

Geothermal Prospects in Zambia – Country Update

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ABSTRACT

Zambia is endowed with a range of energy resources, particularly woodlands and forests, hydro, coal and renewable energy sources such as geothermal, wind and solar energy. During the period under review, Zambia's electricity generation mix was predominantly hydro which accounted for 83 percent of total installed generation capacity. The rest of the generation mix was composed of coal (10%); HFO (4%); diesel (3%); and solar was less than 0.1 percent.

With over 90 hot springs and five pre-selected sites, government is currently trying to mobilize funds for surface studies for the five geothermal prospecting sites such as Chongo and Kapishya in the Northern part of Zambia and Lubungu/Mupiamanzi in the western part of the country and Chinyunyu in the east respectively. Reconnaissance Studies and Stakeholder Engagement Plans (SEPs) have also been conducted for all these sites.

Kalahari Geothermal Company, a private developer has however advanced with their studies in Bwengwa troughs in Lochinvar in the southern part of the country. The studies have advanced with plans to commence Pre-feasibility drilling at an expected budget of **US \$2.2 million** to provide data to allow for increase in confidence in the resource, the location of the reservoir, flow zones etc. needed for feasibility studies. The plan to drill a depth of 1,000-1,100m, intersecting basement contact approximately 500m downhole. Targeted to intersect buried zone which contains the reservoir. (29th Geothermal Steering Committee Meeting,, 2018)

During period under review, our national demand has increased and still on the raise due to industrial development as evidenced by the escalating power demand in the mining sector shown in the figures below.

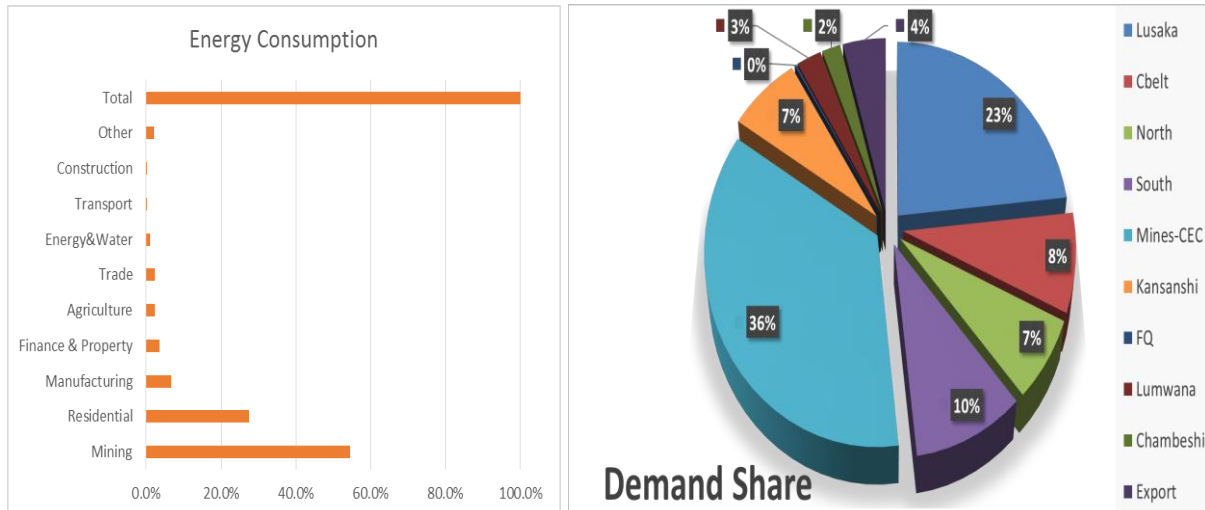


Figure 1: Current power demand and energy consumption by sector. (Board, 2017)

According to the vision 2030 of increased access, our load focus as a country is projected as shown figure 2 below. From the figure below it is clear that our load is growing annually and therefore energy mix is a solution to achieve a sustainable and equilibria environment.

