Status of Geothermal Exploration in Zambia

Brian Sinkala Mainza and Mafayo Ziba
Ministry of Energy, Department of Energy
Email: bsmainza@gmail.com

Keywords: Geothermal, Kapisya, hotsprings, direct use application, KGE

ABSTRACT

The Zambian government has been making efforts to increase the share of renewable energy in the national energy mix. The Country has relied on hydro power for a long time. In the 2015/2016 rain season, the country experienced drought which led to low water levels in the major rivers used for hydro power generation and hence less power generation. This led to massive load shedding of up 8 hours for residential and industrial use. It was at that time that the country increased efforts towards the utilization of renewable energy such as solar, wind and geothermal energy.

The Country has about 80 hot springs which are a manifestation of the possible source of geothermal resources. Despite having geothermal potential, the Zambia has no geothermal power plant currently generating power. In 1986, the Italian company working with the Zambian utility company, ZESCO Ltd, explored and constructed a 220 kW Turboden binary geothermal power plant in the Northern part of the country called Kapisya power plant. The plant has never generated any power since its construction for reasons that may be due to insufficient information collected during feasibility study. Since the construction of the Kapisya Power Plant, there was no interest in geothermal development partly because of the sufficient hydro power potential which required less exploration costs.

Since 2011 however, a private company called Kalahari GeoEnergy Limited has been conducting exploration activities in the Kafue Trough in the Southern Part of the Country. The kafue trough lies at the intersection of the Zambezi mobile belt and the Mwembeshi shear dislocation zone, a previously highly active tectonic zone. So far, the company has drilled exploration wells and has indicated that the area of exploration has a minimum potential of 15 MW. The company is scheduled to complete it feasibility studies at the end of the year 2020 but has been delayed by the Corvid 19 pandemic.

The Ministry of Energy is supporting the company in terms of policy guidance and procedure so that the Country can benefit from the base load power that geothermal power plants provide. In addition, the Country has conducted a study of the value chains around the geothermal power plant and hotsprings which will utilize the geothermal direct applications. Some of the value chains identified in the study are the geothermal spar, aquaculture, green houses, drying and milk pasteurization.
1. Introduction

The Zambia’s power sector has for a long time been dominated by hydro generated power. Hydro has been the main source of power because of plenty water resources in the country for power generation. It is estimated that the water resources in Zambia accounts for 40\% (Zambia Invest, 2016) of the water resources in Southern Africa. Apart from the available water resources, hydro power has been advantageous because it is clean and dispatchable. The installed capacity stands at 2986.23 MW with hydro accounting for about 80.3\% of the total generation. The remainder of the generation mix is from coal (10.35\%), HFO (3.8\%), Diesel (3.08\%) and solar (0.3\%) (ESR, 2018). As can be seen, renewable energy other than hydro is insignificant in terms of its contribution to the national energy mix. 51.1\% of the electricity generated is consumed by the mining sector.

In 2014/2015 rainy season, Zambia experience drought which led to less hydro power production. The deficit of power was about 600 MW with the mining industry recording less production as a result. This in turn prompted the mines to reduce the work force which meant job losses for the citizenly working in the mines. All other sectors were adversely affected and as a result, government decided to double efforts channeled at increasing the share of renewable energy in the national energy mix to complement hydro which is susceptible to climate change. Some of the renewable energies which were considered are solar, wind, mini-hydro’s and geothermal. In terms of geothermal exploration, a private company called Kalahari GeoEnergy Limited (KGE) has been conducting exploration works in the Kafue Trough of the Southern Province of Zambia with a view to establish a geothermal power plant. They have a Memorandum of Understanding with the Ministry of Energy (MOE) Zambia which has been supporting them in their exploration works. Exploration works which are being conducted have given impetus for stakeholders to consider the development of other activities in the area which are linked to the geothermal resource.

