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Combined Heat and Power: Efficient Utilization of Geothermal Energy - A Case Study of Menengai Well -03

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ABSTRACT

After drilling a geothermal well, various parameters are evaluated to establish the energy potential of the well, the chemistry of the geothermal fluid as well as other factors that may affect the wells output during exploitation.

Geothermal energy can be used for both electricity generation and direct use applications. Depending on the evaluated parameters, electricity generation can either be by a condensing unit or by use of binary technology. Hot geothermal brine can be used as a source of thermal energy for industrial processes and can be cascaded to various applications depending on the energy requirements.

Well MW-03 was one of the first exploratory well to be drilled in Menengai, due to its low wellhead pressure (1.5 bara), it cannot be connected to the steam gathering system which will be operating at a minimum of 6 bara. The well has 66 t/hr of geothermal fluid at an enthalpy of 1250 KJ/kg and hence has substantial energy for both electricity generation (using binary technology) and for direct use applications. The well is proposed to supply both electrical and thermal energy to a milk processing demonstration plant, after which the energy is cascaded to laundry facilities and domestic water supply to the drilling campsite, greenhouse heating and aquaculture heated ponds and a swimming pool.

An analysis of the available energy and fluid chemistry of well MW-03 and its optimised utilization, through cascading, is evaluated in this paper.

1.0 INTRODUCTION

GDC (Geothermal Development Company) has adopted a holistic approach in the development of geothermal resources. Several studies have been undertaken by GDC in collaboration with USAID (United States Agency for International Development) funded direct use experts. The studies have identified several applications which are viable in Kenya. The viability is based on considering many factors and weighting them appropriately (USAID et al, 2014).

Based on the studies, GDC has identified some of the viable projects to show-case direct use applications. The demonstration projects are being implemented in the Menengai geothermal field. Most of the projects are at the procurement stage and implementation is scheduled to be completed in early 2015.

2.0 THE MENENGAI WELL -03

The Menengai Well 3 (MW-03) was the third exploration well in Menengai geothermal field. Drilling was completed on 11th September, 2011 to a total drilled depth was 2,107 m and the maximum clear depth is 2,060 m.

2.1 Output characteristics

The output characteristics of MW-03 was analysed for a period of seven months from September 2012 to April 2013 (see Figure1). The well has a low wellhead pressure and has high water flow-rate. Table 1 summarizes the output.

2.2 Energy Available from the Well

The energy available from a well is determined by the enthalpy and mass output. the energy that can be extracted from the fluid id dependent on the energy laws, technology and the fluid chemistry.

Table 1: Summary of output parameters from MW-03

Well Head Pressure (Bara)	Mass flow rate (t/hr)	Water flow rate (t/hr)	Dryness fraction	Enthalpy (kg/kJ)
1.5	66	41.8	0.3	1249

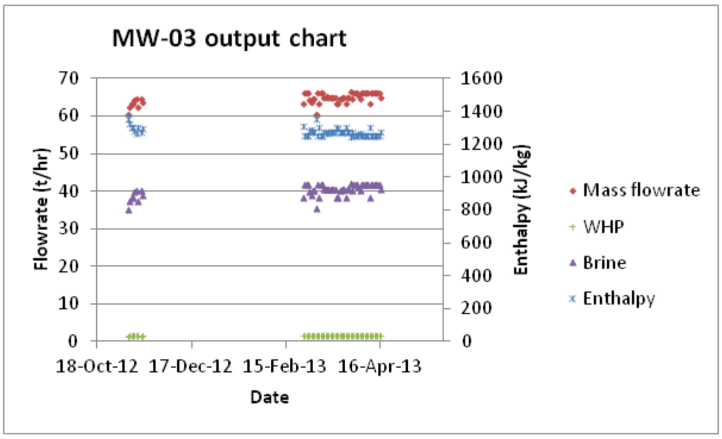

Figure 1: Output data from well MW-03

2.2.1 Carnot Efficiency

The energy potential of the well is a factor of the flow and the enthalpy. From the Carnot's rule, (Wikipedia, 2015) and the second law of thermodynamics., there is a limit to which the energy in a system can be converted into useful work and the efficiency of a system is always less that the Carnot efficiency.

$$\eta_{\text{max}} = \eta_{\text{Carnot}} = 1 - \frac{T_C}{T_H}$$

Where

- TC is the absolute temperature of the cold reservoir
- TH is the absolute temperature of the hot reservoir, and the efficiency
- η is the ratio of the work done by the engine to the heat drawn out of the hot reservoir.

