ZAMBIA: Country Update and Bwengwa River Resource

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6th African Rift Geothermal Conference
2nd – 4th November 2016
Addis Ababa, Ethiopia
INTRODUCTION

This Presentation looks at:

a) the status and challenges of Zambia’s power generation capacity, the historic geothermal work, the rational for a fresh approach and the contribution of ZESCO to a national evaluation of geothermal energy together with appropriate capacity building; and

b) the progress of a private company, Kalahari GeoEnergy Ltd, which is engaged in ongoing exploration of geothermal targets within the Kafue Trough, a non-volcanic, seismically active, sedimentary basin located to the west of Lusaka, for which the initial exploration programme was discussed previously at ARGeo-C5

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ZESCO Stance and Status on Geothermal

Presenter: Abel Chavula (Chief Eng.)

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2. Strategy
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# Current Power Generation Status

<table>
<thead>
<tr>
<th>POWER STATION</th>
<th>INSTALLED CAPACITY (MW)</th>
<th>AVAILABLE CAPACITY (MW)</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kafue Gorge</td>
<td>990</td>
<td>540</td>
<td>Low water level</td>
</tr>
<tr>
<td>Kariba Complex</td>
<td>1080</td>
<td>300</td>
<td>Low water level</td>
</tr>
<tr>
<td>Victoria Falls</td>
<td>108</td>
<td>32</td>
<td>Low water level</td>
</tr>
<tr>
<td>Itezhi Tezhi</td>
<td>120</td>
<td>80</td>
<td>Low water level</td>
</tr>
<tr>
<td>Ndola Energy (HFO)</td>
<td>48</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Lunsemfwa</td>
<td>58</td>
<td>14</td>
<td>Low water level</td>
</tr>
<tr>
<td>Maamba Colliers</td>
<td>150</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>Lunzua</td>
<td>14.8</td>
<td>4</td>
<td>Low water level</td>
</tr>
<tr>
<td>Lusiwasi</td>
<td>12</td>
<td>0.8</td>
<td>Low water level</td>
</tr>
<tr>
<td>Chishimba</td>
<td>6</td>
<td>2.4</td>
<td>Low water level</td>
</tr>
<tr>
<td>Musonda</td>
<td>5</td>
<td>0</td>
<td>Undergoing rehabilitation &amp; uprating</td>
</tr>
<tr>
<td>Shiwang’andu</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2534.8</strong></td>
<td><strong>1,157.2</strong></td>
<td><strong>Hourly average power imports 269MW</strong></td>
</tr>
</tbody>
</table>
ZESCO Strategy & Challenges

**Strategy**

*General:* Favourable regulatory framework & plans to move to cost reflective tariffs have advanced, so presenting opportunity to further investigate Country’s geothermal potential

*Strategy:* Diversify sources of power generation (to include Geothermal, Solar & other RE)
This requires: Technical & financial support for geothermal resource mapping & exploration

**Challenges:**

- At National level, geothermal potential for power generation or direct uses is not available;
- Save for private sector, geothermal technical capacity needs building;
- ZESCO seeks financial support to start exploratory drilling at Kapisya field as per both KenGen and ICEIDA recommendations.

**THANK YOU**
Zambia – Setting and Historic Work

Geological Setting:

a) Non-Volcanic Karoo era, Permian extensional basins that have regionally extensive faulting such as Kafue, Luano, Luangwa and Zambezi;
b) South-westward extensions of the East African Rift System (“EARS”), with major rift structures such as lake Mweru;
c) Highly radiogenic granite intrusions such as Hook of Granite.
Such geologic settings are conducive to geothermal systems

Historic Work:

 Very little geological work relevant to geothermal energy undertaken.
 Zambian-Italian Government joint Geothermal Project mid 1980’s:
  • Hydrochemistry, geophysics and shallow drilling (<150m) at 4 sites;
  • 220KW Turboden binary geothermal pilot plant installed at Kapisya, Sumbu, Lake Tanganyika;
  • Original development programme curtailed by insufficient understanding of geo-technical data and lack of imperative to develop alternatives to large scale hydro;
  • Kapisya plant maintained by Zambia’s power entity, ZESCO; rehabilitation programme under consideration.
  
 (Also in mid 1980’s Placid Oil drilled in the north Luangwa Basin and shot 2D seismic in Kafue basin)
 Kalahari GeoEnergy Ltd conducted regional reconnaissance 2011-2012; currently exploring the Kafue Trough, a Karoo era extensional basin.

Direct Applications of Geothermal in Zambia:

 Currently only small-scale Salt production from geothermal brines (Lake Mweru), ongoing since Omani occupation of Zanzibar
Kafue Trough: Geothermal Energy Targets

A seismically active sedimentary basin filled by Permian-aged Karoo sequence, located to the west of Lusaka and extends westward into the Barotse Basin. It has a surface area of 14,000 km²; it's surface forms the flood plain of the Kafue River known as the ‘Kafue Flats’.

The Kafue Trough lies at the intersection of the Zambezi mobile belt and the Mwembeshi Shear or dislocation Zone a previously highly active tectonic zone, which is a regional transfer fault and to which it is associated. The Karoo basin developed as a pull apart basin as a result of sinistral shear along the reactivated Shear Zone The basin was initiated by a strike slip fault couplet along the Mwembeshi and sub-parallel lateral thrust ramps. Continued subsidence then took place through tensional block faulting and sag – these look like a normal interior fracture tensional grabens.

