CASCADED USE OF GEOTHERMAL ENERGY: EBURRU CASE STUDY

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ABSTRACT

Geothermal energy can be used both for electricity generation and direct applications depending 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 the direct applications.

Geothermal energy in Kenya has been primarily used for electricity generation mainly because of lack of focused attention on direct applications. On commercial level, direct applications are only at Oserian Development Company, a privately owned flower growing firm where geothermal fluid is used to provide heat for greenhouse heating. Minor uses are at the Lake Bogoria Spa Resort where geothermally heated water from a hot spring is channeled to warm a swimming pool and at Eburru where shallow steam wells provide heat energy for drying agricultural products and the condensed steam is used as drinking water.

Cascaded utilization of geothermal energy ensures efficient and cost effective utilization of the available energy. It is hereby proposed that energy from the two shallow wells at Eburru be used in a cascaded manner for drying of agricultural products, greenhouse heating, honey purification, poultry hatching, recreational facility in a steam sauna and for provision of the much needed potable water. This will be used as a demonstration center for utilization of geothermal energy as well as a source of income to the local community.

An assessment of the energy potential and chemistry of the fluid from the two shallow steam wells needs to be carried out to assess the technical viability of the intended uses as well as establish whether there is a need to drill a new well for this project. The cost of undertaking this project has been estimated to be about USD 40,000.

INTRODUCTION

A geothermal resource has heat, pressure and water that can be harnessed for the benefit of mankind. Utilization of geothermal energy and the other by-products depends heavily on the thermodynamic and chemical characteristics of the fluid. These factors require detailed assessment to help determine the energy potential and the technical viability of any utilization project. Geothermal resources have been classified using temperatures and/or enthalpy hence classified to suit either electricity generation or direct applications (Table 1). The high temperature resources are ideally used for electricity generation using conventional power plants while medium to low temperature resources are utilized for direct uses or electricity generation using binary technology.

Table 1. Basic technology commonly used for geothermal energy.

Reservoir Temp.	Reservoir Fluid	Common Use	Technology commonly chosen
High Temp. (>220˚C)	Water or Steam	Power Generation Direct Use	Flash Steam; Combined (Flash and Binary) Cycle, Direct Fluid Use Heat Exchangers Heat Pumps
Medium Temp. (100-220˚C)	Water	Power Generation and Direct Use	Binary Cycle, Direct Fluid Use; Heat Exchangers; Heat Pumps
Low Temp. (30-150˚C)	Water	Direct Use	Direct Fluid Use; Heat Exchangers; Heat Pumps

In 2010, approximately 78 countries were reported to utilize a total of 438 PJ/yr of geothermal energy directly, an increase of about 78.9% in the last 5 years, (Lund et al., 2010). More than half of this energy is being used for space heating and another third for heated pools. The remainder supported industrial and agricultural applications.

Compared to other renewable energy technologies, geothermal is unique as it provides a base-load alternative to fossil fuel based electricity generation, but can also replace those used for heating purposes especially in utilization of low heat energy applications (Mburu, 2010).

In Kenya, commercial direct application of geothemal energy is only at the Oserian Development Company, a flower farm utilizing a leased geothermal steam well with 16 MWt potential, for heating rose flower greenhouses. The heating reduces humidity in the greenhouses and hence eliminates fungal infection resulting in reduced production cost. Flowers grown in a heated greenhouse are of better quality and increased production. The hot geothermal fluid is also used in soil fumigation and for sterilization of the fertilized water for recirculation. Carbon dioxide from the well is also used to enhance photosynthesis hence improved yield.

THE EBURRU GEOTHERMAL FIELD

Eburru geothermal complex, located 40 km north of the Olkaria geothermal power plant, is composed of two major volcanic centers at an elevation of more than 2,600 meters above sea level.

Geothermal Occurrence and Utilization at the Eburru Field

Detailed surface exploration studies at the Eburru geothermal field were carried out from 1985 to 1990, after which six deep exploration wells were drilled between 1989 and 1991. Two of the six wells are productive. Currently a 2.5 MWe project to utilize the steam from one of the wells drilled in Eburru is underway.

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. Steam from naturally occurring fumaroles and from two shallow steam wells have, drilled in the 1950s, has been condensed to provide potable water and to dry agricultural produce.

Direct Utilization of Geothermal Energy at the Eburru Field

Geothermal energy is evident around the Eburru shopping center. Surface manifestations can be seen in the form of fumaroles, steaming and altered ground. The local community has been harnessing this energy, though mostly in uncoordinated and on an individual level (Figure 1).