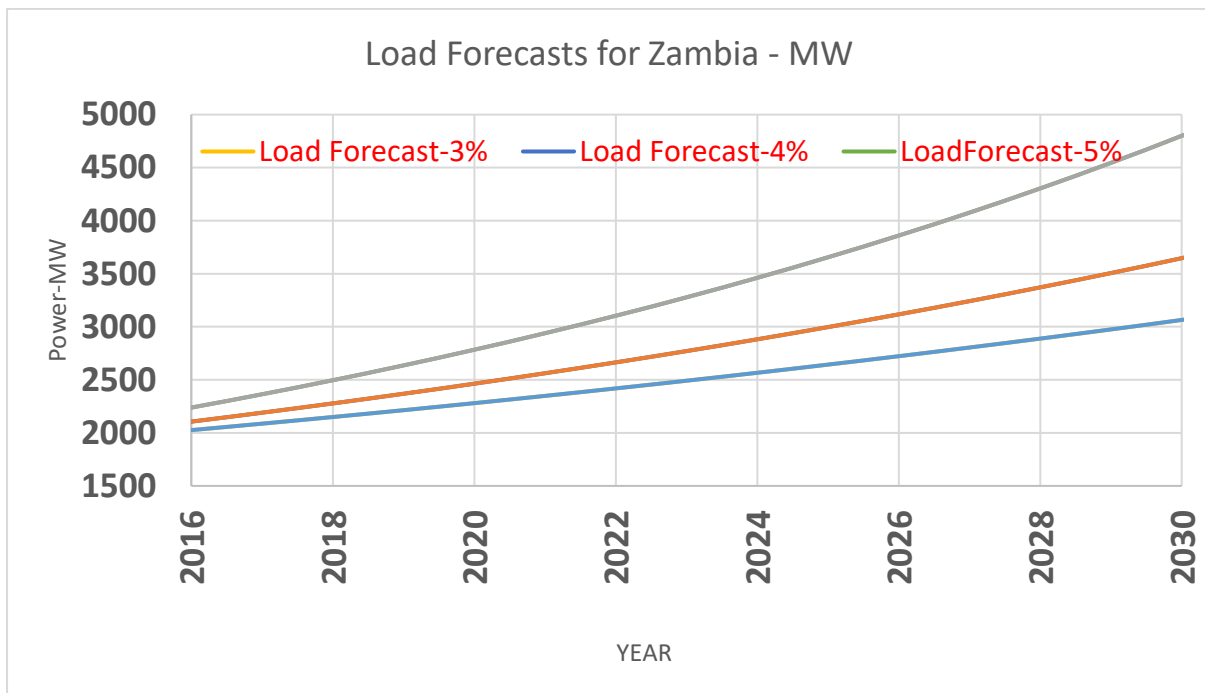


Figure 2: Load focus for Zambia up to the year 2030).

1. Introduction

Zambia belongs to the western branch of East African Rift System (EARS) which develops from Uganda throughout Lake Tanganyika, where it joins the Eastern branch, following the border between Rwanda and Democratic Republic of Congo (DRC). (LEGG, 1974). Zambia does have EARS associated geology and geothermal systems in the Northern part of the country (Kapishya and Chongo hot springs). The western branch is characterised with low enthalpy and much less active in terms of volcanism although both branches are seismically and tectonically active today. This is evidenced from the Kafue trough, Mupiamanzi and Lubungu. Lubungu site just like Kafue trough is a Karoo-area which pulls part of the extensional basin which is still seismically active. A private developer in the name of Kalahari GeoEnergy Ltd is exploring the site for geothermal electricity generation and are at full feasibility stage with the conceptual model indicating more than 20MW potential power capacity. Four sites have been defined and are prospecting to be defined a projects after reconnaissance studies were conducted last year. As a government we wish to commence detailed surface studies for (Chongo, Kapishya, Lubungu and Chinyunyu) ready for surface studies should we have an opportunity for financing.

2. Status of Electricity Production in Zambia

The power generation mix comprised of large, small and mini power generation stations. ZESCO Limited a national utility owns the bulk of the generation stations (hydropower plants) while the rest were owned by Independent Power Producers (IPPs). The national installed capacity increased by 2.5 percent to 2,897.21 MW in 2017, from 2,826.91 MW in 2016. The increase was due to the expansion of Ndola Energy HFO power plant by an additional 60 MW and Musonda Falls power station upgrade to 10 MW. (Board, 2017) The table below gives a summary of the power generation scenario for Zambia which is highly dependent on hydropower as can be seen.

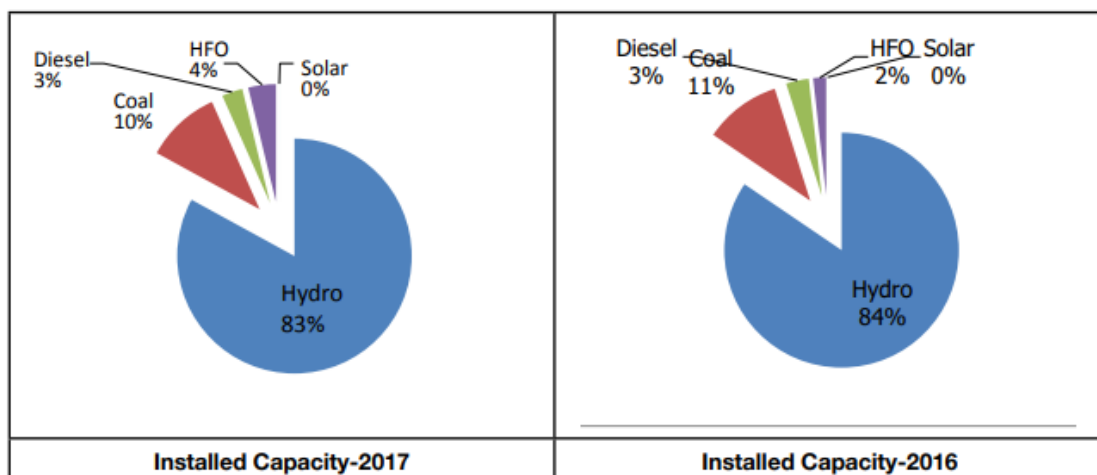


Figure 3: Power generation status in Zambia. (Board, 2017)

The above power generation contributions mainly from hydropower generation does not include thermal power from geothermal plants even with a 200Kw Kapishya geothermal which was never commissioned due to lack of power evacuation facility at that time. This is because all prospecting sites are still under studies with the most advanced by Kalahari GeoEnergy Company.