1.2 Institutional Arrangements

The Ministry of Energy is a government Ministry responsible for energy development in the country and is guided by the National Energy Policy of 2019. It is mainly in charge of policy formulation and interventions to ensure the sector develops to respond to the current and projected power demand to ensue economic growth. The Ministry has its implementation agencies, that is, The Energy Regulation Board, ZESCO Ltd and the Rural Electrification Authority (REA).

ZESCO Ltd is the electricity utility company. They manage the major power generating plants in the country and the grid from generation, transmission, and distribution. There are several Independent Power Producers (IPPs) with a wide generation mix and all their on-grid power generated is injected into the national grid managed by ZESCO Ltd.

The Energy Regulation Board (ERB) regulates the energy sector, that is, both the power and petroleum sub sectors. They ensure security of supply of energy services and products, providing a level playing field in the sector, setting cost reflective prices and safeguarding consumer interests.

The Rural Electrification Authority was established by an act of parliament due to the need to increase access to electricity in the rural areas. This was compounded by the government’s need to ensure that the utility company is commercially viable as opposed to taking electricity where the returns will not match with the investment. REA receives grants from the government to implement projects in rural areas which are in form of grid extension, on-grid
power generation plants and off-grid systems with energy source which may be hydro, solar or wind.

2. Geothermal Resources and Potential

According to the research that was conducted by the Geological Survey Department of the Ministry of Mines in Zambia, Zambia has more than 80 hot springs across the country. Hotsprings are the first manifestation of the presence of geothermal energy resource. Table 1 is a list of major hot springs in Zambia and their temperatures.

Table 1: List of hot springs in Zambia

<table>
<thead>
<tr>
<th>Area</th>
<th>Geothermal field</th>
<th>Hotspring</th>
<th>Temp. °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Northern</td>
<td>Kapisya</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kaputa</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kalaya</td>
<td>51</td>
</tr>
<tr>
<td>Eastern</td>
<td>North Luangwa</td>
<td>Chongo</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nabwalya S.</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>South luangwa</td>
<td>Musaope</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>chikoa</td>
<td>64</td>
</tr>
<tr>
<td>South Eastern</td>
<td>Lusaka East</td>
<td>Chinyunyu</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chongwe</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Lukusashi</td>
<td>Musenseshi</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mafwasa</td>
<td>65</td>
</tr>
<tr>
<td>Southern</td>
<td>Lochninvar</td>
<td>Gwisho</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bwanda</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Kariba</td>
<td>Chibimbi</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kariba</td>
<td>78.5</td>
</tr>
<tr>
<td>Western/</td>
<td>Copperbelt</td>
<td>Kasho</td>
<td>80</td>
</tr>
<tr>
<td>Copperbelt</td>
<td>North Kafue</td>
<td>Lupiemanzi</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lubungu</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>South Kafue</td>
<td>Longola</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Kasempa North</td>
<td>Kaimbwe</td>
<td>52</td>
</tr>
</tbody>
</table>
Among the 80 hot springs, Kapisya hot spring was the first to be exploited for possible generation of electricity. It is located at the west coast of Lake Tanganyika in Northern Province and the temperature of the hot spring is about 85°C. A geothermal power pilot plant was built at Kapisya hot spring with a capacity to generate 220 kW in 1988 but the ground temperature of 85°C was too low for the design temperature of the power plant. Additionally, the agreement did not include the construction of the power transmission line. The nearest grid connection point at that time was more than a 100 km. The nearest population are villages with very low power consumption potential and scattered settlements. Constructing an off-grid system for the nearby villages is therefore not economically viable. It is because of these reasons that the power plant is not functioning up to this time.

However, further survey and investigations of Kapisya hot springs were done by ZESCO Ltd and KenGen Company of Kenya and estimated the underground fluid temperature at depth of 500m or more to be 124°C. This has the capacity to produce more than the 220kW design capacity of Kapisya. The nonfunctional power plant is as shown in Figure 2.
3. Geothermal Utilization

Currently, exploration drilling is going on at Bwanda and Gwisho hot springs. These hot springs lie in Lochinvar National Park in Southern Province of Zambia. KGE, the company drilling the exploration wells estimates the potential of the geothermal resource in the area to be able to produce more than 15 MW of electric power. Apart from the exploration happening at Bwanda and Gwisho hot springs, there are no other hot springs which are being exploited for possible power production now. Most of the hot springs are used as heritage sites for tourism purposes and there is a fee charged for some of the hot springs to have access. The most visited is the Chinyunyu site, on the eastern side of Lusaka which has been fenced by the National Heritage of Zambia.