Currently six identified geothermal resource areas being explored, including Bwengwa River.
Bwengwa River Geothermal Resource Area

The surface manifestations include geothermal springs that extend over 7km. The bounding fault (SBF), hot springs, temperature gradient wells and basement geology show in simplified map.

The springs show strong structural control with respect to the SBF, being located close to major intersections at either end of the duplex / anastomosing fault zone.

Basinward (NW) of the SBF is at least one significant, parallel basement fault (Not shown) and several weak cross faults buried by the sediments. These suggest a major fault zone that would be essential in hosting a significant thermal reservoir.

Results suggest the reservoir is in the basement formations under the sedimentary basin, which forms the Cap Rock.

**Exploration work undertaken:**
- Geological mapping,
- Hydrochemistry sampling,
- Geophysics (including ground magnetics, AMT resistivity, radiometric, gravity)
- Shallow soil temperature measurements
- Geo-Botany, and
- Engineering, drilling and logging of five (5) temperature gradient holes / Slim Wells totalling 1,980m

**Note:** This methodology has been adopted as part of the outcomes of workshop on the geologic and geothermal development of the Western Branch of the Greater East African Rift System, in June 2016
The Bwengwa River Geothermal Resource Area contains compelling evidence of the three key elements required for hosting a hydrothermal system:

1. **Temperature**, reservoir temp from 130°C to more than 160°C is provided by both fluid chemistry and temperature gradient holes.
2. **Permeability** confirmed by the discharge of the hot springs along the regional bounding fault and the associated geologic structures, including fractured basement rocks.
3. **Water** local meteoric water that is plentiful.

Shallow soil temperature survey reveals likely extensions/additional geothermal systems.

Results confirm a geologic setting conducive for geothermal hydrothermal systems and also give a strong probability of a medium enthalpy geothermal resource that can support a power generation project of at least 10MW. Heat-in-place, power density and heat flow methods were used, providing a consistent estimated usable resource capacity in the range of 10-20MW.
The Bwengwa River Resource Capacity estimates
Projected Life: 20 years

<table>
<thead>
<tr>
<th>Reservoir Area</th>
<th>Reservoir Temperatures</th>
<th>MW</th>
<th>% confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>P90</td>
<td>P50</td>
</tr>
<tr>
<td>Heat-in-Place</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 to 10</td>
<td>130°C to 170°C</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Density</td>
<td>2 to 10</td>
<td>130°C to 170°C</td>
<td>6</td>
</tr>
<tr>
<td>Heat Flow</td>
<td>7.45</td>
<td>-</td>
<td></td>
</tr>
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<td></td>
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The most commonly used method for estimating geothermal resource capacity for power generation is the heat-in-place model with power density as a common back-up. Heat flow or heat loss provides an important additional measure of potential heat. Similarities between the MW estimates at 50% confidence from heat-in-place and power density and the heat flow estimates provide strong reassurance that the Bwengwa River Geothermal Area contains sufficient heat to support at least a small to moderate sized geothermal power generation project.

Additional exploration drilling is being undertaken to confirm that the heat can be extracted by water at commercially reasonable rates.
Bwengwa River – Steps to Development

<table>
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<tr>
<th>Time-line to Development</th>
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<tbody>
<tr>
<td><strong>Indicative Dates</strong></td>
</tr>
<tr>
<td>October 2016 – April 2017</td>
</tr>
<tr>
<td>April 2017</td>
</tr>
<tr>
<td>May – September 2017</td>
</tr>
<tr>
<td>From September 2017</td>
</tr>
<tr>
<td>2018</td>
</tr>
<tr>
<td>2019</td>
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</tbody>
</table>

**Development Scenario:** Based on current geotechnical data and financial model, to develop 2 x 10MW binary power plants sequentially thereby fast tracking initial power production, lowering financing requirement, construction, logistics and skills hurdles. This scale would qualify for inclusion in the Renewable Feed-In Tariff programme, with standard documentation, defined tariffs and funded guarantees.

**Concurrent Ongoing Exploration:** KGE has established presence of other similar systems to Bwengwa River including at Nkala River and Mwako Hills at which preliminary exploration has been conducted with objective of identifying and developing additional MW resources.

**Socio-Economic Implications: Cascade of Applications**

- Ongoing research to upgrade community water quality to ‘Potable’ in support of Millennium Challenge initiatives.

- Investigation into direct applications of energy with potential users (Milk processing). Some 90,000 head of cattle graze in immediate area of Bwengwa River. Opportunity to create rural development with sustainable employment.

- Studies to be made into using geothermal power for sustainable production of hydrogen for fuel cells; in which there is a strategic interest in South Africa for both off-grid power solutions and transport as part of the development of the platinum industry.
Key Highlights

- Zambia is geo-politically stable; has a favorable regulatory environment and is committed to implement cost reflective tariffs, so becoming attractive to the private sector. The power market is in long term deficit to demand.
- Bwengwa River Geothermal Resource Area has the characteristics of a technically and commercially viable power resource.
- Exploration has identified further geothermal targets within the Kafue Trough, so supporting assertion that a significant cumulative geothermal energy resource could be available.
- Cascading, secondary, direct applications of geothermal energy for chemical, agro and dairy industries could positively impact on revenue as well as being a factor in National Food and Job Security.
- At National level, capacity is sought to undertake resource mapping and exploration