2.1. Medium and long term power development plan

During the period under review, the power sector continued to grow with new investments in generation and other infrastructure projects. Notably, the Batoka Gorge Hydro Electric Power Scheme is expected to be launched in the near future. The project is estimated to cost US\$ 6 billion and is expected to produce 2,400 MW to be shared equally between Zambia and Zimbabwe. Further, the Kafue Gorge Lower (KGL) project which is expected to produce 750 MW recorded steady progress, 86MW Lusiwasi Lower and Lusiwasi Upper with 15MW and Chishimba falls Power plant to be upgraded to 15MW respectively. In the renewable energy sector, we have geothermal planned implementation capacity of 50MW from the preselected sites after studies are concluded, 250MW solar PV under Scaling Solar program, 200MW Solar PV and 150MW Wind power under ZESCO Limited and MASEN of morocco under the Renewable Energy MOU.

2.1 Status of Geothermal Development in the country

In order to tap into the available opportunity arising from many geothermal potential sites with various surface and sub-surface manifestations like hot springs, ZESCO Limited has prioritised five geothermal potential sites with the intention of subjecting them to full surface studies. These sites were arrived at after a review of all the studies that have been done previously by (LEGG, 1974). Measurements of water temperature, discharge and radioactivity were made, the geological setting briefly studied, and samples of water and chemical deposits collected for analysis. More detailed investigations were made at a few springs of outstanding interest. The map below shows hot springs in red with the five preselected sites given in the table below the map.