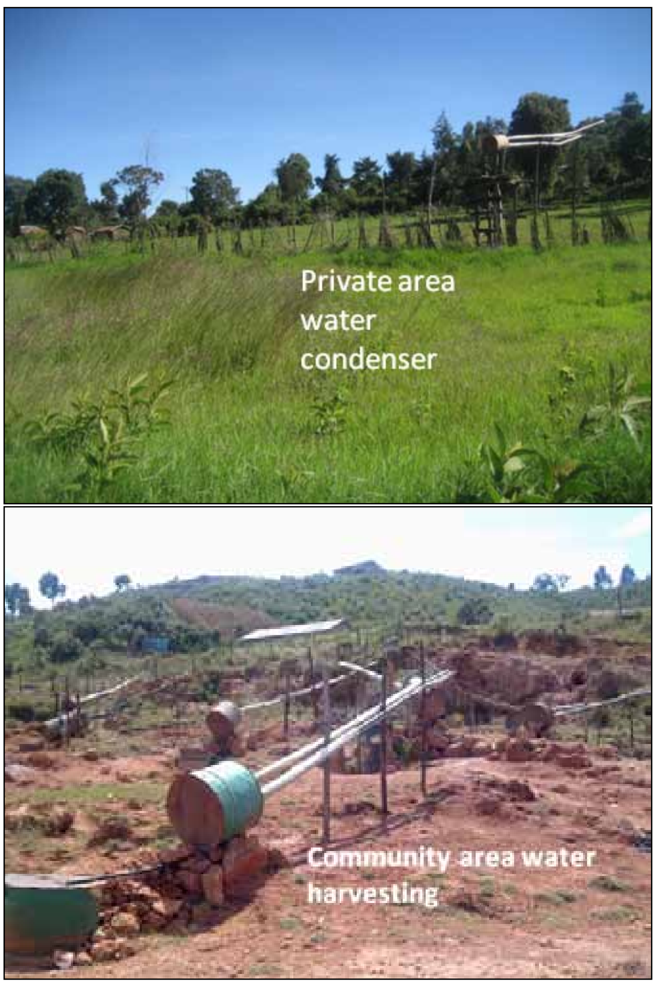

Figure 1. Uncoordinated local steam condensation at Eburru.

The community has however made some efforts and are currently using and managing two shallow steam boreholes drilling in the 1950s to provide potable water for the community and heat for drying pyrethrum and maize (Figures 2 and 3).

Figure 2. Geothermally heated pyrethrum drier.

Figure 3. Shallow steam boreholes used for portable water and crop drying.

PROPOSED DIRECT APPLICATIONS AT EBURRU PROJECT

The Eburru water harvesting from the two steam shallow wells and the pyrethrum drying projects (The Ex-Peter's dryer) have been running from the colonial times. Though the project is owned and managed by the community, an evaluation done on 19th January 2010 showed that the project is not efficiently operated. There are substantial leakages of steam and the condensed water (Figure 3). More-so, heat energy from one of the boreholes is not utilized at all. Heat from the 2nd borehole can be used for greenhouse heating, refining honey or to warm an artificial brooder. The steam exhausting from the condensing pipes can be used in a recreational sauna. If upgraded and maintained, the proposed projects can avail more water and energy as well as act as a training and demonstration center.

Figure 4. Inefficient utilization of the geothermal energy.

Upgrading the Tree Nursery Project

Next to the condensed water storage tanks is a community tree nursery (Figure 5). At the tree nursery, tree seedlings are grown for local uses and for sale. The seedlings are irrigated using water obtained by condensing steam. By increasing the amount of condensed steam, more seedlings can be raised hence more returns.

Growing the tree seedlings in a geothermally heated greenhouse will enhance productivity and quality as well as reduce the amount of water loss through evaporation. Horticultural crops such as tomatoes and cucumber can also be grown in the geothermally heated greenhouse (Figure 6). Such a project would have economic benefits to the community.

Figure 5. Tree nursery project in Eburru.

Figure 6. Geothermal heated tomato greenhouse, Tunisia.

Upgrading the Bee Keeping Project

When the bee keeper removes the honey from the honey combs he has to process the raw honey immediately to prevent it from crystallizing. Once the raw honey comes into contact with the oxygen in the air it reacts and begins to crystallize immediately. One of the cheap and common methods of purifying honey is through heating under low and controlled temperature. Heat-treatment after extraction reduces the moisture level and destroys yeast cells. Though honey can be extracted faster and more completely at higher temperatures, the combs will become softer and might break. Therefore, extraction temperatures should be kept low.

