An Update on Applications to Direct-uses of Geothermal Energy Development in Kenya

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ABSTRACT

The Kenyan part of the East African Rift Valley is endowed with plentiful of geothermal resources. In a country where the availability of jobs is a problem, the exploitation of geothermal energy aimed at electricity generation and direct uses can become a source of employment and hence a pillar for raising the living standards of the local people and trigger social and economic development. The Olkaria geothermal area (located in the rift valley) is also blessed with fertile volcanic soils and adequate climate to grow and farm basic food crops and support local agro industry such as flowers. The utilization of the geothermal resources of the Olkaria area has in recent times spurred social development. Besides the strategic and environmental values of exploiting geothermal energy, this source of energy has offered other attractive direct uses. The use of exothermally heated waters in the greenhouses has enabled higher competition as it has allowed variation in the soil use pattern resulting in yield increase and decrease in production and infrastructure costs. As a result of employing geothermal heating and carbon dioxide in the Rose Flower project, Kenya is now the largest Geothermal Greenhouse Heating Project in the world.

These two products (electricity and floriculture) have proved good returns from the geothermal development costs and spurred both local agricultural and national industrial activities. This paper attempts to highlight efforts being made on geothermal energy development in Kenya with special emphasis on promoting direct uses of this resource in the country especially its applications to horticulture.

1. INTRODUCTION

Surface thermal manifestations are common in Kenya. These include high-, low- and moderate resources. The Ministry of Energy of the Government of Kenya and the Kenya Electricity Generating Company (KenGen) Ltd have carried out exploration activities in the rift valley since the early seventies, using local expertise. Scientific research has also taken place over other areas in the country. The methods employed during the studies included mapping of structures and occurrences of geothermal manifestations and the characterization of the volcanological associations, important in the development of geothermal systems. Gas and steam condensate samples were obtained from fumaroles to determine the nature of the geothermal reservoirs while ground radon surveys were undertaken to indicate the presence of geothermal reservoirs and to map buried structures above the geothermal systems. Ground temperature surveys were also carried out over most areas to further confirm the existence of hot bodies under the prospects.

These investigations have identified both high enthalpy geothermal systems associated with young volcanic centres and low enthalpy systems associated with extremely weak surface manifestations. Models obtained from these data analysis suggested that the hot magmatic bodies resulted in the development of geothermal systems under these centres. Hence a sizable amount of data exists from the high temperature volcanic centres within the rift valley, but there has been no significant effort to investigate/confirm and compile all the available information on low temperature resources and their current or potential uses.

In previous World Geothermal Congresses, Mwangi, (2000 and 2005) reported a horticultural farm using well OW-101 on the Olkaria field, with an output capacity of 1.28 MW for use in a greenhouse for flower growing on an experimental basis which later was converted to a commercially viable operation. This development was first mentioned at the WGC1995 meeting by Melaku et al., (1995) where a study had been made to utilize heat from the well to pass through a heat exchanger to produce clean fluid to be sprayed onto the soil to sterilize it. This paper updates previous information on the use of geothermal fluids for direct heat utilization in Kenya.

2. ROLE OF GEOTHERMAL IN KENYA'S ENERGY MIX

Commercial Energy in Kenya is mainly produced from hydropower, accounting 70-80% of total electrical energy generation. Rivers that supply water to its dams span large catchment areas. The Seven Forks Cascades Project, which supplies the bulk of the hydropower, has its water catchments in central Kenya. The changes in rainfall patterns and pressure on land use in these areas has resulted in a lot of silt (from soil erosion) being deposited in the Seven Forks dams, a situation which is raising concern.

The country is dependent on biomass and fossil fuels as primary energy sources. The over-dependency on hydropower and thermal makes their electricity not only expensive but also unreliable due to erratic weather conditions and the ever-escalating oil prices. At present, Kenya has some active geothermal operations as part of the country's electricity generation infrastructure, much of it owned by the Kenya Electricity Generating Company (KenGen). Geothermal has proved to be reliable and economical, running at 98% availability.

Population growth, a growing economy and aspirations to achieve 10% GDP growth, fuelled by Vision 2030 requires Kenya to almost treble its Electrical power capacity in the coming decade. Peak demand has outstripped available capacity of 997 MW today. The company needs to deliver 260 MW capacity by end of 2011 and another 1,570 MW between 2012 and 2018. By 2018 Kenya must have 32% electricity penetration to reach the Vision 2030 target of half the population (KenGen Annual report, 2006 and 2007; KenGen Business plan, 2007; Porter, 2007). The burning platform for KenGen today is to stabilise the power situation in Kenya over the next 5 years by delivering ongoing projects/optimisations, initiating power conservation and maintaining emergency power. The company will need also to kick-start future projects that will bring significant capacity on-line over the next 5-10 years, in order to alleviate current “fire fighting” to meet demand and create sustainable growth for Kenya, including the right to explore regional expansion opportunities. Much of this is envisioned to come from geothermal resources.