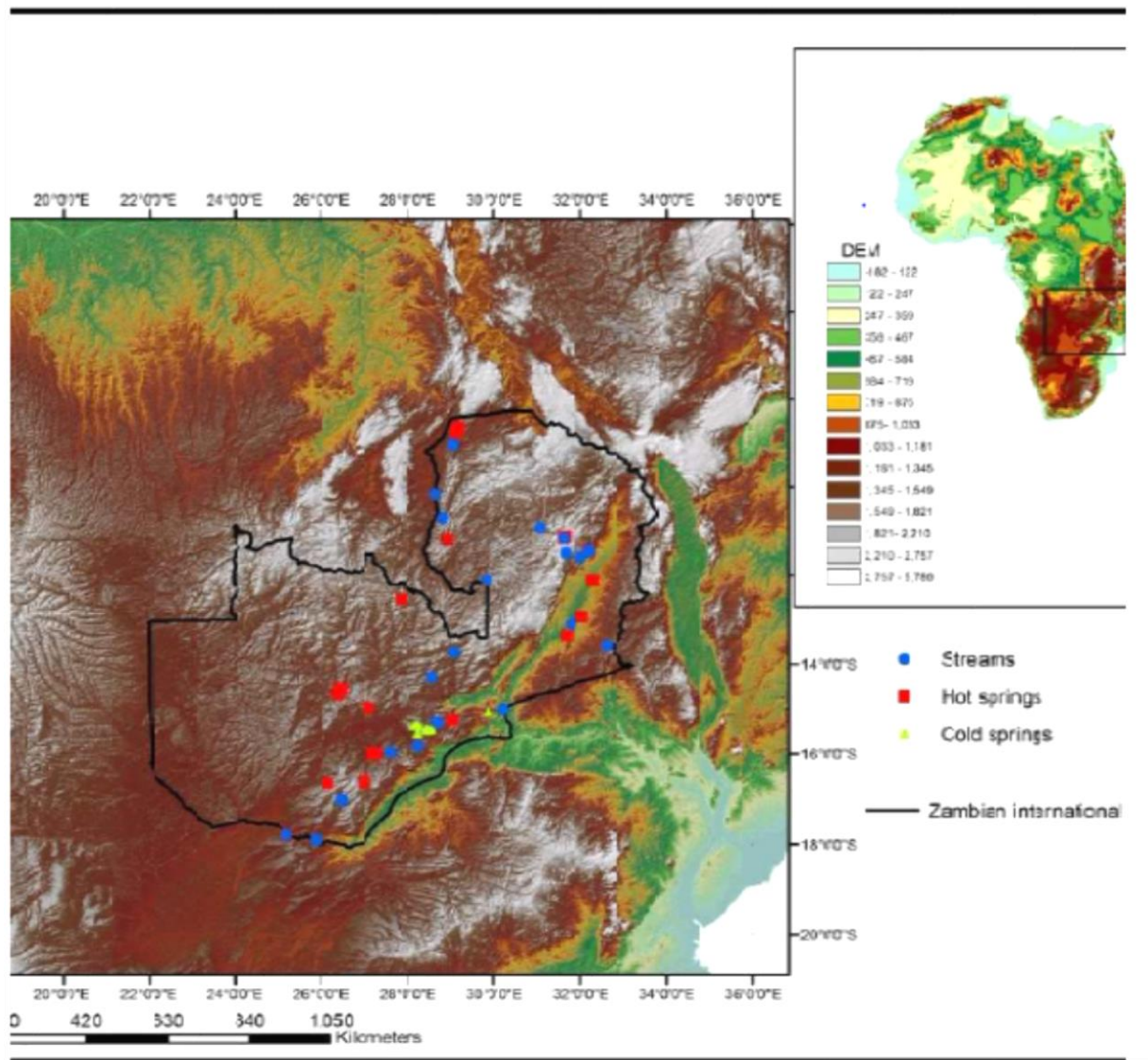


Figure 4: Shuttle Radar Topography Mission (SRTM) map overlay with sample sites (Matende, 2014)).

Geothermal potential sites in Zambia

S/No.	Site Name	Longitudes	Latitudes	Location	Project Status
1	Kapishya	30 ⁰ 28'34.002''S	8 ⁰ 20'59.9314''S	Northern	Reconnaissance
2	Mupiamanzi	26 ⁰ 40'12.92''S	14 ⁰ 26'49.855''S	Western	Reconnaissance
3	Chongo	31 ⁰ 55'43.476''S	12 ⁰ 17'17.234''S	Northern	Reconnaissance
4	Lubungu	26 ⁰ 25'17.944''S	14 ⁰ 24'43.467''S	Western	Reconnaissance
5	Chinyunyu	29 ⁰ 01' 24''S	15 ⁰ 15' 41''E	Eastern	Reconnaissance

Table 1: Status of Zambia geothermal prospects**2.1.1 Kapishya Geothermal site description**

Kapishya geothermal potential site and power plant is located in the Northern part of Zambia in a new district called N'sumbu district in Mushi village. The site can be accessed by boat through the Lake Tanganyika. The point of boarding is N'sumbu harbor and it takes approximately 30 – 45 minutes to reach the other side of the lake where the site and the power plant is located. (DAL, 1986-1987)

The springs are located where a major fault of the Lake Tanganyika trough cuts impervious porphyritic igneous rocks. The presence of numerous well-developed beach terraces on the hillside above the springs, up to 20 m above the present lake level, indicates that formerly the springs were subaqueous, and it is probable that other springs occur along the northern, submerged portion of this fault. No outcrops of porphyry are seen in the area of the springs, which is covered with coarse rubble consisting entirely of fragments of columnar-jointed porphyry.

Many of the springs are very hot, the maximum temperature - recorded in the largest spring – being 85°C. Although the spring waters are relatively dilute, rocks in the vicinity are covered with encrustations, mainly of calcium carbonate with less sodium and potassium sulphate and chloride. The total discharge in May 1971 was in the order of 25 litres per second, but accurate estimates are difficult to make because of the large number of springs and the dense vegetation surrounding them. Large amounts of gas with a slight sulphurous smell are given off by some of the springs, and the area is moderately radioactive, the level of gamma radiation being approximately double that over porphyry outcrops 100 m to the west. The figures below show the map and the geological map of the region surrounding Kapishya.