During heat treatment, honey is subjected to a double heat treatment, both aimed at purifying the honey. First the honey is heated to 50ºC. The crystals formed in the honey will melt. The honey is held at this temperature for 24 hours. Undesired substances like parts of bees and pollen will float and they are removed. Then the honey is heated quickly to 75ºC, filtrated and cooled immediately to 50ºC. This second process takes only a few minutes. The wax cappings are melted down and collected for sale to cosmetic companies.

A bee keeping project next to the tree nursery (Figure 7) would benefit from the availability of a geothermal heat. Honey can be purified using heat from the geothermal fluid.

Figure 7. Eburru community bee keeping project

Honey Purification Process

Careful heating the honey in a water bath to wax melting temperatures (about 65˚C) and subsequent cooling in a water bath with running water (Figure 8) may prolong storage life. For small quantities, this is an acceptable compromise between spoilage by fermentation and some loss of quality by heating.

Figure 8. Small-scale heating of honey in a water bath.

Figure 9. Commercial Purifier (India).

Another method is based on pasteurization and the destruction of the yeasts. The osmophilic yeasts found in honey die after only a few minutes of exposure to temperatures between 60 to 65˚C. If the honey is heated and cooled quickly enough, with special heat exchangers feasible only on an industrial scale, very little damage occurs to the honey. Often these pasteurization treatments have two functions, the prevention of fermentation and the postponement of crystallization (Figure 9).

A Geothermal Steam Bath

Geothermal fluid has many dissolved minerals some of which are essential for skin therapy. The geothermal fluid has therefore been used in many countries for this purpose. The Blue Lagoon for example is a major tourist attraction in Iceland. The Lagoon has a warm pool and two steam baths, all believed to have therapeutic effect on the users (Figure 10 and 11).

A steam sauna is proposed at the Eburru to utilize the naturally occurring geothermal steam from the shallow steam wells or from the fumaroles.

Figure 10. A steam sauna at the Blue Lagoon, Iceland.

Figure 11. Geothermal warm spa at the Blue Lagoon, Iceland.

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.

Aquaculture

Aquaculture refers to growing of aquatic creatures using a controlled environment. Many of the farmed species grow faster and larger in warmer-than-ambient water. Geothermal fluids can be used to control the temperatures of the aquatic ponds to enhance productivity hence faster growing fish, allow production in the winter and cold seasons when it would otherwise not be possible resulting to greater economic gains.

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.

CASCADED USE OF GEOTHERMAL ENERGY

Cascade Uses Depending on Temperature

In many countries direct utilization of geothermal energy is from low to medium temperature geothermal systems (Lindal, 1973). The temperature of the fluid dictates the applications the fluid (Figure 12). For medium to low temperature geothermal systems the fluids have very low dissolved salts and pose no major scaling problem hence temperature can be lowered significantly (Ballzus et al, 2000). Figure 13 shows the proposed cascaded use of geothermal energy at the Eburru project.

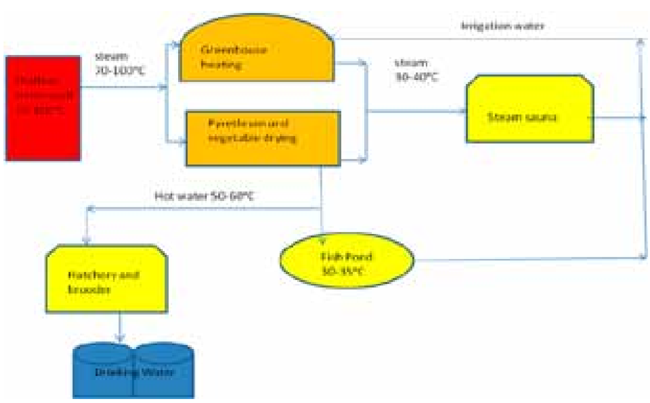

Figure 13. Proposed cascaded use at Eburru direct utilization demonstration center.

When using geothermal brine from high temperature resources, the limiting factor is the brine re-injection temperature to ensure no scaling of amorphous silica in the surface equipment and in the re-injection wells. High temperature geothermal brine of Nesjavellir power plant, Iceland is used for hot water supply with minimal problems. Controlling the flow rate of the brine in the heat exchanger significantly reduces the possibility of silica scaling but reduces the heat transfer (Arnorsson, 2000). A detailed design takes into account all conflicting factors ensure utilization is both technically and economically feasible (Orme, 2003)

The steam from the two shallow wells has been condensed and used as potable water by the local community at Eburru due to lack of water. There are no comprehensive studies to show the effect of exploitation of the two shallow wells to the reservoir. The current proposal does not consider reinjection of the fluid since the condensed steam, after heat extraction, will be used as potable water. However, there will be comprehensive monitoring of the reservoir to monitor the effect.

