OPPORTUNITIES FOR DIRECT UTILIZATION OF GEOTHERMAL ENERGY IN EBURRU AREA, NAKURU COUNTY IN KENYA

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ABSTRACT

Geothermal energy is the natural heat from the earth's interior. The energy is indigenous, reliable and environmentally benign resource that is inexorably gaining momentum in many parts of the world endowed with the resource. Kenya is endowed with vast geothermal resources in excess of 10,000MWe, located in the Kenyan Rift. Irrespective of the great energy potential, nearly 700MWe has been harnessed at Olkaria and Eburru Geothermal Fields for electricity generation. However, direct utilization of geothermal energy in Kenya has been low, estimated at 22.4MWt. Some of the direct uses in Kenya include greenhouse heating by Oserian Development Company Ltd, pyrethrum drying at Eburru, swimming and bathing at Olkaria Geothermal Spa and Lake Bogoria Spa Resort. This paper assess opportunities for direct utilization of geothermal energy in Eburru area, where KenGen is currently operating a 2.4MWe Geothermal Wellhead Power Plant. Eburru is a settlement scheme where a shallow well drilled in the 1950s is still used by the local to dry pyrethrum. This study proposes to broaden the use of geothermal energy for large-scale agricultural drying, geothermal steam bath, pasteurization, poultry hatching and provision of potable water which is a big challenge in the area. The proposed applications of geothermal energy in Eburru will improve the socio-economic life of people living in the area. Further, it will be a platform for KenGen to exchange knowledge and show-case direct uses of geothermal resources in Kenya.

Keywords: Geothermal energy, Eburru, direct utilization, enthalpy

1. INTRODUCTION

Direct use of geothermal energy worldwide is gaining momentum in many parts of the world. Realization of the various utilizations of geothermal energy depends on the enthalpy and chemistry of the resource. High to medium enthalpy resources are used for electricity generation while medium to low resources are mainly used for direct applications. Worldwide, geothermal resource has been utilized indirectly in over 24 countries for electricity generation and in 82 countries for direct applications. Some of the direct applications include space and district heating, agricultural drying, greenhouse heating, aquaculture, snow melting, industrial applications, bathing and swimming including balneology, among other uses. However, the last three decades have seen a rapid increase in geothermal utilization. Currently, 24 countries in the world are using geothermal energy for power generation while 82 countries are utilizing geothermal energy for direct purposes (Lund et al, 2010).

Kenya is the first country in Sub-Sahara Africa to tap power from the Earth's crust in a significant fashion (Karekezi and Kithyoma, 2003). The country has plentiful geothermal resources that have not been exploited to full potential. The resources are located in the Kenyan Rift and over 23 geothermal fields and prospects have been identified (Figure 1). These prospect fields from south to north are Lake Magadi, Suswa, Longonot, Olkaria, Eburru, Badlands, Menengai, Arus Bogoria, Lake Baringo, Korosi, Paka, Silali, Emuruangogolak, Namarunu and Barrier Volcano. Kenya has a potential of over 10,000 MWe of geothermal energy, endowed within the Kenyan Rift (Simiyu, 2008). Irrespective of this great potential, only 677 MWe has been harnessed for power generation at Olkaria and Eburru. Direct utilization of geothermal energy in Kenya has been low, and some of the uses noted include greenhouses, aquaculture, swimming, therapeutic bathing and drying agricultural products.

Figure 1: Kenya geothermal fields and prospects (Simiyu, 2010)

2. STUDY AREA

Eburru geothermal field is among the 23 geothermal prospects in the Kenyan Rift. The field covers an area of about 16km^2 with an altitude of up to 2800 m.a.s.l. (Wetangula et al, 2008). Administratively, the project site is located in Eburru location, Gilgil division, Gilgil District of Nakuru County. The geothermal field is approximately 140 km north-west of Nairobi and 40 km north of the Olkaria geothermal power plants. The field is located within/near the Eburru forest reserve which was gazette in 1936 as an indigenous forest forming the eastern boundary of the Mau escarpment and thus part of the Mau Narok Forest System.