Despite the fact that over 90% of geothermal utilization in Kenya is in the generation of electrical power, in recent years direct uses have started to feature in some parts of the country. Traditionally, natural hot springs and fumaroles found in some parts of Kenya have been utilised by residents for worship and offering of sacrifices, particularly when afflicted with ailments that were difficult to cure (Tole, 2002). An example of a more modern direct use of geothermal fluids is that of farmers using geothermal heat to dry pyrethrum flowers and condense steam for drinking at Eburru village, near Naivasha. However, more uses are being adopted in green houses and bathing as will be discussed in more details in the following sections. Nevertheless more efforts need to be put in place to expand use of these low enthalpy fluids in the country.

3. LOW ENTHALPY RESOURCES IN KENYA

Apart from those thermal manifestations located within the rift, some surface manifestations have been located in western and coastal areas. There are two main groups of thermal springs in the country: (i) hot springs discharging at or close to boiling point, with about 4-20 g/l TDS (total dissolved solids); (ii) low-enthalpy springs (warm springs) with temperatures of 25–45°C and dilute waters (< 3 g/l TDS). The thermal fluids are mainly Na-Cl-HCO3 in composition, reflecting silicate hydrolysis (mainly alteration of feldspars) in catchment areas and acquisition of solutes by thermal fluids circulating underground. The hottest waters discharged are poor in calcium (< 2mg/l), rich in bicarbonate, with moderately high silica concentrations (< 130 mg/l), (Dunkley *et al*. 1993; Sturchio *et al*. 1993). An example of a hot spring in western Kenya is at the Homa Hills near Homa-Bay and at the coast is that at Jombo Hills in Taita Taveta. But the most studied are those in the Rift Valley, where high geothermal gradients, permeable young faults, and adequate rainfall combine to provide ideal conditions for forming hot springs on valley floors (Renaut and Jones, 1997).

4. CASE EXAMPLES OF DIRECT USES IN KENYA

Around the world many of the direct use applications employ geothermal fluids in the low-to-moderate temperature range between 50°C and 150°C. Further, low-temperature systems are applied more than high-temperature systems since they are more likely to be located near potential users. Gudmundsson et al., (1985) have summarized the common direct uses in what they have referred to as a Lindal diagram, relating these with temperatures of the geothermal fluids in use. The majority of direct applications use hot water in the range 20-30˚C. In recent times, carbon dioxide gas is being derived from geothermal fluids and used directly in green houses.

Lagat (2005) has discussed potential direct uses in Kenya. These include swimming, bathing and balneology (therapeutic use), space heating and cooling, agriculture, aquaculture and industrial applications

4.1 Balneological Uses

Bathing in naturally occurring warm or hot waters has been practised by many civilizations over history such as the Romans, Greeks, Turks, Japanese and Mexicans. Today, balneology continues to be practised in many countries. Tole (2002) has indicated that natural hot springs and fumaroles found in various parts of Kenya have been utilised by the local residents for worship and offering of sacrifices, particularly when afflicted with ailments that were difficult to cure. He notes, however, that although it is evident that thermal waters are beneficial in the management/cure of some ailments, the curative mechanisms of thermal waters are less well understood. He recommends that despite Kenya having benefited greatly from using geothermal systems for electrical power generation, there is need to evaluate the different sites for balneological applications in the country as well as understand the factors that impart curative qualities to these geothermal waters.

At Lake Bogoria, natural hot water is directed towards a swimming pool, in which guests in a nearby tourist hotel bath. The hot water is derived from a nearby Loboi spring at 38˚C to heat a spar pool (see plate 1). Further north, within the Kenya Rift, spectacular manifestations of hot springs exist at Lake Baringo, Kapedo and Lorusio (Plate 2).

Plate 1: Lake Bogoria Hotel using natural hot water in a swimming pool from the nearby Loboi Hot Spring.

Plate 2: The spectacular Kapedo Hot Springs within the Kenya Rift.