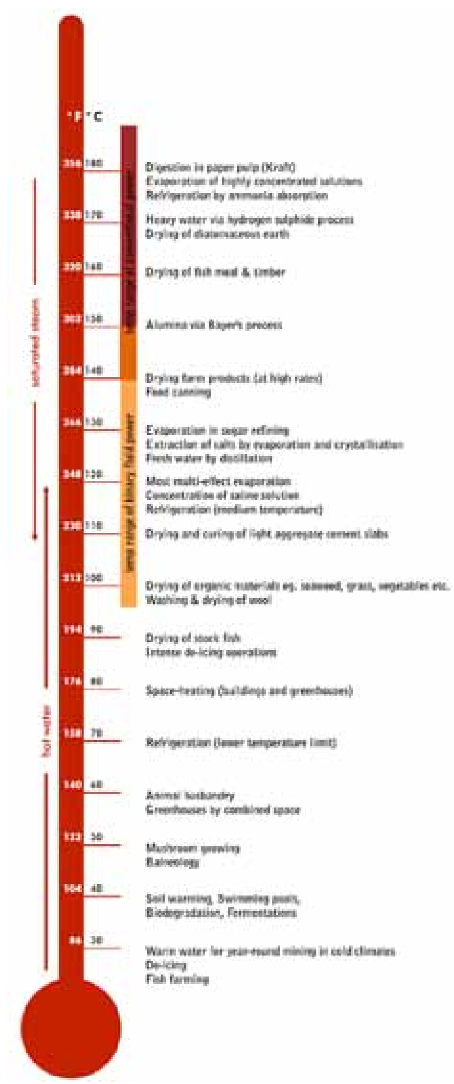

Figure 12. Utilization of geothermal energy at different temperatures (Lindal, 1973).

Proposed Cascade at the Eburru Project

The cascaded use of the geothermal energy will involve different applications as shown in the schematic diagram (Figure 13). 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.

Technical Data Collection and Presentation

Technical data collected at one of the shallow wells (the drier well) on March 22, 2011 (Figure 14).

- Atmospheric temperature 21.8˚C
- Well Head Temperature 89.6˚C
- Drier inlet 78.0˚C
- Drier exhaust 56.8˚C
- Chamber pipe 74.0˚C
- Inside of chamber 40.0˚C
- Water pipe at tank entry 38.9˚C

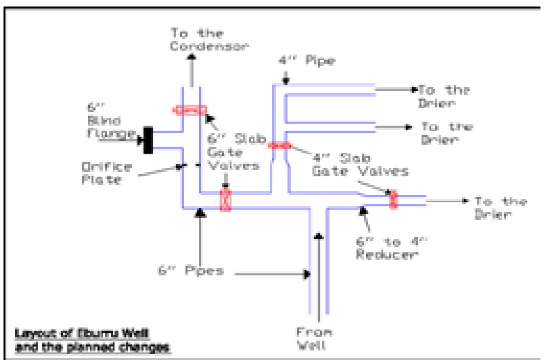

Figure 14. Schematic diagram of the drier well mechanical parts.

In order to establish the energy potential of the wells, the technical team established that the wellhead valves have to be replaced since they are worn out and are stuck in open position. The following items are being procured.

- M/S 6" Class 150 Slab gate valve – 2 Pcs
- Brass gate valve 4" – 2 Pcs
- M/S Reducers 6" x 4" - 2 Pcs
- Flanges 6" class 150 – 2 Pcs
- Bolts
- 3/8" ball valve
- Accessories

Other equipment and resources required are:

- Portable welding set
- Welding gas cylinders
- Grinder and accessories
- Transport for equipment and personnel

CONCLUSIONS

A cascaded use of geothermal energy at the current drier and water condensation site at Eburru field is hereby proposed.

- The project is to comprise of the following:
- Pyrethrum/crop dyer
- Greenhouse heating
- Honey purification
- Steam sauna
- Fish pond

Before the cascaded use is implemented, there is a need to carry out technical energy evaluation exercise to establish the energy available from the two shallow steam wells. To do so, the old worn-out wells need to be rehabilitated i.e. replace worn-out valves, pipes and other accessories in order to allow for testing.

The current proposal does not consider reinjection of the fluid since the condensed steam, after heat extraction, will be used for drinking. However, there will be a comprehensive monitoring program of the reservoir to monitor the effect once the project is implemented. The appropriate decision will be made depending on the monitoring observations.

RECOMMENDATIONS

- Set up a cascaded use of geothermal energy near the Eburru drier/water harvesting community project. This will act as a demonstration center for the direct utilization of geothermal energy.
- Evaluate the energy potential from the two existing shallow steam wells.
- 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.

EDITOR'S NOTE

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