3. BACKGROUND INFORMATION

Geothermal exploration at Eburru started in the 1980s. The Kenya Electricity Generating Company (KenGen) then Kenya Power Company (KPC) carried out detailed surface exploration studies at the Eburru geothermal field from 1985 to 1990, after which six deep exploration wells were drilled between 1989 and 1991. The wells drilled were EW-01, EW-02, EW-03, EW-04, EW-05, and EW-06, and have average depth of 2.5 km. The results from the exploration wells indicate that the field had experienced temperatures of over 300°C possibly due to localized intrusive, and the maximum discharge temperature was 285°C. From these wells, only EW-01, EW-04 and EW-06 were thermally productive with a potential of 2.4 MWe, 1.0 MWe and 2.9 MW_t respectively. The other wells EW-02, EW-03 and EW-05 recorded maximum temperatures of 131°C, 161°C and 156°C respectively. The exploration results indicated that Eburru volcanic complex has about 2 km² high enthalpy area that can support a 60 MWe power station (Lagat, 2003, Simiyu, 2010). To harness the geothermal energy resource at Eburru area, KenGen has used steam from EW-01 and has installed a 2.4 MWe pilot power plant at Eburru that was commissioned in 2011. The power has been connected to the national grid and this is a major milestone for KenGen, as it is the first geothermal wellhead power plant in commercial operation. Active fumaroles and hot grounds are abundant in Eburru. Previous studies by

Velador et al. (2003) documented that 80% of the fumaroles are associated with north-south faults in eastern Eburru, and 50% are associated with one main north-south fault.

Two shallow wells were drilled in 1950s at Ex-Peter in Eburru. One of these wells is being utilized to dry agricultural produce in small scale. Steam from this well is also being condensed to provide potable water for domestic use. The second well is no longer in use due to poor maintenance. It is hereby proposed that energy from the two shallow wells at Eburru be used directly in a cascaded manner for drying of agricultural produce, poultry hatching, pasteurization and recreational facility in a steam sauna and for provision of the much needed potable water. The proposed projects will not only showcase some of the direct uses of geothermal energy, but will also improve the living standards of the local community.

4. PROBLEM STATEMENT

Eburru area has a potential of generating 60 MWe. Despite this great potential, only 2.4 MWe has been harnessed by KenGen for electricity generation. Availability of clean drinking water is a big challenge in the area. The local community has been condensing geothermal steam using traditional techniques in order to get potable water for domestic use. Though the area is fertile and the climatic conditions are favorable for growing pyrethrum, no commercial factory exists for drying the pyrethrum. This has led the community to employ traditional techniques to dry their pyrethrum using geothermal heat from two shallow wells drilled during the colonial era.

There exist great opportunities for direct utilization of geothermal energy in Eburru area. It is hereby proposed that energy from the two shallow wells drilled in 1950s at Ex-Peter in Eburru be used directly for large-scale agricultural drying, geothermal steam bath, pasteurization, poultry hatching and provision of potable water which is a big challenge in the area.

The proposed applications of geothermal energy in Eburru will improve the socio-economic life of people living in the area. Further, it will be a platform for KenGen to exchange knowledge and show-case direct uses of geothermal resources in Kenya.

5. POSSIBLE DIRECT UTILIZATIONS OF GEOTHERMAL ENERGY IN EBURRU AREA

Direct utilization of geothermal energy consists of various forms for heating and cooling and the geothermal resources that can be utilized are in the lower temperature range that are more wide-spread than the higher temperature resources used for electricity generation. The primary forms of direct use include swimming, bathing and balneology (therapeutic use), space heating and cooling including district heating, agriculture (mainly greenhouse heating, crop drying and some animal husbandry), aquaculture (mainly fish pond and raceway heating), industrial processes, and heat pumps (for both heating and cooling).

In general, the geothermal fluid temperatures required for direct heat use are lower than those for economic electric power generation. Most direct use applications use geothermal fluids in the low-to-moderate temperature range between 50^{o} and $150^{o}C$, and in general, the reservoir can be exploited by conventional water well drilling equipment (Lundal, 2005). The Lindal diagram (Gudmundsson *et al.*, 1985) indicates the temperature range suitable for various direct use activities (Figure 2).

Possible opportunities for direct utilization of geothermal energy in Eburru area include; large scale agricultural drying, steam bath, pasteurization, poultry hatching and provision of potable water through condensation of steam. Some of the direct uses of geothermal resource in Eburru area are discussed below.

Figure 2: Lindal diagram showing utilization of geothermal energy depending on temperatures (Lindal, 1973)

5.1 Upgraded condensate harvesting system

Geothermal surface manifestations in Eburru are visible in the form of fumaroles, steaming and altered grounds. The Eburru Local community condenses steam from naturally occurring fumaroles to provide potable water. The local community has been harnessing this energy in uncoordinated (individual) way. The community has however made some efforts and are currently using and managing two shallow steam boreholes drilled in the 1950s to provide potable water for the community (Figure 3).

