Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Geothermal Exploration and Development in Zambia

Geoffrey Musonda and Maka Sikazwe

Department of Energy, Minstry of Energy and Water Development, P.O BOX 51254,Lusaka, Zambia

E-mail address: doe@zamnet.zm

Keywords: Zambia, Geothermal

ABSTRACT

Zambia has an installed electrical capacity of 1,774 MW with a peak load of 1,028 MW, most of which comes from three main hydroelectric stations: Kariba North Bank (600 MW), Victoria Falls (108 MW) and Kafue Gorge (900 MW). Despite the country's surplus of available electricity, only 20 percent of the total population and two percent of the rural population has access to the electricity grid. Zambia currently is pursuing plans to construct 200 km of 123 kV transmission lines between the Western province of Zambia and parts of Namibia. Discussions are also underway to interconnect the grid with Tanzania and Kenya.

Zambia has a widespread occurrence of hot springs (over 80 recorded), some of which could be utilized to generate electricity using binary cycle technology. Two geothermal energy projects have been initiated: the first included the construction of a small geothermal plant while the second was planned but never implemented.

In 1986 the Zambian Geological Survey, in conjunction with DAL, SpA (Italy), determined that the hot springs in Kapisya are favorable for commercial power generation. A pilot plant located in Sumbu on the shores of Lake Tanganyika was subsequently built with funding from the Italian government. The plant uses a total of 15 shallow exploratory and production wells, four of which have submersible pumps installed. The plant also has two Organic Rankine Cycle (ORC) turbogenerators, with a nominal capacity of 200 kW which were last inspected by the Italian government in 1988.

The project never became operational because resource temperatures were found to be too low. The government of Zambia is currently exploring options for refurbishing and commissioning the Kapisya geothermal plant after 15 years of being idle. Proposed project objectives include:

• Identify an alternative geothermal prospect with higher resource temperatures.

• Commission the turbogenerators by replacing missing and faulty parts and conduct trial operations.

• Train local technical personnel in the maintenance and operation of the geothermal plant.

• Form a consortium of local communities and the private sector in Nsumbu to operate the power plant and pay for its operation and maintenance.

The second project involved planning for the development of a health resort and construction of a geothermal power plant to provide electric power to the local community at Chinyunyu Hot Springs, that is located 50 km east of Lusaka on the Great East Road. The Japanese International Cooperation Agency, in conjunction with the Zambian Geological Survey, undertook this project, which remains in the planning stages due to lack of funds.

Figure 1 – Map of Zambia

1.0 HISTORY, POPULATION, GOVERNMENT STRUCTURE

From September 1953 until December 1963, Zambia (known as Northern Rhodesia) was part of the Federation of Southern Rhodesia, Northern Rhodesia and Nyasaland). The Zambian people gained self-rule from the British on 24th October 1964. Since 1964, the country has undergone three major phases of governance. During the post independence era, the country first experienced multi-party politics until 1971 when the one party system was put in place. This second system of governance was brought to an end by reverting back to multi-party politics in October 1991.

Administratively the country is divided into nine provinces, namely Central, Copperbelt, Eastern, Luapula, Lusaka, Northern, and Northwestern, Southern and Western provinces. These provinces are further divided into seventy two (72) districts. Lusaka is the capital city of Zambia and seat of government. The government comprises of central and local government. The seventy-two district councils conduct local government administration. The district councils are classified into three categories; city councils, municipal councils and township councils. There are four cities in Zambia; Lusaka, Ndola, Kitwe and Livingstone.

The preliminary estimate for the 2000 Population of Zambia is 10,285,631 persons as at 25th October 2000 (census date) compared to 7,759,167 as at 25th August 1990. Of the 10,285,631 persons, 5,070,891 are males while 5,214,740 are females. Copperbelt province has the highest population followed by Lusaka, Northern, Southern and Eastern provinces. Northwestern province has the lowest population followed by Western province.

The country has an area of approximately 752,618 Km^2. The currency is the Kwacha and the official language is English

1.2 Business/Economic Data

Zambia is one of the most urbanized countries in Sub Sahara Africa with about 40percent of the population living in urban areas. The rest of the population (60 percent) is scattered throughout the rural parts of Zambia.