2.2.2 Amorphous Silica Scaling

Depending on the chemistry of the geothermal fluids, there is a limit to which the geothermal fluid can be cooled in a heat exchanger to avoid silica scaling. According to the geochemical analysis, Figure 2 depicts the saturation state of well MW-03 aquifer water with respect to amorphous silica. The solubility of amorphous silica decreases with decrease in temperature and forms one of the troublesome scales. It is evident from Figure 2 that the water in MW03 is under-saturated with respect to amorphous silica even to lower temperatures. It is therefore concluded that deposition of amorphous silica is not likely to be a problem in the utilization of the well fluid.

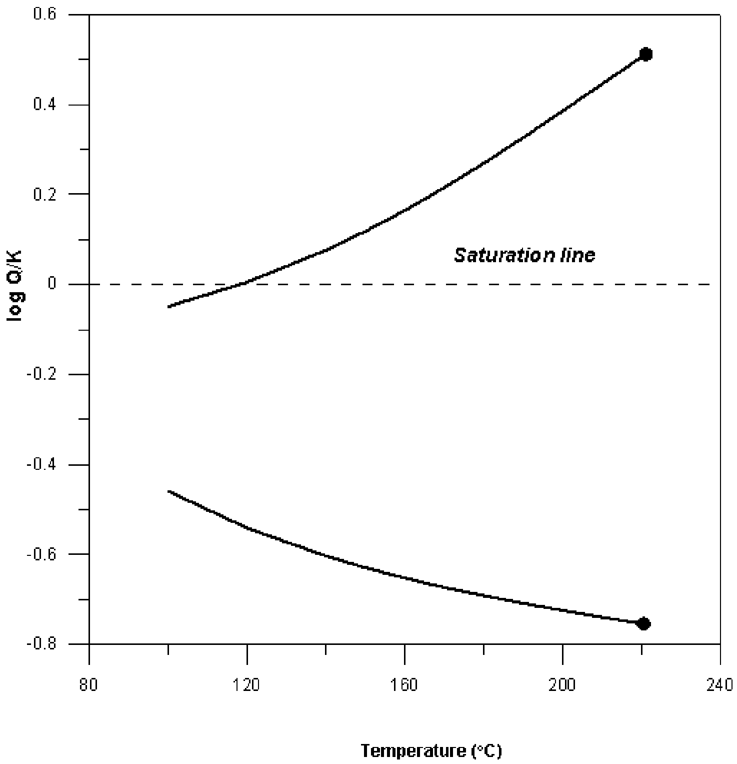

Figure 2: Calcite and amorphous silica saturation state during one step adiabatic boiling,

From the chemical consideration, the brine at 130^{o}C will be cooled to 90^{o}C so as to heat fresh water from 20^{o}C to 80^{o}C

- Energy from the Brine
- Mass (Mt) = 18 kg.s
- Enthalpy (tt) = 1249 kJ/kg
- Energy of the brine = MtHt=22.5 MWt
- Enthalpy of the brine at 90oC (hb)= 377 kJ/kg
- Energy mined from Brine = Mt (ht-hb)=15.7 MWt

3.0 CASCADING THE AVAILABLE ENERGY

A cascade is a succession of stages, processes, operations, or units in a consecutive and logical sequence. Cascading the use of geothermal energy refers to the process using the energy for various applications depending on the energy need with the higher energy needs being done at the beginning and the processes requiring lesser and lesser energy following. The level of cascading depends on the available energy and the energy requirements of the various processes. This is done to enhance efficiency and cost effectiveness of the project. Technical evaluation of the available energy and the proposed applications therefore is required.

