

Geothermal Brine, From Waste to Alternative Thermal Energy Source

Fitri Oktaviani Purwaningsih, Gugun Abdurrahman

Master of Geothermal Technology, Institut Teknologi Bandung, Jl. