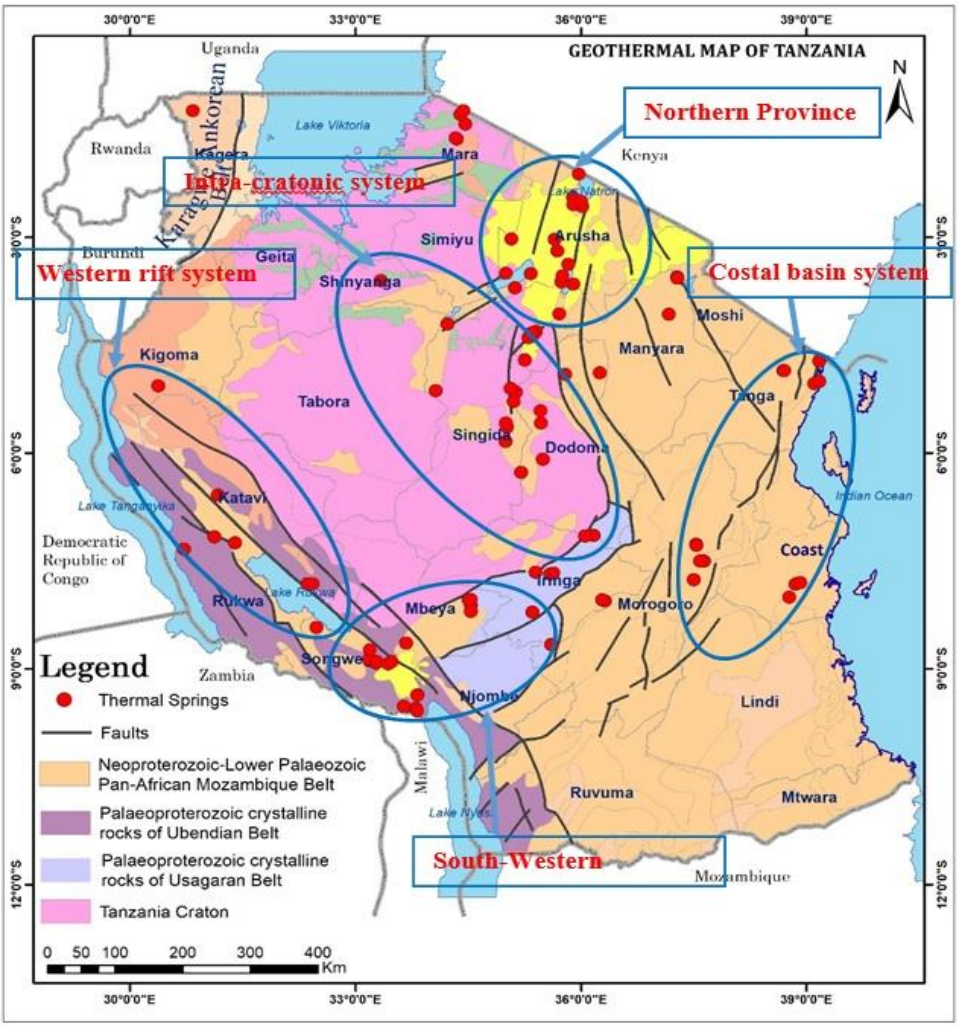

FIGURE 4: Geothermal occurrence in Tanzania depicted in a simple geological map

(ii) **Coastal basin geothermal systems:** includes geothermal resources in Morogoro, Coastal and Tanga regions. The occurrence is associate with coastal sedimentary basins, mainly fault hosted systems. Some of the geothermal prospects occurring in the coastal basins includes Kisaki, Tagalala, Mtende, Luhoi, Utete, Bombo, Kidugalo and Amboni.

(iii) **Intra-cratonic 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 including those occurring in the intracratonic rift basins of the Tanzanian craton. They are likely fault hosted, low to medium temperature geothermal systems. Such prospects are Mponde, Takwa, Hika, Gonga, Msule, Isanja, Ibadakuli, Balangida, Kondoa, Balangidalalu, Mnanka, Nyamosi and Maji Moto-Mara.

