Status of Geothermal Exploration in Malawi

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Keywords: geothermal potential, recent documented hot springs, further studies

ABSTRACT
Malawi’s location at the southern end of the East African Rift System provides convective/conductive systems of high heat fluxes from the crustal rocks, which provide favorable conditions for geothermal resource reservoir as manifested through hot springs across the country.

Several studies have been conducted to assess Malawi’s geothermal potential but definite conclusions are yet to be made. Earliest works dates as far the past two centuries (1890’s) but yielded too little for geothermal energy development. Though others opine that, so far, assessed geothermal resources could not add power supply significantly to the electricity grid Gondwe et al (2012) indicate that recent assessment of the field resulted in the delineation of 6 to 7 groups of springs with appropriate temperatures and geology for electricity generation of up to 200MW.

Currently, Malawi Government, private firms and various regional and global players in the geothermal energy sector continue to define the future of geothermal energy in Malawi. The Malawi Government continues to commit delegates to the UNU-GTP short courses and different forums. In addition to geothermal policy being drafted Department of Energy is undertaking geothermal energy feasibility studies in the country. Geological Survey Department does not only continue to conduct collaborative researches, on the rift system which could directly/indirectly be used for geothermal development, but is also finalizing a concept paper on geothermal exploration program to source funding for further research.

Despite Malawi being positioned in the EARS, there is not much that has been done towards harnessing the geothermal energy. Research and capacity building in the sector though being fundamental, remain a challenge to Malawi.

1. INTRODUCTION
Malawi lies at the southern end of the East African Rift System (EARS) within latitudes 9°S and 18°S and longitudes 32°E and 36°E. The country is defined by 94,000Km² land area (80%) and 24,000Km² water surface of which rift related Lake Malawi (about 586 km long and 16 - 80 km wide) dominates. This location provides convective/conductive systems of high heat fluxes from the crustal rocks which provide favorable conditions for geothermal resource reservoir as manifested through earth’s interior heat escaping to the surface, through hot springs across the country. Several studies have been conducted by various researchers on Malawi’s geothermal potential but a lot more needs to be done to understand the potential fully. The studies have gone, basically, as far as documentation and characterizing the geothermal field. This paper sums up progress made so far in geothermal exploration in Malawi.

Figure 1: East African Rift System (after state of the art, The Earth Institute of Columbia University)
2. GEOTHERMAL MANIFESTATION

Geothermal potential in Malawi manifests itself generally in form of hot springs. This is though at Chinuku in Chitipa some “geothermal grass” (*Fimbristylis exilis*) was observed. Traditionally, up to around 21 major hot springs had made topics of discussion with some registering gas discharges. The highest recorded temperature, at Chiweta spring in Rumphi, stands at 79.3°C. Recently, as reported by Gondwe et al. (2012), an exercise aimed at classifying hot springs in Malawi, resulted in about 14 more unknown hot springs being recorded including the third hottest (Mtondoro) at 74°C (Table 1). The exercise further resulted in categorizing the streams into 6 to 7 groups basing on their temperatures and geological settings as regards their potential for electricity generation.

Table 1: Recent recorded hot springs in Malawi

<table>
<thead>
<tr>
<th>Spring</th>
<th>(UTM)Eastings</th>
<th>(UTM)Northing</th>
<th>Alt(m)</th>
<th>Stream-temp(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mtondoro</td>
<td>0610536</td>
<td>8665522</td>
<td>564</td>
<td>74</td>
</tr>
<tr>
<td>Julaye village1</td>
<td>0654117</td>
<td>8237664</td>
<td>225</td>
<td>55</td>
</tr>
<tr>
<td>Chiyagha</td>
<td>0618316</td>
<td>8721422</td>
<td>705</td>
<td>49</td>
</tr>
<tr>
<td>Kajilirwe1</td>
<td>0610144</td>
<td>8716255</td>
<td>703</td>
<td>49</td>
</tr>
<tr>
<td>Tisola</td>
<td>0686533</td>
<td>8212845</td>
<td>98</td>
<td>48.5</td>
</tr>
<tr>
<td>Kajilirwe 2</td>
<td>0610172</td>
<td>8716299</td>
<td>704</td>
<td>46</td>
</tr>
<tr>
<td>Chadonga 1</td>
<td>0616078</td>
<td>8714909</td>
<td>603</td>
<td>42</td>
</tr>
<tr>
<td>Mwaya</td>
<td>0618821</td>
<td>8721677</td>
<td>727</td>
<td>42</td>
</tr>
<tr>
<td>Karwe</td>
<td>0635878</td>
<td>8718265</td>
<td>527</td>
<td>42</td>
</tr>
<tr>
<td>Chadongo2</td>
<td>0616097</td>
<td>8714699</td>
<td>610</td>
<td>39.6</td>
</tr>
<tr>
<td>Saka 1</td>
<td>0607229</td>
<td>8717700</td>
<td>856</td>
<td>36</td>
</tr>
<tr>
<td>Kajilirwe 3</td>
<td>0609564</td>
<td>8716489</td>
<td>702</td>
<td>33</td>
</tr>
<tr>
<td>Chimaliro</td>
<td>0623411</td>
<td>8686536</td>
<td>512</td>
<td>26</td>
</tr>
</tbody>
</table>