Apart from exploitation for possible power generation, there is an opportunity for geothermal direct use applications for most of the hot springs because of low temperature levels as compared to sites in the East African Rift system.

In recognition of this opportunity, the Ministry of Energy working with the Ministry of Commerce and KGE have started a deliberate programme to prepare for direct use application of geothermal when KGE sets up a power plant. This is appropriate now that the KGE exploration works are yielding positive results as indicated in Figure 3.
The two Ministries with funding from the United Nations Development Programme (UNDP) working with other stakeholders engaged a consultant to conduct a study of the value chains which can utilize geothermal direct heat that can be developed around the geothermal power plant. The idea is to establish an Industrial Park where all the direct use applications can be developed. The concept is develop value chains suited to the kind of life in the area which is cattle heading and crop agriculture and further identify possible economic sectors that could be targeted for investment in the park, outlines a financing plan and makes recommendations through a multi-year implementation plan that lists activities that need to be undertaken leading to the establishment of the proposed Industrial Park.

4. Possible Direct Uses of Geo-thermal Energy in Zambia

Some of the possible value chains in the area which can utilize geothermal direct heat from the geothermal power plant to be established by KGE are:
4.1. Animal Husbandry

Livestock keeping has been practiced for centuries in Bweengwa, Monze as in other areas of Southern Province. Traditionally, keeping cattle is a way of life for the people of Southern Province, however, there has been very little value addition derived from the livestock industry in the area. It is estimated that there are over 90,000 heads of traditionally managed cattle in the Lochinvar area of Monze and Namwala Districts. The people also practice dairy farming producing milk, which is supplied to Large Milk Processors predominantly based in Lusaka. The milk output of the area accounts for one of the highest in the Country and can reach up to 200,000 liters per month (FAO, 2017).

Therefore, it can be concluded that Dairy Processing is one of the most viable value chains to prioritize because the raw products are already available.

4.2 Pasteurization

Geothermal brine can be used as a heating liquid for a Milk pasteurization unit either by directly use of the brine to heat up the raw milk, or by heating secondary fresh water. Pasteurization is a mild (as opposed to frying, baking or roasting) heat treatment which aims to fulfill two purposes, to remove pathogenic bacteria from foods, thereby preventing disease, and to remove spoilage (souring) bacteria to improve its keeping quality. Pasteurization can be done to various kinds of food and beverage products, such as tomato juice, honey, ice cream mix, and including milk. Each food has different temperature and time for pasteurization process. A diagram of one of the milk collection centres in Monze is indicated in Figure 4.

Figure 4: Nteme Milk Co-operative, 10Km North of Monze (and 35km from Lochinvar), the nearest milk collection point
4.3 Horticulture

The use of geothermal energy to provide controlled heating for greenhouses is being increasingly implemented globally. A good example is Kenya where significant volumes of roses and vegetables such as peppers are grown in greenhouses adjacent to and heated by the Olkaria power plants. The growing and ripening times are reduced by an average of 30%.

4.4 Aquaculture

The aim of geothermal aquaculture is to heat water to the optimum temperature for aquatic species. This involves the raising of freshwater or marine organisms in a controlled environment to enhance production rates. The geothermal water is commonly used to heat water in raceways, ponds, and tanks. The water temperature depends on the species involved, ranging from 13 to 30°C. By controlling the rearing temperature, the growth rate of the fish can be increased by about 30%, thus increasing the number of harvests per year.