(iv) **Western rift geothermal systems:** occurring in the western branch of the EARS which is seismically. Some prominent features in the western rift includes Lake Tanganyika which is the deepest lake in Africa. Some of the geothermal prospects in this zone includes Mtagata, Maji moto-Rukwa, Mapu, Ivuna and Rock of Hades.

3.2 Development strategy for geothermal

The existing energy relevant policies and strategies such as Energy Policy (2015) and PSMP (2016 Update) acknowledge geothermal potential and set out national targets for development of the resources. The Government is therefore implementing its geothermal development efforts through TGDC, a national geothermal company and a sole geothermal developer dedicated to spearhead geothermal resources development. In realization of its role, TGDC is operating under 25 years Strategic Plan (TGDC 25yrs SP, 2017) which depicts the growth path and guides the company business decision and processes in the 25 years horizon. The Strategy has been linked and harmonized into the geothermal energy development goals and targets with that of the broader national economic and sector development. The country's short-term target is to contribute 200 MW electricity generated from geothermal resources into a national grid by 2025 which has been highlighted in the Power System Master Plan of 2016 Update (MEM, 2016) and TGDC's 25 years Strategy is aligned with the national target. The Strategic plan is broken down into 5 years rolling Business Plan which allows the company to focus and drive implementation of its strategy into 5 years phases.

In order to meet the 200 MW target, TGDC identified four (4) focus areas for concentration in the next 25 years which are (i) financial sustainability, (ii) build up research and development capabilities, (iii) create a conducive enabling environment, and (iv) strong organization capabilities in terms of human resources and equipment. These focus areas reflect well TGDC mandates as a way to ensure compliance to relevant regulatory framework and alignment to national development agenda while providing confidence stakeholders that TGDC is moving in the right direction. The focus areas provide TGDC a basis on which to articulate its strategic intent in terms of high-level strategic objectives and targets. The execution of strategic objectives and targets are the means through-which TGDC will realize success in the four focus areas and finally meets its goals.

3.3 Implementation of geothermal projects

For achieving 200 MW generation by 2025, five (5) priority projects to flagship geothermal projects have been earmarked for development in the country. These projects are Ngozi, Songwe, Kiejo-Mbaka, Luhoi and Natron. Four projects (Ngozi, Songwe, Kiejo-Mbaka and Luhoi) out the five have advanced to resources confirmation by test drilling programme. Natron project is still under surface exploration stage. The country is also mobilizing the resources as its efforts among others to make it happen while different approaches are implemented for each project with the intention to shorten time. Briefly, current status of each project is herewith highlighted under the subsections below.

3.3.1 Ngozi project – South-Western Tanzania

The Ngozi project is ranked as one of the most promising fields and therefore stands as a mostly country's geothermal flagship project. It is located within Rungwe Volcanic Province (RVP), South-Western Tanzania, at a triple junction of the Eastern and Western arms of the Eastern African Rift Valley. The primary geothermal features are thermal water discharges (up to 89°C) on the bottom of the Ngozi crater lake. The estimated reservoir temperature of the Ngozi field is 232 ± 13 °C which is classified as high temperature volcanic liquid-dominated system, suitable for both power generation and direct heat projects. Stepwise extension is recommended as sustainable development approach while monitoring the reservoir responses to production. It is therefore, TGDC intension to develop the 30 MW geothermal power project as initial phase and increasing generation as per the reservoir responses.

The project is currently under the test drilling phase that will see TGDC drill its first three (3) geothermal slim wells in 2021. The test drilling programme is co-financed by the Government of Tanzania and the Geothermal Risk Mitigation Facility (GRMF). The programme implementation is underway of which drilling consultant who is responsible for planning, designing, supervising and managing the drilling programme and development of infrastructure to support drilling operation is on site for contract implementation. Relevant permits like the EIA certificate, water rights, way leave accesses have been obtained for the project. Infrastructures (access roads, water supply) development – maintenance and new constructions are in final preparations prior to actual works. The contract for procuring TGDC own rig capable to drill slim wells has been signed in this November and the rig will be delivered in June next year. This is the strategic country decision that since TGDC as a national geothermal company will have a lot of test drilling activities to confirm geothermal resources round the country, therefore it is wise to develop capacity in terms of drilling (human capacity and equipment). Other procurements like drilling contractor, materials etc. are expected for the launch in the first quarter of the 2022.