The economy of Zambia took on a socialist stance a few years after independence in 1964. The government controlled most of the social and economic activities, until 1991 when a multiparty political system was reintroduced. In 1991 the government embarked on a vigorous Structural Adjustment Programme (SAP) with it's collaborating partners including the World Bank, in order to address the imbalance in the economy. The long-term goal of the restructuring programme is to reduce inflation in the economy and stabilize the economy with a view to stimulate economic growth, reduce poverty and improve living standards of households.

The structural Adjustment programme included:

- Privatization of state owned companies
- Liberalization of domestic and international trade
- Liberalization of the foreign exchange market
- Strong Fiscal Policy, which includes government operating on a cash budget to reduce inflation
- Health and education sector reforms, which include the introduction of user fees
- Transformation of the civil service
- Transformation of the agriculture and transport sectors

Table 1: Targets and Outturns in key macroeconomic targets in 2001

Indicator	Target	Outturn	Difference
GDP growth rate (%)	5.0	5.2	0.4
Money supply growth rate (%)	20.5	11.0	(14.2)
Inflation rate (%)	17.5	18.5	1.2
International reserves US $ million	150	74	76
Fiscal deficit (%GDP)	0.75	2.4	1.65

Source, Economic Report 2001, Ministry of Finance and National Planning

The economy in Zambia has now been turned from a state-controlled economy to a market led economy. There are no price controls any more. A Stock Exchange has been established and it is fully operational. The economy registered a growth of 5.2 percent in 2001 compared to 3.6 in 2000. This was higher than the targeted growth of 5 percent for the review period. This outturn was due to strong growth in value added, especially in the larger sectors of the wholesale and retail trade, manufacturing and mining in 2001. During the same period, the electricity, gas and water sector's real output grew from K72.9 billion in 2000 to K82.1 billion in 2001, representing an increase of 12.5 percent. Table 1 shows targets and outturns in key macroeconomic targets in 2001:

1.3 Political/Social Issues

A steep decline in copper revenues, the heavy debt burden, and the diminished external aid flow has limited the Government's ability to reduce poverty. Sustaining economic reform, which was initiated ten years, ago, achieving consistent growth, and bringing tangible benefits to Zambia's people are the central concern of the Government.

The lack of access to electricity is a significant factor in undermining the pace and scope of rural transformation as it hinders productive and income generating activity. It also affects the welfare levels of the under-privileged population. In most rural areas, and peri-urban areas, people use kerosene for lighting and most of commercial farmers use diesel-powered irrigation

2.0 THE ZAMBIAN ELECTRICITY SECTOR-OVERVIEW

Zambia is a country richly endowed with Hydro- Electric Power (HEP) Potential. The country has an estimated HEP potential of 6000 MW. Of this, only 1,774 MW is installed against a peak load of 1,200 MW. Most of the power is generated from three main hydro power stations: Kariba North Bank (600MW), Kafue Gorge (900MW) and Victoria Falls (108MW). The minimum excess HEP available for export and further local connections to the Grid is 400. About 80 % of the country's overall population (98% of the rural population) does not have access to electricity.

According to the Poverty Reduction Strategy Paper (PRSP), THE Zambian Government intends to increase the electricity access rate from the current 20% to 35% by the year 2010. This will translate into an increase in access rates of 2% to 15% in rural areas and 35% to 50% in urban areas. On the other hand, the country intends to increase it electricity exports by selling power to Tanzania and Kenya. The Zambia – Tanzania – Kenya Interconnector will be constructed at an estimated cost of $ 153 Million and will supply an estimated load of 200MW of power. In its bid to develop the Agriculture sector, the Government is embarking on the electrification of Farm Blocks e.g. Mkushi Farm Block at an estimated cost of $40 Million. Due to this expected increase in electricity demand (local and foreign), the Government has been rehabilitating the existing Power Plants, and is also planning to develop other HEP Power Stations. The immediate projects include: the Kafue Gorge Lower HEP Scheme with a rated capacity of 750 MW at an estimated cost of $ 600 Million; and, the Itezhi-tezhi HEP Scheme with rated capacity of 120MW at an estimated cost of $100 Million.