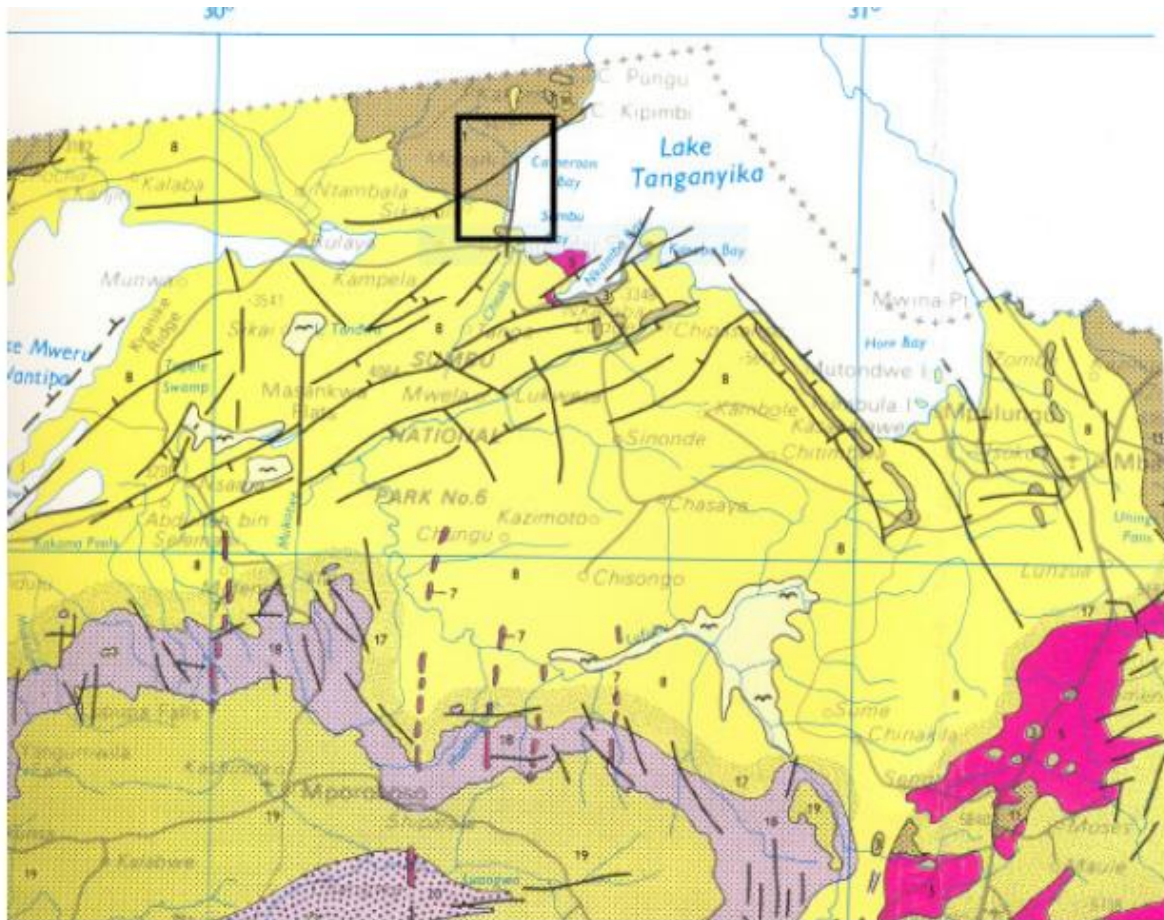


Figure 6: Regional geological map of the region surrounding Kapishya. Project area is boxed. Legend is contained in Appendices 1a, 1b. (KENGEN, 2007).

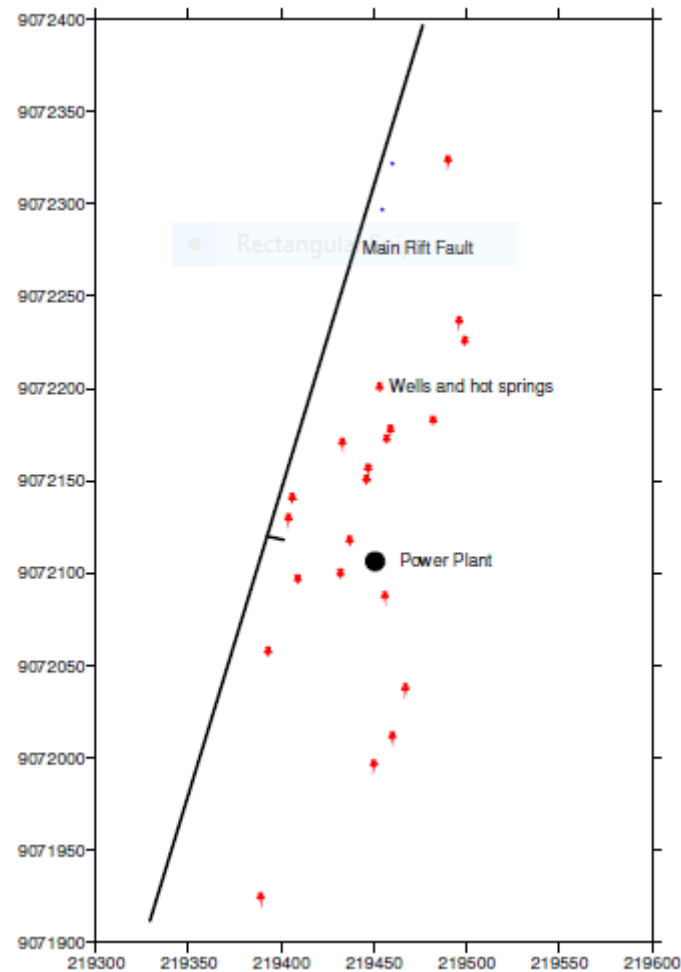


Figure 7: Map showing the location of hot springs in the Kapishya area. (KENGEN, 2007)