Figure 3: Traditional water harvesting at Eburru

The Eburru water harvesting from the two steam shallow wells has been running from the colonial times. Though the project is owned and managed by the community, it is not efficiently operated. There are substantial leakages of steam and the condensed water (Figure 4). More-so, heat energy from one of the boreholes is not utilized at all. The two wells, which are located on community land, can be rehabilitated and the condensate harvesting technique upgraded to allow for large scale water harvesting.

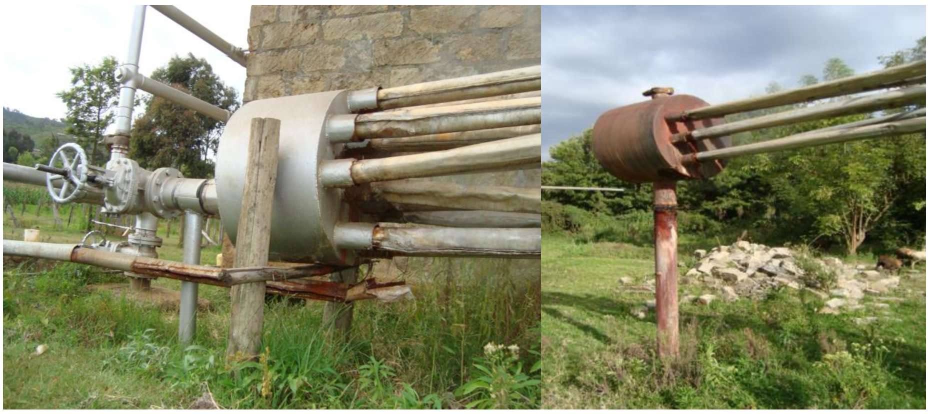

Figure 4: Two Shallow steam wells at Ex Peter-Eburru drilled in 1950s

5.2 Geothermal steam bath

Geothermal heated swimming pools and hot baths have been constructed in several places in the world where geothermal resources are located. These are mainly for recreational and social purposes. The use of geothermal water for treatment and preventive therapy of ailments is also a common practice. The Japanese, Turks and the ancient Romans were the pioneers of using geothermal fluid for therapeutic purposes but other societies have adopted it. The important factors to consider in balneology are the temperature of the water and it mineral content.

Figure 5: Steam bath at Olkaria

KenGen has constructed a geothermal spa at Olkaria (Figure 5), which has seen tremendous increase in number of tourists to Hell’s Gate National Park. A steam sauna is proposed at Eburru to utilize the naturally occurring geothermal steam from the shallow steam wells or from the fumaroles. Besides being a great form of relaxation, steam bathing has a lot of health as well as beauty benefits. A steam bath relaxes overworked and stressed muscles, reducing aches and pains.

5.3 Pasteurization

Dairy processing is yet another application of geothermal energy where fresh milk from the farmers can be pasteurized using hot geothermal water. A series of plate heat exchangers are used to keep the milk and heating water separated during pasteurization. Concentration of milk, one of the stages in milk powder production, requires temperatures below 100°C. This is done in a falling film evaporator and the evaporation temperature can easily be obtained from geothermal water. Meat from livestock can be preserved by refrigeration or canning. This involves the use of a vapour absorption machine running on water/ammonia mixture as the working fluid that provides the necessary refrigeration at about 0°C, which is sufficient for meat preservation. On the other hand, canning of beef entails precooking it and packing it in sterilised containers using hot water or steam at about 140°C. These processes require temperatures which can be supplied from a geothermal resource.

Eburru area has favorable conditions for dairy farming and hence developing techniques for preservation and refrigeration of animal products will go a long way. This will also encourage the introduction of biogas technology, and hence lead to conservation of Eburru forest since firewood will no longer be the primary fuel.

5.4 Chicken hatchery and brooders

Incubators and brooders in poultry industry act as a substitute for hens. This often results in higher hatch rates due to the ability to control both temperatures and humidity. The simplest incubators are insulated boxes with an adjustable heater, typically going up to 60˚C to 65˚C, though some can go slightly higher (generally to no more than 100˚C). Geothermal heat can be utilized to provide adequate and constant heat for such uses. The Eburru project will involve design and fabrication of a commercial hatchery.

5.5 Drying and dehydration

These are important moderate temperature uses of geothermal energy. Geothermal energy has been used to dry various vegetables, fruits, wheat and other cereals (Lund and Rangel, 1995; Lund et al, 2005). The basic design for drying will includes an air flow heat exchanger using the heat from 180°C brine. The air temperature will be designed to reach 50-150°C.