In Zambia, Rural Electrification Projects have proved to be unattractive due to their low returns. Rural communities are sparsely populated making Grid Extension very expensive. In addition to this, demand for electricity is low and the ability to pay for electricity is also low making the returns on the connected electricity unprofitable. In an effort to increase the rate of rural electrification and create conditions favourable in the development of rural areas, the Government of the Republic of Zambia made a policy decision in January 1994 aimed at improving the funding of Rural Electrification Projects. Government decided to create a Rural Electrification Fund (REF) by committing 3.45 percentage points of the sales tax on electricity to expanding the electricity network to rural areas The Government has been using a Rural Electrification Fund (REF) to carry out Rural Electrification Projects (REPs). In order to accelerate the rate of rural electrification the government has decided to set up a Rural Electrification Authority (REA) which will be responsible for the implementation of REPs. It is envisaged that the REA will manage the REF more efficient and transparent manner. The REA will also be able to identify REPs on least cost energy source option. Areas that will prove to be expensive for grid extension will be electrified using other means like mini grids and stand-alone systems. The REA will be set up to operate independently and award contracts to the most competitive bidder, this is expected to end the monopoly of ZESCO as the sole rural electrification contractor. The REA will be responsible for mobilizing resources from government, the private sector and the donors. The electricity levy will now be deposited directly in the account of REA. Legislation (the rural electrification Authority Act) has been prepared to back up the existence of the REA and its authority to receive and use the REF. Hence the Ministry of Finance and National Planning will not divert the levy to other social and economic sectors.

The World Bank in partnership with the Zambian Government has reached advanced stages in the planning of the Increased Access to Modern Energy Services Project. The Bank has committed up to $25 million to the project in grants and loan facility. The project will include extension of the grid to rural and peri-urban areas, use of mini grid systems using renewable sources of energy, which could include geothermal.

Geothermal resources in Zambia provide an opportunity for least cost energy source options for REPs, by way of Binary Cycle System. Currently, Kapisya Hot Springs and Chongo Hot Springs offer the best opportunities for Geothermal Electricity development.

3.0 HISTORY OF GEOTHERMAL EXPLORATION IN ZAMBIA

Hot springs have a widespread occurrence in Zambia (over 80 recorded), some of them capable of being utilized to generate electricity using the binary cycle system. The Zambian Springs are found along fault zones cutting thick sequences of rock cycles ranging in age from Precambrian to Karoo.

Hot springs have been known to exist in Zambia for a long time. The earliest description is by Wallace in 1889 who visited and described springs on the southern edges of Lakes Mweru Wantipa and Chishi and observed salt production by villagers. (Legg, 1974). Ferguson (1902) made chemical analyses of springs in the Zambezi Valley and attempted to relate them to mineral occurrences. Guernsey (1941) compiled data on hot springs from different sources and listed 31 geothermal occurrences in the Luangwa concession area.

Since 1950, the Geological Survey of Zambia has examined some springs during routine regional mapping exercises and others by the Department of Water Affairs and mining companies. Little else has been done to use water from the hot springs for industrial applications.

Legg (1974) presents detailed geochemical data on the major hot springs and speculates on their potential use for geothermal power. He also presents the first concise genetic model of the hot springs.

Two hot springs, Kaimbwe and Kaputa, were studied in 1976. Shallow exploration wells were drilled up to 80m depth to intercept feeder zones of high salinity from which brines could be tapped and processed for salt. Although not successful in this regard, the project provided information that could be used for future geothermal activity

A critical investigation into Zambia's geothermal potential as initiated by the Geological Survey Department through the Ministry of Mines and Minerals Development in conjunction with DAL in.te.sa SPA of Milan Italy following a bilateral agreement between the Governments Of Zambia and Italy in 1984. The project was funded through an Italian Grant of $2 Million, to carry out a country wide geothermal investigation. Out of the exercise, geothermal potential and social economic factors favored development of a binary cycle geothermal power plant at Kapisya Hot Spring in the Northern Province of Zambia on the banks of Lake Tanganyika. The Geothermal Exploration started in early 1986 and included Geology, Photogeology, Geochemistry, Trace Element Geochemistry, Radon Surveys, Geophysics (electric) and drilling operations. Photo geological interpretation by aerial photos and landsat images was very helpful in understanding the structural setting of the areas.

Phase I of this project, namely the Preliminary Site Selection Phase of the 'Zambian-Italian Geothermal Project" terminated at the end of August 1986 after having surveyed 90,000 square km of the Zambian territory, visiting over 80 spring sites and studying 40 of the more promising springs in detail.