3.3.2 Songwe Project – South-Western Tanzania

Songwe geothermal field is located in Songwe Region, just North-West of Ngozi field. It is categorised as a low to medium temperature resource (112 ± 16 ºC) fault-controlled system, more suitable for direct heat uses project and binary power plant.

The Songwe project being more suitable for direct heat application, is now approached as a demonstration site for the direct heat uses projects. This approach is taken to fast-track the implementation of direct uses projects so as to contribute to the Nation's development vision 2025 which envisages to transform the country into a modern economy with high level of human development. Using directly geothermal energy from available resources in the country to fuel multi sectorial projects piloted and tested at Songwe will bring that impact directly to the communities around. Different projects from different economic sectors like agricultural, aquaculture, industrial, tourism, livestock and health will be implemented in Songwe in small scale and tested before full commercialization or application to other sites. This approach will also help TGDC to promote and introduce geothermal products and technologies into the markets that will have direct impact to the potential service providers, suppliers, investors and consumers.

To start with, TGDC has now ventured into development of the demonstration recreation center, greenhouse and fish farming at Songwe using hot water surface runoff directly from the hot springs. The center comprises of two geo-spas (38-43°C temperature range) of surface areas 5 m^2 and 40 m^2; depths of about 0.7 and 1.5 m taping geothermal heated water from one of the naturally flowing hot springs with an average temperature of 70°C. A demonstrating greenhouse and fishing pond are also built in the area which utilize one of the warm springs in the area. Figure 5 below shows the Songwe geo-spas and greenhouse.

FIGURE 5: Demonstration small geo- spas (top), view point (bottom left), and greenhouse (bottom right) at Songwe geothermal field

The work that is ahead TGDC plans for the first quarter of year 2022 is to finalize the constructions, testing and assessing for their viabilities technically, financially, economically, environmentally and socially for commercialization into large scale projects. The projects also justify the need for drilling of shallow wells for sustainable hot water flows to fuel the direct uses projects.

3.3.3 Kiejo-Mbaka Project – South-Eastern Tanzania

Kiejo-Mbaka geothermal field is located in the Southern part of the Rungwe Volcanic Province (RVP) which hosts Ngozi, Rungwe and Kiejo volcanoes in the South-West of Tanzania. It is another medium temperature system with estimated reservoir temperature around 140°C which is suitable for power generation and direct heat projects. Hot springs discharge in the areas of Kilambo, Kajala and Ilwalilo with temperature ranging 59 – 64°C are the main geothermal manifestations of the Kiejo-Mbaka system. The project approach is very different from the Ngozi and Songwe which is being fast-tracked by firstly drilling three (3) shallow wells at the maximum depth of 300 m each (Figure 6). The primary objective of the drilling being to obtain more subsurface information for the purpose of refining the conceptual model and increase confidence of the resource before embarking to exploratory drillings programme. The secondary objective is access hot geothermal fluids at a shallow depth with minimum temperature enough to fuel the direct heat uses projects to support local communities' economy and wellbeing.

The shallow drilling programme utilized local drilling contractor applying diamond drilling with final HQ diameter which allow collection flow of geothermal fluid for direct uses projects. The programme was kicked off in March 2021 and lasted for a period of 18 weeks. To date three (3) geothermal shallow wells (<300m/75°C) have been drilled in Kiejo-Mbaka geothermal field, where two out of them are well discharging hot water (75°C) at a rate of 100 l/s.