At Eburru, the local community uses steam from a shallow borehole drilled in 1950s to dry pyrethrum (Mwangi, 2005). This is as illustrated in figure 6. However, this is uncoordinated and is on a very small scale. When such activities are co-ordinated, they can be a major benefit to the farmers of the area and to the environment. Some of the opportunities that the local community may tap include drying pyrethrum, fruits, vegetables, curing and drying of tea and raw wool washing and drying.

Figure 6: Pyrethrum drier at Eburru

Most of the direct utilization of geothermal heat involves the use of heat exchangers. A *heat exchanger* is a partition that keeps the hot and the cold fluid separated during heat exchange. The heat exchangers used with geothermal fluids are made of stainless steel which has a good overall heat transfer coefficient and is relatively corrosion resistant. However, where highly corrosive fluids are involved, titanium could be used though it is expensive.

There are basically three types of heat exchangers for geothermal fluids namely the plate, shell and tube and down hole heat exchanger. The most common of these is the plate heat exchanger. Figure 7 indicates a typical heat exchanger. We propose to rehabilitate the existing pyrethrum drier at Ex-Peter in Eburru.

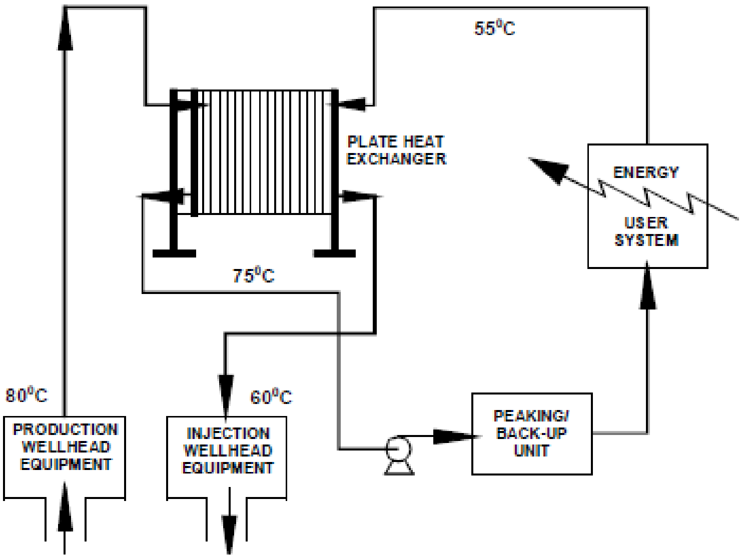

Figure 7: Geothermal direct-utilization system using a heat exchanger

6. ENVISAGED BENEFITS OF THE PROPOSED DIRECT UTILIZATIONS

A cascaded use of geothermal energy at Eburru is proposed. The project will comprise of the following:

- Upgraded steam harvesting system
- Geothermal steam bath
- Pasteurization
- Poultry hatching
- Drying and dehydration of pyrethrum and other crop products

The proposed developments will promote research and will be used as demonstration center to showcase direct utilizations of geothermal resource.

7. RECOMMENDATIONS

The following measures are recommended:

- Set up a cascaded use of geothermal energy near the Eburru drier. This will act as a demonstration center for the direct utilization of geothermal energy.
- There is need to evaluate the energy potential from the two existing shallow steam wells. Technical evaluation of the well's depth, temperature, chemistry of the fluid and the energy potential of the two shallow wells, need to be done to establish the optimum applications.
- Undertake a comprehensive monitoring program of the reservoir and the well output once the project is implemented.
- Hold a meeting with the community representatives and the larger community to establish the land ownership and assess the acceptability of the project by the local community.
- Evaluate the possibility of drilling a new well near the existing well to supplement the existing energy.

8. COST ESTIMATES

The estimated cost for implementation of the proposed development is as tabulated below:

Activity	**Estimated Cost (KES)**
Technical evaluation of the existing well's depth, temperature, chemistry of the fluid and the energy potential of the two shallow wells near the pyrethrum drier	100,000
Environmental and Social Impact Assessment (ESIA) studies/licenses and permits for the direct use facilities	500,000
Repair and maintenance of the existing two wells at Ex-Peter (Replacement of well head valves)	500,000
Upgrading steam harvesting system	300,000
Repair of existing drier at Ex-Peter for drying and dehydration of pyrethrum and other crop products	500,000
Geothermal steam bath	2,000,000
Pasteurization & refrigeration	500,000
Chicken hatchery and brooders	200,000
Grand Total Cost (KES)	**4,600,000**

*The currency conversion from KES to USD is, 1USD = KES 101.

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