From this reduced list of 40 springs, after taking into consideration a series of factors, including geothermal potential, desirability of developing particular sites and accessibility, a short list of priority sites emerged for subsequent consideration and possible development as pilot demonstration projects. Further deliberations (phase II) resulted in the selection of the following priority sites: Kasho, Lubungu, Lupiamanzi, Chinyunyu, Chikowa, Kapisya and Chongo.

Phase II of the project continued the investigations by evaluating the Seven (7) sites in detail. Economic and sociological considerations as well as accessibility of the sites were used in the selection of the sites for further development. The seven sites and their associated surface temperatures are as follows:

- Kapisya (85 deg C)
- Lupiamanzi (73 deg C)
- Lubingu (77 deg C)
- Chongo (87 deg C)
- Chikowa (64 deg C)
- Chinyunyu (73 deg C)
- Kasho (72 deg C)

Kapisya was chosen as the most suitable site. Fifteen exploration and production wells were drilled at Kapisya in 1987 and 1988 below 150m. A Pilot Plant with four wells fitted with submersible pumps, two binary cycle turbo generators was set up by December 1988.

3.1 Kapisya Geothermal Power Plant

Kapisya is located in the Northern Province of Zambia, 500m off the shores of Lake Tanganyika and 14Km North of Nsumbu Boma. Kapisya is the first Geothermal Energy Plant in Zambia, and was the first of its kind in the world (i.e. a small scale geothermal binary cycle turbo generators for Rural Electrification). The plant was meant to promote tourism, the fishing industry and the nearby Government Administrative Center in Nsumbu.

The two turbines were examined and cleared by inspectors from the Italian government in 1988 (test certificates are not available to confirm this) and what had remained is the construction of transmission lines from the Plant to the community. Construction of the lines was not covered in the bilateral agreement between the two governments

The geothermal power plant was handed over to the Geological Survey Department in 1988. On 20th October 1999, the Plant was transferred from the Geological Survey Department to ZESCO (the electricity utility company) in order to facilitate construction of a power line, which has never been done to date.

Technical Aspect of the Plant

The Geothermal Power Plant is composed of four submersible pumps (each with a 2.2kW motor) and two of each of the following units: Evaporator; Spray Type Cooling Tower; Condenser and Turbo generator. The Plant is designed to operate on the principle of Binary Organic Rankin Cycle. The hot water pumped out of the aquifers and passing through the heat exchangers heats pacroethylene (the low boiling point organic medium used). When heated, the organic medium changes its form into vapor and expands, thereby rising. The expanded and rising vapor drives the turbines of the turbo generators (located above condensers) thereby generating electricity. After driving the turbine, the organic medium enters the condenser units where it is cooled and condensed by the cold water from the cooling towers. The condensed organic medium goes back to the heat exchangers for heating for subsequent electricity generation. Each turbo generator has a nominal capacity of 100kW and maximum capacity of 120kW, giving 200kW as the nominal capacity and 240kW as the maximum capacity of the Plant.

Community Power Needs

The total demand of power in the community near the geothermal plant was oscillating around 80kW at the time the plant was completed. The potential clients included the fisheries, tourist resorts and the government Administrative Centre. Hence the plant was going to be able to meet the demand assuming that it would operate at the designed capacity. The contractor working on the geothermal plant estimated that construction of 100kW line from the plant to Nsumbu over a distance of 18Km would cost $500,000 half the price required to connect to the national grid. Currently, the Nsumbu community is using electricity generated by private diesel generators, which is a very expensive venture. The need to connect the community to either the grid or to the geothermal plant cannot be overemphasized.

Shortcomings of the Kapisya Project

The main shortcomings that led to the unrealized commissioning of the geothermal plan include the following:

Construction of the lines was not covered in the bilateral agreement between the two governments. Hence the transmission lines were not constructed making the plant of no use to the surrounding community.

The maximum surface temperatures of 85°c are below the temperatures for which the turbo generators were designed. Thus the generators are likely to operate below the intended generating capacity. There is need to source deeper geothermal waters, which are likely to have higher temperatures, so that the plant can operate at the intended 240KW maximum and 200KW minimum capacity.

The project was initiated from geological study point of view and hence its use as an energy service provider was not prioritized.

3.2 Chongo and Chinyunyu Hot Springs

Phase II of the Geothermal Project recommended Chongo hot Springs as the second most ideal place for establishment of a binary cycle geothermal power plant, after Kapisya. Chongo hot spring actually has higher surface temperatures than Kapisya, but the later was preferred on social economic considerations.