2.1.2 Mupiamanzi Geothermal site description

Mupiamanzi are located in the Kafue National Park about 98km from Mumbwa town. These springs, remarkable for their high water temperature and low content of total dissolved solids, occur on the eastern margin of a small fault-bounded outlier of lower Karroo rocks containing thin seams of coal - the 'Hot Springs Coalfield' Cikin 1971). Although there are no rock outcrops in the vicinity of the springs, fragments of siltstone, sandstone, quartzite and vein-quartz occur in the eyes of the springs. Water is discharged from large numbers of small eyes in broad areas of muddy seepage extending for 140 m in a north-westerly direction. The most southerly springs are located along the banks and the bed of the Mupiamanzi river, and the others drain into the river through tributary streams. The springs provide most of the flow of the Mupiamanzi river during the dry season, and attract large numbers of game in this otherwise dry area. Hippopotami appear to enjoy wallowing in the hot muds around the springs and are apparently unaffected by temperatures in excess of 65°C. The springs are a popular camping site for hunters in this Game Management Area. (LEGG, 1974), (DAL, 1986-1987)

2.1.3 Chongo Geothermal site description

This spring, located in Luangwa National Park which is 874 km from Lusaka and about 1.5 km north-west of Nabwalya, is the most spectacular seen in the Luangwa Valley. It is the

hottest and largest spring in the valley, and its situation at the base of a prominent scarp, without marshy surroundings, makes it easy to approach and observe. The main spring rises from beneath coarse scree material at the base of the scarp, which probably marks a fault in Karroo sandstones.

Sandstones seen in outcrop along the base of the scarp are commonly strongly brecciated, and have abundant quartz veins trending north-east, parallel to the line of the scarp. The main spring is flanked by smaller hot seepages rising also from below scree, and 200 m to the south-west a muddy, densely grassed mound with warm seepages on its crest, occurs. Rocks in and around the springs are covered with abundant encrustations, and soils on the flat land west of the scarp show efflorescences during the dry season. Little gas is emitted from the spring, but there is a slight sulphurous smell. The spring is moderately radioactive, with a radiation level of twice the local background. (LEGG, 1974), (DAL, 1986-1987)

2.1.4 Lubungu Geothermal site description

Lubungu hot springs are located in the Kafue National Park about 98 km from Mumbwa town and there is pontoon to cross to access the site from the other side. This is without doubt the most spectacular hot spring in Zambia from a scenic point of view, with its large discharge, multicoloured travertine mound and dense tropical vegetation. Furthermore. Its waters are exceptionally hot, of complex composition and have a high radioactivity. This spring has been studied in detail by the Geological Survey, and by the staff and students of the University of Zambia Physics Department.

The spring is located 1 km north of the Kafue River, and within the Kafue National Park. 92 km by road to the north-west of Mumbwa. The spring occurs in an area of medium-grained and strongly tourmalinised pink granite, probably a roof phase of the Kafue Hook granitic intrusive complex. The Lubungu Fault occurs a short distance to the west of the spring, and appears to form the eastern boundary of a northward-trending graben containing downfaulted metasediments of probable Upper Katanga age.

The fault zone is marked by intense tourmalinisation and hematization, giving rise to a prominent and very persistent ridge. A minor, east-northeast trending fault branches from the Lubungu fault near the Kafue-Lunga confluence, and is marked by the patchy development of metasomatic magnetite, hematite and tourmaline, and by alteration and brecciation of the granite. The Lubungu hot spring appears to occur on the northern edge of this fault or shear zone. Detailed geoelectric, magnetic and gravimetric surveys have been conducted over the area of the spring by the Physics Department of the University of Zambia (Chapman, Cowan. Legg and Topfer 1972 and Legg, Topfer and Cowan in prep.), in order to define more accurately the position and attitude of the fractures controlling the position of the spring. (LEGG, 1974), (DAL, 1986-1987)

2.1.5 Chinyunyu Geothermal site description

The Chinyunyu geothermal area falls in the Basement complex system of Zambia which comprises the basement rocks and those of the Katanga system all of Precambrian age (Simpson, 1967, Garrard, 1968). The geology of the area in the vicinity of the prospect includes sheared granite gneiss, metavolcanics, quartzite and meta-sedimentary schists of various formations and ages. The rocks are products of intense deformation related to the main phase of the Lufilian and end-Katanga orogenies that created intense folding, schisting, thrusting and faulting that is common in the area (Figures 2 and 3). Tectonism during the Cainozoic reactivated old structures and caused rifting as evident in Mwapula area in the

The Agency was empowered by the Act of Parliament called Zambia Development Act of 2006 (ZDA Act, No. 11 of 2006)) to promote investment in the country for investment thresholds that have to be met to qualify for fiscal and non-fiscal incentives. Projects that qualify may be new or existing ones undergoing expansion or modernization. These are the categories of investors especially priority sectors such as energy and water development who can be considered under the ZDA Act.

1. Investors who invest not less than **US\$500,000** in the **Multi Facility Economic Zone, an Industrial Park, a Priority Sector** and invest in a Rural Enterprise under the ZDA Act, are entitled to the following fiscal incentives:
 - a. Zero percent tax rate on dividends for 5 years from year of first declaration of dividends.
 - b. Zero percent tax on profits for 5 years from the first year of operation.
 - c. Zero percent import duty rate on capital goods, machinery including specialized motor vehicles for five years.