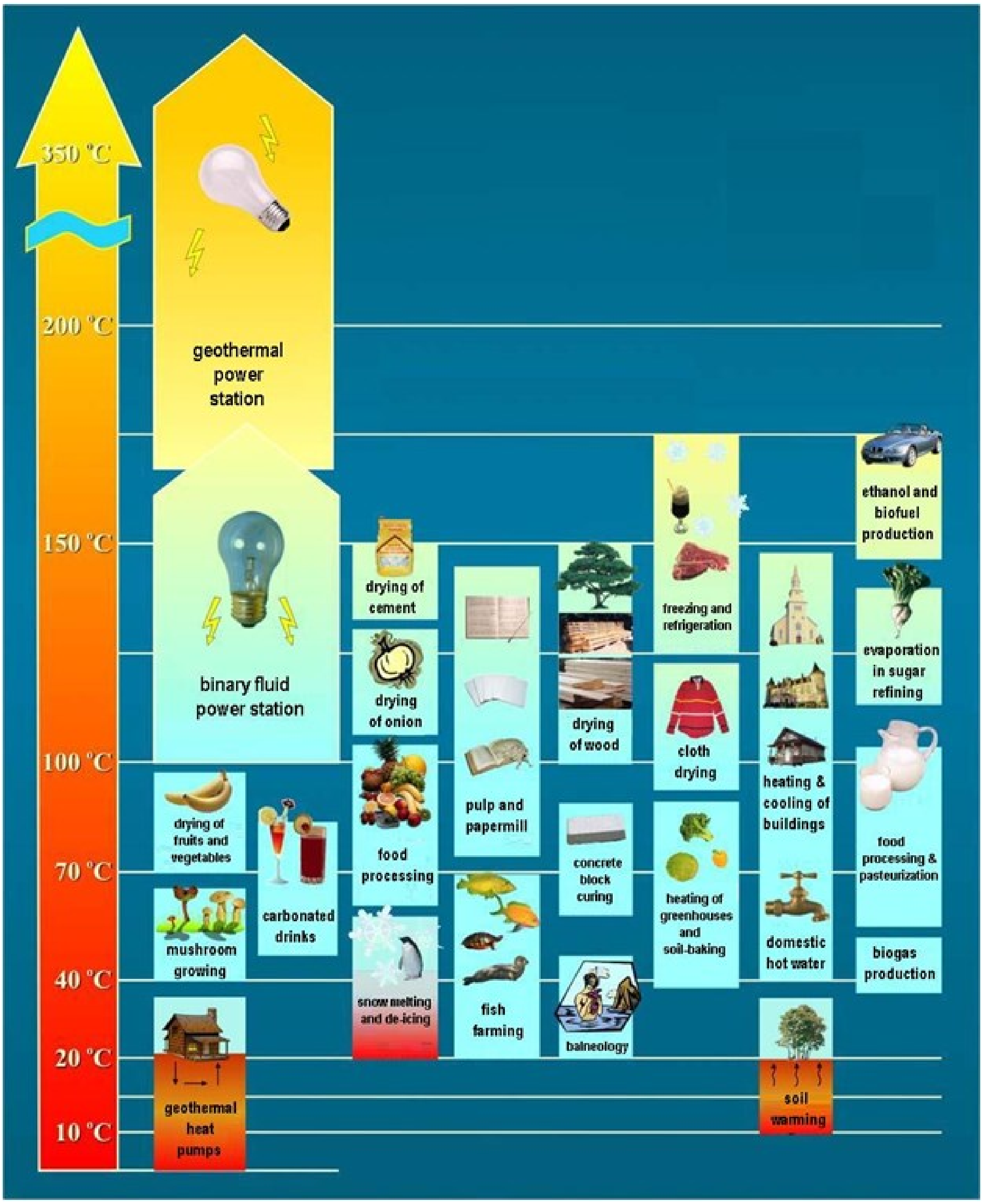

Figure 3: Various geothermal uses related to their most appropriate temperature range (Lund et al, 2011).

3.1 Energy Use for Direct Use Applications

At the well MW-03 direct use project centre, the following demonstration projects have been planned for. The design is complete and at different stages of procurement and installation.

i. Milk Processing
ii. Laundromat (washer and drier)
iii. Aquaculture
iv. Greenhouse Heating
v. Domestic Hot Water Supply
vi. Geothermal water for drilling

3.2 Electricity Generation using a Wellhead Unit

Since the well has a large mass output of 66 t/hr, the flow can be used for electricity generation and for high energy uses first. The energy can then be cascaded to other uses requiring less energy. This arrangement ensures efficient utilisation of energy from the available resources.

The electrical energy generated from the well is to be utilised to power the applications that require electrical energy such as motors and pumps. A standby generator will also be required for use when the wellhead is being maintained.

3.3 Brine Disposal

The cooled brine is as a source of drilling fluid since the well's chemistry is benign. When not in use, the spent brine will be reinjected into a cold reinjection well.