4.2 Green Houses - Oserian Development Company

Kenya is one of the five largest flower exporters in the world. About 55% of the country's flowers are exported to the European Union. This figure is contributed mainly by a few tens of large-scale commercial farms. The cut flower industry employs around 60,000 people, excluding over 2 million indirect dependants for their livelihoods. The Kenyan cut flower industry dates from the late 1960s but it wasn't until the 1990s that investment transformed it into a major player in the international market. It has an annual growth rate of 20% and is among the fastest growing sectors of the Kenyan economy generating revenues in excess of USD 250 million annually, making it the country's second largest agricultural foreign exchange earner after tea. Hence this industry does contribute significantly to the national economy in poverty alleviation.

Flower and other plant growers acknowledge that some of the major production factors are light, water, warmth and CO_2. These growers are convinced of the beneficial effects of CO_2 enrichment, regardless of poor ambient light conditions their crops may face during the year. Kenya, being on the equator is endowed with enough sunshine with average temperatures of about 20^0C much of the year. These temperatures may drop much lower at night, necessitating artificial warming. The Naivasha area which produces the bulk of the cut flowers in the country, uses irrigation water from the fresh nearby Lake Naivasha. Hence for the Naivasha environment, at an average altitude of 2000 m.a.s.l., the single growth limiting factor for flower production is the availability of CO_2; more of this gas could easily mean more photosynthesis and better production. This is because at higher altitudes ambient CO_2 concentrations are much less than at sea level at sea level.

Oserian Development Company is a horticultural business, located on the shores of Lake Naivasha in the Rift Valley. It employs about 6,000 workers. The farm produces and exports about 400 million stems a year, mainly roses and carnations, on a production area of about 250 hectares.

Since temperatures in Naivasha often drop considerably at night, flower growers need to heat their greenhouses at night, so the Oserian owners decided to make use of the geothermal wells drilled during the initial exploration of the nearby Olkaria geothermal field, wells which aren't suitable for electrical power production KenGen needs, but are perfect for supplying the warmth and carbon dioxide needed for growing roses. The heating system has been in operation since May 2003.

Oserian Development Company has invested about 25 million euros into its geothermal utilisation efforts. The CO_2 for its greenhouses, derived from its geothermal plants, is part of the non-condensable gases not needed for power and heat production. The gas is piped into the cut rose greenhouses, resulting in little or no emission of CO_2 into the atmosphere, which further increases the environmental friendly nature of this renewable energy source. An alterative source would have been the burning of fossil fuels to produce the required gas for injection into the greenhouses, increasing costs of production, more so as oil prices continue rising. Oseria generates electric power for almost all its internal use from its two geothermal power plants with installed capacity of 1.8 MW and 2.5 MW, respectively. The geothermal fluids are also used to heat and control the humidity in the greenhouses, which in turn protect the flowers from fungal diseases and so reduces the amount of fungicides used.

5. OTHER POTENTIAL USES

5.1 Heating and/or Cooling of Houses

Geothermal hot waters are often used in geothermal heat pumps (GHP) to provide heating and/or cooling of residential houses and offices. In many parts of Kenya, the annual temperature ranges are not extreme and therefore GHP's would be mainly used to cool and to a small extent heat residential houses in the cooler months of the year to provide for stable temperatures in the houses. Lagat (2005) recommends that at Olkaria and Eburru where boreholes have been drilled for electric power generation, heat from the effluent hot water be supplied to the residential houses and hotels around Lake Naivasha and urban centres like Nakuru. These developments if realized will enhance local and foreign tourism hence boosting the economies of the local population and the country.

5.2 Multipurpose Utilization - Eburru Area

Other Geothermal Prospects include Eburru, just north of Olkaria geothermal field. A pre-feasibility study for multiple uses of geothermal for electricity generation and water production for agriculture and domestic use was carried out in this area (Lima *et al.*, 2004). The study concluded that multipurpose utilization of geothermal energy in places where there is scarcity of water and availability of geothermal is possible. This utilization would create win-win situations because the exploration and exploitation costs will be shared between different users. It was noted, however, that the success of the project would depend on the government of Kenya providing the supporting infrastructure, land concessions and appropriate policies.

A feasible enterprise would be the drying and dehydration of agricultural products (see plate 3). These activities use moderate-temperatures (40 to 100°C) geothermal energy, in which geothermal water heats air for drying fruits such as onions, pears, apples and pyrethrum. Already the Eburru community condenses the steam from fumaroles and uses the water for domestic purposes (see plate 4) as well as drying pyrethrum flowers at 98^0C.

Plate 3: Pyrethrum drier at Eburru using geothermal fluids.