In addition to fiscal incentives, the above category of investors is entitled to the following **Non- Fiscal incentives**;

- a. Investment guarantees and protection against state nationalization;
 - b. Free facilitation for application of immigration permits, secondary licenses, land acquisition and utilities
2. Investors who invest an amount not less than US\$250,000 in any sector or product not provided for as a priority sector or product under the Act. This category of investors is entitled to non-fiscal incentives as follows;
 - a. Investment guarantees and protection against state nationalization; Free facilitation for application of immigration permits, secondary licences, land acquisition and utilities. (Agency, 2014)

4.0. Results from previous studies

It is recommended that at least three (3) deep exploratory wells are drilled in Chinyunyu to depths of about 500 m within the prioritized area. Results from the three wells would thereafter be used for siting of additional wells to meet the target mass flow. (KENGEN, 2007) See figure below for details.

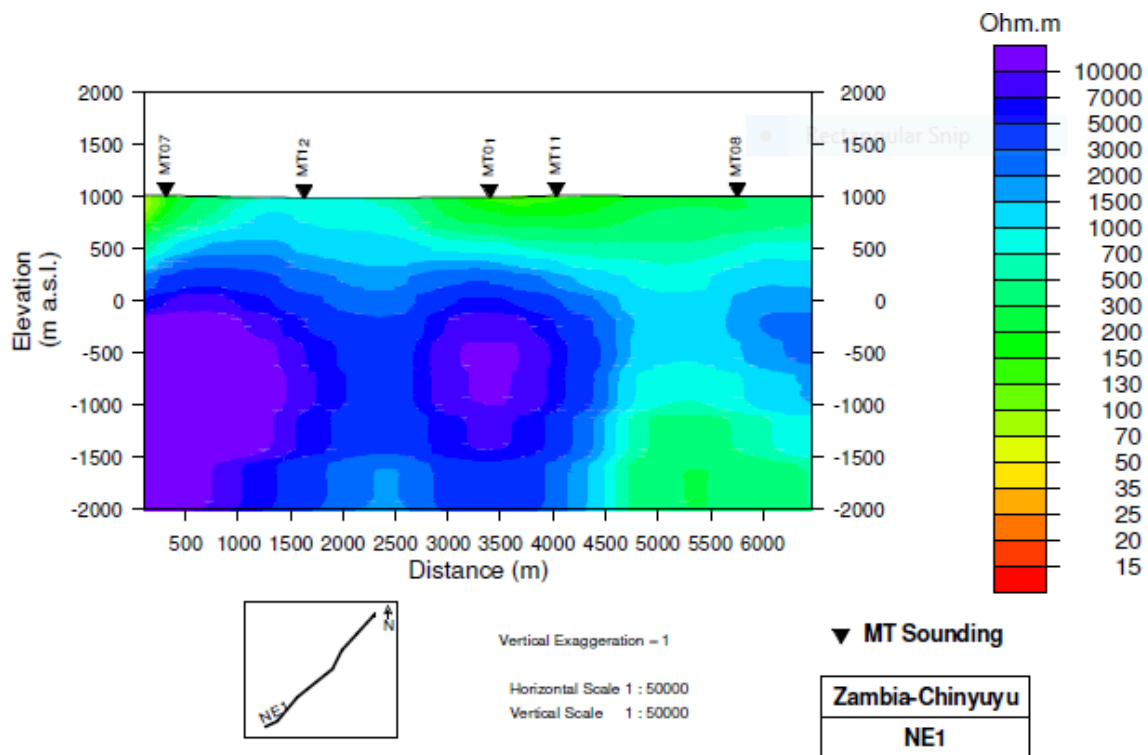


Figure 6: 2-D resistivity section across Chinyunyu area (KENGEN, 2007)

At Kapishya power plant and site, 2-D MT resistivity modelling indicates that the resource depth is about 250 – 500 m (Figure 7). Resistivity models show that the high potential area extends northward of the Kapishya Power plant along the fault zone. It is recommended that large bore holes are drilled to maximum depths of 500m and the top cool zones cased off to prevent cold water incursion into the bores. The wells should be designed to target fault zones at depth for increased permeability and high temperature fluid flow.

If further geothermal exploration is to take place in Kapishya the following should be kept in mind: Drilling would need to be targeted towards the NW-SE fault and the SSW-NNE Tanganyika Rift fault. (ISOR, 2014)