4.5 Geothermal Spa

Spas and hot baths associated with geothermal are another common application. Examples include the man-made Blue Lagoon in Iceland which has been created from the outflow of the Svartenji Geothermal power plant, and the Olkaria Spa associated with KenGen’s Olkaria power plants in Kenya shown in Figure 5. These can include restaurants, accommodation, and other amenities, which make them popular tourist destinations. Such a spa could be developed at Lochinvar within the proposed Industrial Park as part of the improvement of the Park for tourism purposes. The national park already has a lodge which can utilize the geothermal heat for bathing.

Figure 5: Olkaria hot Spa in Kenya

4.6 Water Filtration

The local communities draw water from drilled wells with hand pumps and hand dug scraps. Sampling suggests that those wells at Lochinvar Lodge and in the Lupiamanzi and Namulula...
Mainza and Ziba

areas are contaminated either or both by brines and pathogens. Kalahari GeoEnergy has drilled two water wells and has instituted research into possible filtration processes including slow bed filtration to remove pathogens and the future possibility of using geothermal energy either in forward osmosis or multiple effect distillation. Certainly, any commercial development will require potable water that could also be supplied to the community.

4.7 Fuel Synthesis

KGE is interested in determining the feasibility of using geothermal power for sustainable fuel synthesis, including production of hydrogen and other commercial gases by electrolysis. The fuel cell industry which uses hydrogen as a fuel is slowly gaining momentum globally. Such utilisation of geothermal power would be appropriate if the plant were to be utilised as a spinning reserve to the grid during peak production by variable energy sources and so provide secondary revenue streams. The direct use applications mentioned are not limited to the geothermal heat in Lochnivar. Other hot springs in the Country can also be used for the same application.

In addition to the concept paper stated, there are other programmes which have developed and recognized geothermal direct use application as an opportunity to be considered. The programmes are the Scaling up Renewable Energy Programme (SREP) and the Sustainable Energy for All (SE4ALL). The programmes has the Implementation Plan (IP) which recognizes geothermal direct application as one important use of renewable energy for the activities mentioned.

5.0 Discussion

The apparent reason why geothermal heat has not been exploited despite so many hot springs is the high cost and a perception that they are of low temperature even without a comprehensive study. It is understood that the failure of the Kapisya Geothermal Plant has affected future possible investment in the geothermal sector. Another reason is the availability of less risky and low investment power generating options which are a low hanging fruit for power developers.

Since the KGE exploration is the first exploration being conducted after the Kapisya, it is difficult to determine the tariff that can be reached at the point of power production now. The tariff being charged for hydro power being produced is not cost reflective and is comparatively cheap in the Southern African region. In addition, the recently solar power plants that have been developed under the Scaling Solar Project are US Cents 6.015/kWh for the 54MW Bangweulu project and US Cents 7.84/kWh for the 34MW Ngonye Solar project. Another solar programme called the Global Energy Feed in Tariff (GETFiT) with a total of 120MW segregated into 20MW each has produced even lower tariffs of US Cents 4.99 /kWh. It is important to state that the tariffs for the projects were low because they had incentives specifically targeted at reducing the tariff to a level where ZESCO Ltd can offtake. The tariff for the KGE project may be higher than the stated tariffs for solar and there may be need for incentives to lower the tariff for easy uptake by ZESCO Ltd.

The National Energy Policy and other policy interventions such as SREP and SE4ALL recognises geothermal as one of the renewable energies which can be used to increase the national energy mix. The policy and regulatory framework are therefore not adequate to support the nature of geothermal exploration to include incentives which will attract private sector involvement. It is however anticipated that the success of the KGE project would
encourage other investors to consider investing into geothermal power production and the associated direct use applications.

REFERENCES

National Energy Policy, 2019
Vivian Neal, P, 2017. Lochinvar stakeholder engagement on cascading uses of geothermal, KGE Ltd.
Hila Attaie. 2003. Guidelines for value chain analysis in the agri-food sector of transitional and developing economies, FAO.
VEGA. 2015. Powering African Agriculture (PAA), USAID.