6. BARRIERS TO EXPANSION OF DIRECT USES

A lot of research effort and funds have gone into geothermal development and hence substantial information exists on location and potential of geothermal resources in Kenya. Present development has largely been on high enthalpy use for power generation and little interest has been placed on low enthalpy direct uses. Several factors can be attributed to this scenario. Lagat (2005) has discussed in detail several of these barriers, including, Markets, Commercial financing, Exploration Risk, Technological Constraints, Political Risks and Legislative Framework. However, investigations carried out by this author indicate that while these factors do contribute to the slow expansion on direct uses of geothermal resources in the country, only two can be regarded as significant but even then these can be addressed. These two are markets and financing.

Plate 4: Water harvesting from geothermal fluids at Eburru.

It has been said that in Kenya most of the geothermal areas are located in the rural and remote sites where the markets are not readily available. And therefore this may have slowed the rate of development for direct use of geothermal resources. This is true but only to a certain degree. Three of the geothermal prospects/fields, namely, Olkaria, Eburru and Menengai are in close proximity to urban centres, flower farms or major hotels but concerted effort has not been put in educating potential customers on the benefits of using geothermal heat by either the government or KenGen, the largest company currently exploiting geothermal for electricity generation. A market certainly exists.

The other factor often quoted as hindering direct use applications is funding. Geothermal energy projects often require higher up-front costs, to cater for exploration, well field development and plant equipments such as water and steam lines. Nevertheless if the market is proved, interest by investors will be spurred. To prove this market, there is urgent need to show whether direct use applications can favourably compete with conventional fuels as this varies from place to place, depending upon the local energy supply infrastructure and prevailing market forces. That variability in the country has made it difficult to develop simple cost comparisons for evaluating energy use options. Even so, the increasingly volatile fossil fuel in the world energy market makes it likely that this barrier will not persist.

Feasibility of using geothermal resources in a given application must be beneficial and provide energy at a lower cost than the next best alternative. Once in place, a geothermal energy system will not be subject to the fluctuating costs of fuel prices that are common to other energy sources. Geothermal direct-use projects tend to have higher capital costs than their alternatives (though not always); therefore the annual savings resulting from the use of geothermal energy must be large enough to repay such increases in capital investment. Life-cycle costs can be favourable for geothermal projects. The energy alternatives to the direct-use of geothermal resources are typically electricity, natural gas, and propane. However, these alternatives are not always available and their availability will be a significant consideration when choosing to implement a geothermal direct-use application.

7. CONCLUSIONS

Currently, in Kenya, the primary use of geothermal energy is for the production of electricity. However, not all geothermal waters are warm enough to be used to generate electricity, but they are and can be valuable nevertheless because they all contain heat energy. Resources of low to moderate temperatures (500-1500C) can be used for a wide variety of applications in the residential, commercial and industrial sectors. The direct uses include swimming, bathing, balneology, agriculture, and aquiculture. For example, a few farmers have, for decades, used geothermal heat to dry pyrethrum flowers and condense steam for drinking at Eburru, near Naivasha while the Oserian Development Company (also in Naivasha) is using geothermal energy to heat greenhouses for growing flowers for export. A tourist hotel at Lake Bogoria is utilizing spring water at 38°C to heat a swimming pool. Direct uses are only a tiny fraction of the total geothermal energy resource in Kenya, i.e., about 1.3 MWt. In recent years, this small figure of direct uses has been increasing, albeit slowly, in various parts of the country. But the rate of increase is insignificant, largely due to lack of information on availability of the resource and its benefits to potential customers. Other factors that have been attributed to this scenario include technological constraints, commercial financing and the low price of competing energy sources.

The major element chemistry of some of the geothermal waters in Kenya is similar to that of waters used at established balneological sites in other parts of the world. Trace element concentrations, however, are less well known. More research is required to understand the factors that impart curative qualities to geothermal waters. Kenya has been developing its geothermal systems for electricity generation, but should also evaluate the different sites for balneological and other direct applications.

8. RECOMMENDATIONS

In order to be seriously considered as an alternative in any project, an energy source must be easily characterised in terms of cost, both capital and unit-energy cost. Historically, this has been a difficult hurdle for geothermal energy, whose cost varies with depth and character of resource, number of production and injection wells and a host of other parameters. As a result even cases where developers (such as KenGen) are interested in using the geothermal energy, identifying its costs may be a cumbersome process. To address this problem, a detailed survey may need to be conducted which will provide potential users to quickly evaluate the capital cost and unit-energy cost for utilising a geothermal resource. It is envisaged that the survey will contribute to wider dissemination of the potential of the low to medium temperature geothermal resources in direct use applications.

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