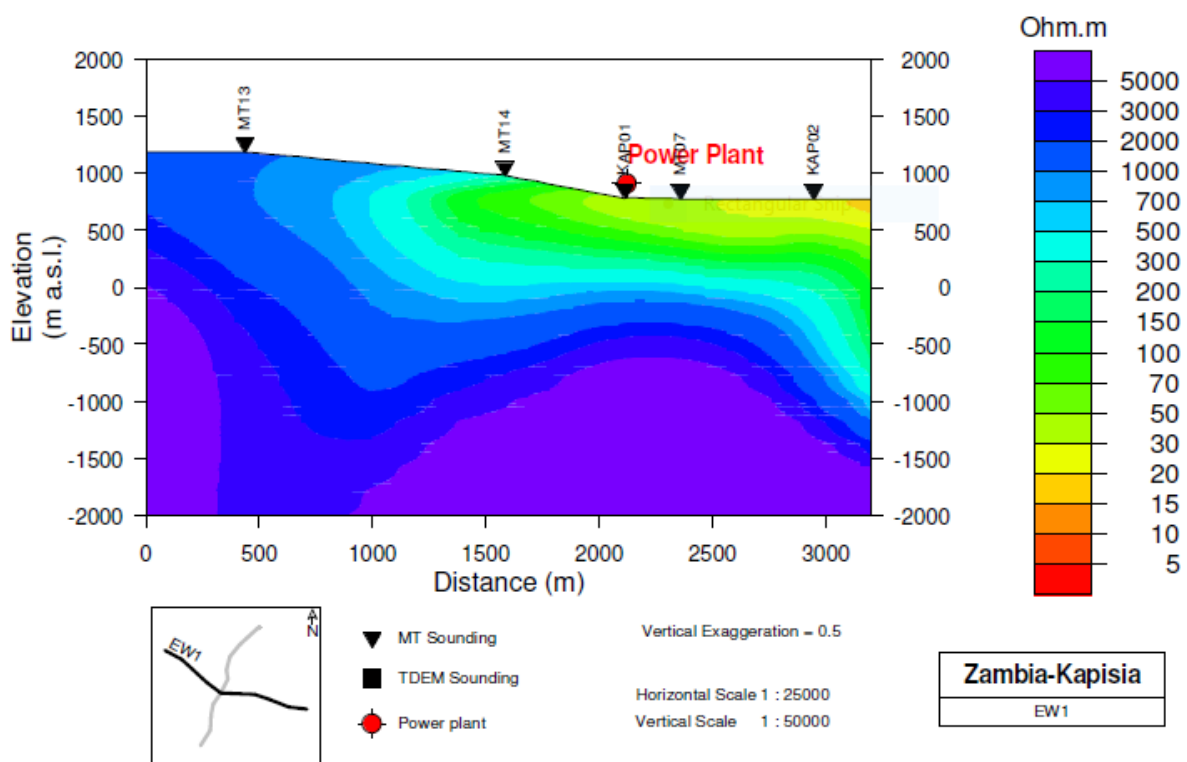


Figure 7: East-West MT cross-section based on 2D interpretation (KENGEN, 2007)

5.0. Discussion

Recognising potential contribution of renewable energy to the country's future energy mix, the Government of Zambia is determined to support geothermal development. Geothermal is environmentally friendly, can improve access to sustainable, modern and cleaner energy services with the potential for contributing to job creation, income generation, and improved livelihoods.

The main challenges facing geothermal development in the country are limited awareness, high upstream costs and resource risk. Different countries have taken various approaches to scale-up geothermal development through public support including public sector taking on the full resource risk, government-led exploration and rights are transferred to the private sector to complete and install power plants, geothermal resource risk insurance and fiscal incentives.

Zambia is progressively developing strategic local capacity in terms of specific knowledge and skills relevant to exploration, development and utilization for supporting the geothermal development. However, as a country we need a legal and regulatory framework which will create an enabling environment conducive for geothermal development. With attractive resource at our five sites with evidence at Kapishya Power Plant even when it is non-operational, the country is still keen to encourage investors to come and invest in the geothermal sector for both direct and power generation purposes. The Zambian government is also in the process of looking for financing for detailed surface studies at the selected sites and develop a strong legal and regulatory framework.

6.0. Conclusion

The high potential area in Kapishya and Chinyunyu measures between 0.5 and 1 km² and are controlled by rift faults. There is a high chance (> 60%) of getting more than 2 MWe using binary system of generation at both prospects as currently installed at Kapishya (Figures 33 & 34). The estimates are based on volumetric stored heat model (Monte Carlo simulation) which assumed a reservoir temperature range of 120-130°C, resource area of 0.5 - 1 km², reservoir thickness of 100 – 500 m, porosity of 3-6% and heat exchanger outlet temperature of 70°C. This is the best model that can be employed for now for these areas due to limited deep drilling data. Monte Carlo simulation is widely used for geothermal resource estimation and has also been done for Olkaria I field in Kenya with some realistic estimates (Ofwona, 2005). (KENGEN, 2007)

Reconnaissance studies on these five sites have already been done. This was done by engaging the Geological Survey department to take care of the geological surface studies which forms an integral part of the inception report. The Stakeholder engagement plans (SEPs) have also been drafted after the site visits. As a development strategy, these five sites needs to be subjected to fresh surface studies for a conclusive and bankable conceptual model to be developed. The kinds of surveys and studies required include:

- Satellite imagery and aerial photography;
- Volcanology studies;
- Geologic and structural mapping;
- Geochemical surveys;
- Geophysical surveys; and

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