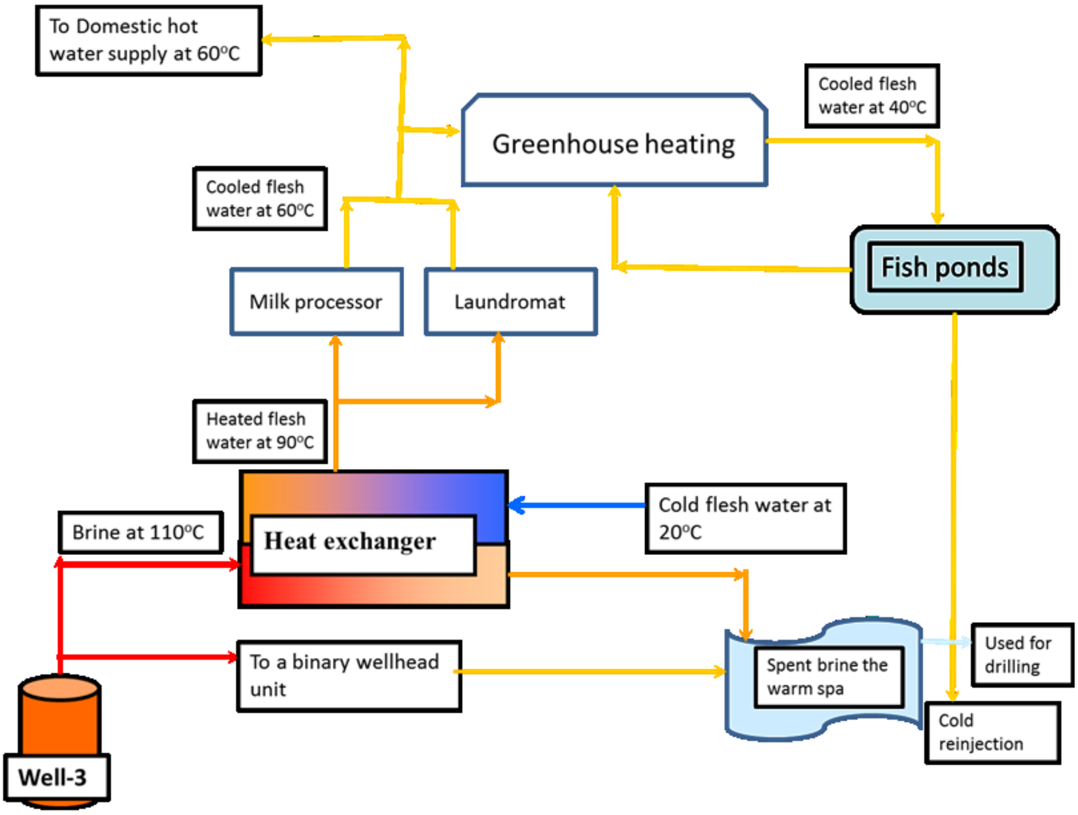

Figure 4: Schematic diagram of the proposed utilisation at MW-03

4.0 ONGOING ACTIVITIES

GDC is at an advanced stage in implementation of the pilot direct use projects at MW-03. Several studies have been done to establish the viability of undertaking such projects.

Prefeasibility studies on milk processing, greenhouse heating, laundromat and aquaculture have been done and the recommendations are that the projects are viable. A full feasibility study for an eco-dairy processing facility has been finalized. A 1000 l/day plant has been proposed. The pilots are a recommendation of the pre-feasibility studies. (USAID and GDC, 2013 a, b, c). The proposed projects have all been designed and are currently undergoing fabrication and procurement.

The projects will be implemented by March 2015.

5.0 CONCLUSION

GDC's approach in holistic development and utilisation of the geothermal energy for both electricity and direct use application should be adopted in all fields where geothermal energy is being utilised. Such an approach would improve the efficiency of the plants as well as reduce, to a considerable significance, reliance on fossil fuel especially for the low grade heat.

All wells that have been drilled but cannot be used for electricity generation should be evaluated for their potential for direct use applications, more so, brine from the geothermal wells which cannot be used for electricity generation can be used as a source of thermal energy for industrial and agricultural application.

Pricing of the thermal energy needs to be established so that the economic value of the direct use projects can be evaluated with ease this will also help in accessing the cost saving resulting from using the waste heat from geothermal resources as a substitute to the use of conventional fossil or electricity.

Once the pilot projects being implemented by GDC are complete, an assessment of the economic, environmental and social benefits will be done and documented for reporting and future reference. Of greatest importance is to assess the energy costing for the thermal energy since this will dictate the returns for the projects.