FIGURE 6: Simplified map showing well locations (top left) and drilled wells photos at Kiejo-Mbaka geothermal field

3.3.4 Luhoi Project – Eastern Tanzania

Luhoi geothermal field is located in the 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 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. From the detailed surface exploration conducted in 2017 (ELC, 2017), the results indicated that 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.

In the surface study conducted in 2017 by ELC, the initial assessment of direct uses applications viability at Luhoi field was also conducted based on the needs of the local population to solve the economic and social challenge around. The assessment came out with project scheme under cascade comprising of four main components namely water treatment (pasteurization), food and vegetables drying, greenhouse heating and fish ponding. The component will be connected in cascade but independently from one from the other, which allows separation or partially by-passed from the scheme of any component if found no longer interesting without significant effect of other components (Figure 7).

3.3.5 Natron Project – North-Eastern Tanzania

Natron geothermal prospect is located within the Eastern arm (Gregorian Rift) of the East African Rift System (EARS) or Natron Rift which has recorded the complex history of faulting, sedimentation and volcanism. The photo presented as Figure 8 depicts the geothermal manifestations at Natron geothermal prospect. The prospect has been studied to preliminary surface exploration. TGDC is now aiming to conduct a detailed exploration progamme with the aim to confirm the existence and location of a

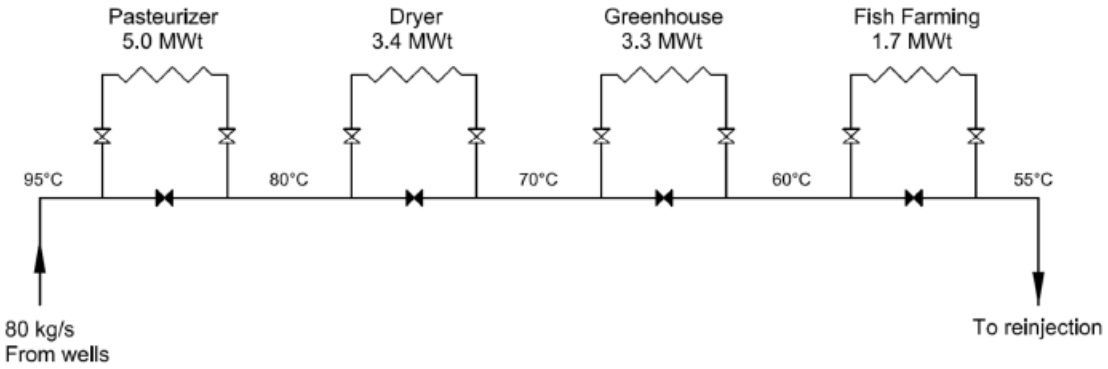

FIGURE 7: Schematic flow diagram of Luhoi direct uses application project scheme

geothermal system, extent of heat source and hydrogeological patterns, characteristics of geothermal fluids in the system and eventually develop the conceptual model to describe the geothermal system at Natron and finally siting of wells for the exploratory drilling.

The project timelines are expected to commence during the financial year 2021/22 and are currently under financing mobilization from the Government as internal source while the external sources is expected to be GRMF.

FIGURE 8: Photo showing Natron geothermal prospect

3.4 Innovation and technology development

In the area of innovations, TGDC has developed an egg incubation technology that utilizes energy from geothermal heated water. This was motivated by need of simplifying egg incubations in terms of cost and natural way as it is naturally. The technology has been developed locally with TGDC's internal capacity. It is a high-tech and automated controls and monitoring all the parameters with a capacity of 240 eggs per incubation. Five tests of the geo-incubator have been conducted so far with success rate of over 90%. Figure 9 shows chicks incubated by the geo-incubator.

FIGURE 9: Pictures showing chicks hatched from the geo-incubator

Tanzania has also been able to develop a data logger for measuring hot spring parameters: temperature and flow rate. The equipment is able to log, store and transmit data from the hot springs remotely to a computer or send mobile phone messages at the time interval of choice, e.g. hourly, daily or monthly. Alongside flowrate and temperature, the logger sends coordinates of the location, time and date, ambient temperature and internal electronic system temperature. The technology has been tested with successive rate of more than 85%, and now is under improvement to include other important geothermal parameters like the chemistry of the hot spring water. Figure 10 shows a graph of the hot spring flow data obtained during the test.