1 Sampling done from a village borehole which is source of drinking water and also domestic chores
Figure 2: Map showing Major hot springs in Malawi Map
3. Current Malawi Energy Supply Situation

Electricity supply in Malawi is unreliable and inadequate. Almost all the power generation for the country depends on Shire River flow. The arrangement puts Malawi at a high power security risk hence need for the country to diversify its energy sources. Furthermore, demand and supply difference continues to significantly grow in Malawi and thus putting more pressure on the current power generation system. The effects have been proved to be drastic as far as economic growth, environmental sustainability and social delivery is concerned. As of 2008 it is reported that for lighting 85.7% of the population used paraffin in hurricane and pressure lamps, 7.2% used electricity, 2.2% used candles, 2.6% use firewood while 1.4% used other means. And as for cooking, 88% of the population used firewood, 8% used charcoal, 2% used electricity, 1% used paraffin and 1% used other means such as crop residues and animal dung (Gregory et al, 2013). Among the alternative sources of energy in Malawi, it can be opined that geothermal potentially leads, due to its current attention geothermal is getting in the region (EARS) and also for other factors such as being green, renewable and sustainable.
Figure 4: Graph showing difference in demand and supply of energy in Malawi (after Gamula G.E.T et al, (2013), p 11)

On the other hand, though the Government seems not to have done much on diversifying energy supply, due to reasons such as insufficient studies, technical capacity and funds, great potential remains untapped in several other sources (apart from hydro) as wind, solar and geothermal. This is also recognized in the National Energy Policy which projects to up the contribution of these renewable energy sources to 7% and 10% by the years 2020 and 2050 respectively.

And on a positive note, as discussed by Gondwe et al, in the current Model for Energy Supply System Alternatives and their General Environmental Impacts (MESSAGE) study for the analysis of different supply options, geothermal energy is expected to begin contributing to Malawi energy mix before the year 2021. In the MESSAGE the geothermal potential of Malawi is estimated at 200MW, about 66% of the current installed capacity for Electricity Supply Commission of Malawi Limited (ESCOM). ESCOM is the sole entity in the country currently generating (from hydro), distributing and supplying of electricity.


4.1 Government initiatives

In 2003, the Geological Survey reviewed hot spring resources for suitability for geothermal power. During this assignment all known hot springs were recorded with a GPS and plotted on a map.

Furthermore, in 2007 Zuze Dulanya et al conducted a study on silica and cation geothermometers to determine the subsurface temperatures of thermal springs. The results predicted a highest subsurface temperature of 240°C.

Currently, the GSD has almost finished drafting a geothermal development concept paper targeting to lobby for funds from the Government and other agencies. The concept paper generally proposes activities such as surface exploration surveys (geological, hydro-geological, geochemical and geophysical) and drilling of shallow gradient wells. This could well compliment a geothermal development feasibility study currently in the pipeline and being championed under World Bank funded Energy Sector Support Project (ESSP). ESSP is under GSD’s sister department (Energy) in the Ministry of Natural Resources, Energy and Mining. And to this far Department of Energy was receiving bidding documents for the geothermal development feasibility study. The project will among others enhance (geothermal energy) capacity of at least three geologists/scientists from GSD through on the job training.

4.2 Private sector initiatives

4.2.1 Geothermal Projects Limited and Geothermal Development Cooperation (GDC)

Geothermal Projects Limited and Geothermal Development Cooperation (GDC) of Kenya in 2010 conducted a reconnaissance survey to characterize geothermal fields for purposes of exploration license application to the Malawi Government. The exercise among other involved scientists from the GSD.

Malawi Government acting through Ministry of Natural Resources Energy and Mining issued three exclusive prospecting licenses to the companies in Chiveta (Rumphi), Kasitu-Chiwe (NKhatabay) and Mawira-Ling’ona (Nkhotakota) which were later revoked in 2013 due to failure to honour some conditions of the licenses. Currently these area are covered in planned geothermal energy feasibility studies by Department of Energy in the Ministry of Natural Resources, Energy and Environment.
4.3 Other initiatives

4.3.1 The Federal Institute for Geosciences Germany (BGR)

The Federal Institute for Geosciences Germany (BGR) in collaboration with Geological Survey Department (GSD) of Malawi in March 2013 conducted a reconnaissance survey for possible geothermal project. Samples were collected and analysis results are yet to be released.