Another geothermal project that was being considered by the Geological Survey Department involved planning for the development of a health resort and construction of a geothermal power plant to provide electric power to the local community at Chinyunyu hot springs, fifty kilometers east of Lusaka on the Great East Road. The Japanese International Cooperation Agency (JICA) in conjunction with the Zambian Geological Survey undertook this project. The project remains in the planning stages due to lack of funds.

4.0 THE GOVERNMENT'S VISION FOR GEOTHERMAL ENERGY

The Government of the Republic of Zambia does not have specific policy on geothermal energy, however it does have policy on renewable energy as a whole. It is the Governments intention to exploit renewable energy resources apart from HEP especially where they present opportunities for least cost energy sources in Rural Electrification exercises. In light of this, the government is considering options for the refurbishment and commissioning of the Kapisya Geothermal Power Plant. Some proposed actions for the way forward include:

Carry out further geothermal resource testing and exploration at Kapisya or Identifying an alternative geothermal prospect with higher resource temperatures;

Commission the turbo generators by replacing missing and faulty parts and conduct trial operations;

Carry out further hydraulic testing at Kapisya in order to establish the suitable extraction rate and hence firm energy potential;

Form a consortium of local communities and the private sector in Nsumbu to operate the power plant and pay for its operation and maintenance.

The Government's desire to make headway in the implementation of REPs creates an enabling platform as far as the way forward for geothermal energy is concerned in Zambia. The setting up the REA is a step in the right direction for the exploitation of geothermal energy.

The Rural Electrification Authority (REA) will involve the private sector, which could include private geothermal operators to implement REPs. The REA will employ smart subsidies to make implementation of REPs economically attractive, as well as the service provided to rural communities affordable. The REA will outline strategies on how REPs will be implemented through the Rural Electrification Master Plan (REMP). One of the

Characteristics of the Master Plan is that energy will be used as an income-generating tool, which will enhance sustainable development and reduce poverty. Hence, productive areas like the community surrounding the Kapisya geothermal Plant will be priority areas in the implementation of REPs especially that it already has infrastructure for electricity generation on the ground.

5.0 LESSONS LEARNED FROM THE ZAMBIAN GEOTHERMAL EXPERIENCE

The Zambian experience on geothermal energy development, particularly that at Kapisya Geothermal Power Plant presents several lessons to be learnt, as follows:

Social economic consideration in the selection of a site to be developed is of utmost importance. There has been a consistent outcry from the community near Kapisya for the re-commissioning of the power plant due to their need for electricity;

Future geothermal power developments should be developed from an energy service perspective, and not just as a geological study exercise. Such an approach will ensure that issues such as construction of transmission lines to communities are planned for, unlike what happened in Kapisya;

There is need for a Rural Electrification Master Plan which clearly outlines all available energy resources to avoid dominance by traditional sources of electricity;

Geothermal energy exploration and development units of Government should be located in the Ministry responsible for Energy or Power Development;

Special units to promote geothermal energy development should be set up preferably not in the electricity utility companies. This is very true for countries like Zambia where these utility companies tend to promote hydro power production;

Government and utilities should invest in capacity building of staff in geothermal energy planning, and development technologies; and,

Private sector should be encouraged to participate in geothermal energy development. Kapisya geothermal power plant would have probably received more attention had it been in private hands.

6.0 CONCLUSION

Geothermal Energy presents one of the solutions to the problems of low electricity access rates in the rural areas of Zambia and Africa as a whole. More in country studies should be devoted to the exploitation of this resource, relative to social economic needs and the sustainability of the use of particular geothermal fields.

Though Zambia has a huge HEP potential, the increasing demand on this resource- both local and foreign calls for exploitation of other renewable sources of energy such as geothermal energy. This is especially so for rural electrification which usually cannot compete with more profitable ventures such as exporting of electricity.

The opportunity presented by geothermal resources as a renewable energy cannot be overemphasized and hence should be given the attention they deserve in the energy sector.

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000						
2001						
2002						
2003	2	1				
2004	3	1				
Total	3	1				

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1990-1994	None	None	None	None	None	None
1995-1999	None	None	None	None	None	None
2000-2004	None	None	None	None	None	None