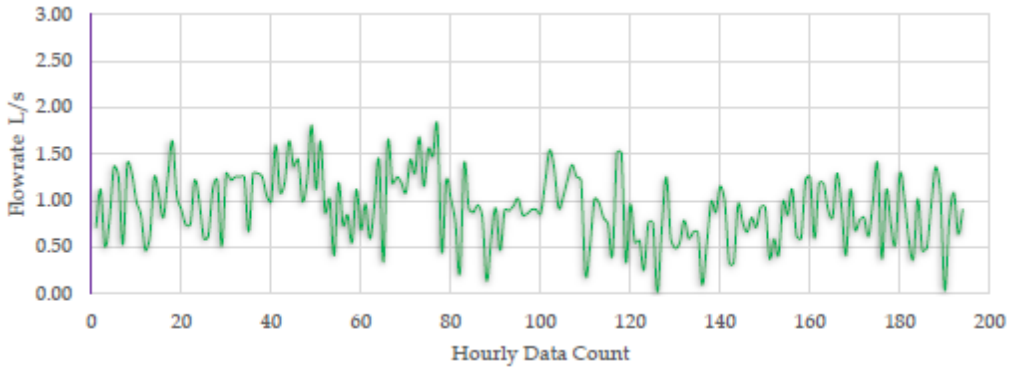

FIGURE 10: Hot spring flow rate measured by the spring logger during the testing period

3.5 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 set it apart from other renewable sources, and over the other sources of energy. These include among others, resource identification and ownership, accessibilities, investment risks as well as resources uncertainty which require sufficiently accurate resource assessment and evaluations to reduce risks and uncertainties. Other unique feature is an inability to access global markets as a commodity (as e.g. oil, minerals and gases) which are freely and transparently priced; unlike geothermal which can be utilized and sold into energy market with localized specific regulations and price.

These unique features require creation of suitable legal and regulatory environment for sustainable development of geothermal resources. The aim here is to strike a balance between resources owner's (public) benefits, investment risks, environmental managements and community impacts. The Government is evaluating alternative options for geothermal regulatory environment, whether by

enactment of specific geothermal law or integrating geothermal with other existing laws. Among other issues, the legislation is expected to address the challenges pertaining to definition of geothermal, and licensing for geothermal development and utilization.

4. DISCUSSION

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

Preparations for test drilling at Ngozi geothermal prospect are in progress whereby processes for engaging the supervising consultant has been completed and procurement of drilling rig and materials is ongoing. Relevant permits such as environmental certificate, water use permit, and way leave access have been obtained, thus providing the rights to infrastructure development (access roads and water supply) and test drilling.

Songwe prospect is being developed as a demonstration site for non-electrical utilization. Pilot projects (geo-spa, greenhouse, fish pond, egg hatchery) have been developed using existing hot water from natural flow of hot springs in the area. TGDC is proceeding with development of geothermal direct use projects, testing and assessing for their viabilities technically, financially, economically, environmentally and socially for commercialization into large scale projects. Scaling up of direct use is envisaged after execution of drilling of shallow wells to increase hot water flows for running the projects. The Kiejo-Mbaka project is being implemented in three stages, i.e. shallow wells drilling followed by direct heat uses projects and deep exploratory drillings. Luhoi and Natron are scheduled for implementation after the three flagship projects (Ngozi, Songwe and Kiejo-Mbaka) to avoid spreading of the resources.

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, agricultural, animal husbandry aquaculture, tourism and recreation.

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

5. CONCLUSION

Geothermal development journey in Tanzania has taken a huge milestone since the establishment of Tanzania Geothermal Development. Many achievements have been registered and many initiatives are ongoing to ensure realization of the 2025 target of connecting 200 MW to the national grid. The country acknowledges support and contribution from local, regional and international stakeholders towards development and utilization of its treasure.

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