4.3.2 Japanese International Cooperation Agency (JICA)

In July 2013, a team from Japan International Cooperation Agent (JICA), Mitsubishi Material Techno Cooperation (MMTEC) and GSD conducted a fact finding mission on a possible geothermal project. This involved preliminary geothermal investigation in thermal springs of the country and various tests including in situ stream temperature, power of hydrogen (pH), conductivity of hot springs and surrounding water bodies as well as atmospheric temperatures. The team further made brief observations on the geology of the areas surrounding the hot springs.

4.3.3 Boone Pickens School of Geology (Oklahoma State University)

Boone Pickens School of Geology, under the Project for Rift Initiation Development and Evolution (PRIDE), is investigating the drivers for rift initiation in the less evolved region in the East African Rifts System (EARS) which has well expressed topographic rift basins with a fully developed border fault system but lacks any expression of sub-aerial magmatism.

In July 2013, as part of the PRIDE study, scientists from the GSD and researchers and students from the Boone Pickens School of Geology conducted ground geophysical surveys (magnetic and gravity) and investigated thermal springs, lake water and streams. Twenty eight hot springs, five samples across a north-south profile from Lake Malawi, a sample from Lake Chilwa and nine streams including North Rukuru, South Rukuru, North Rumphi, Shire and Muloza were measured for in situ temperature, pH, electrical conductivity, total dissolved solids and dissolved oxygen. In addition, these samples were analysed for major cations and anions, dissolved inorganic carbon and stable carbon isotopes and stable hydrogen and oxygen isotopes. The results from these diverse set of samples will be useful in understanding deep crustal and near surface interaction due to rifting. In addition, the results could also be used to assess the geothermal potential.

5. Capacity building in geothermal sector in Malawi

In 2010 two geologists from GSD attended geothermal surface exploration in Kenya by United Nations University Geothermal Training Program (UNU-GTP) of Iceland. Currently more than 10 Malawians have attended short courses in geothermal surface exploration, decision making and database management.

Later, two candidates (from GSD and Malawi Energy regulatory Authority (MERA)) participated in Six months fellowship in Iceland on Geological Exploration and Geothermal Utilization respectively. And recently, the two been accepted for Masters Degree courses in geology (Malawi Government sponsorship program) and Engineering (UNU-GTP sponsorship) at the Universities of Iceland and Reykjavik.

Furthermore, Department of Energy is currently implementing Energy Sector Support Project (ESSP) which among other thing provides for countrywide geothermal energy development feasibility studies. Activities in this component of the EESSP include capacity building among scientists and other stakeholders in the geothermal sector. This will be achieved through profession attachment and short term training program within and outside the country.

6. Further investigations

As indicated before, the reported 6 to 7 groups of hot springs, each apparently associated with rift parallel faults and potential porous sedimentary reservoirs at depth, needs further detailed understanding or studies. Most of these springs exhibit surface temperatures in excess of 60°C while some are in the range of 50-60°C. In addition, the Nkhotakhota group of streams needs to be investigated further. This is though they appear to be surrounded by Precambrian rocks, and no clear fault structure controlling their location has been determined.

Further investigations of all the selected springs should include geophysical surveys to delineate the precise orientations of the fault conduits bringing the geothermal waters to the surface, together with continuous monitoring of temperature, discharge and various hydrochemical parameters over a period of a year to determine the seasonal fluctuation of these parameters in order to estimate the degree of intermixing of the geothermal waters with surface waters.

Furthermore, sampling of these springs for chemical and isotopic analyses should also be undertaken and geothermometric calculations conducted to determine temperatures of the source reservoirs, in an attempt to estimate the depth of these reservoirs.

In the light of these recommended further investigations, it should be possible to assess which of the groups of springs have sources with the greatest potential to generate electricity and on that basis could be graded in terms of priority for exploration drilling. Drilling sites and estimated depths to the source reservoirs should also be indicated by the geophysical and geochemical results. Borehole core data, plus downhole geophysics and pumping tests will allow hydrogeological parameters such as temperature,
hydraulic conductivity, transmissivity and storativity of the source reservoirs to be determined. On the basis of these parameters, the suitability of any of the delineated geothermal reservoirs to generate electricity will ultimately be determined.

7. Conclusions

Although Malawi, due to its location within the EARS, has potentially significant geothermal resources, to date little effort has been made to assess and develop the resources. This is despite the fact that the electricity generating capacity of the country is limited, with an over-dependence on hydroelectricity which is affected by climatic fluctuations leading to frequent blackouts and a demand that surpasses supply.

The paper highly recommends that, the responsibility for further investigations in the Malawi geothermal field should be a shared responsibility among the government, development aid agencies and lending institutions rather than private entities to see to it that the process is systematically and fully undertaken. This will ensure an ordered long term scientific approach to the exploration process and deter short term profit driven approach. However, this thinking does not necessarily encourage the government to stop working on possible ways of attracting private investors in geothermal energy sector. Incentives that would attract private investors should be paramount.
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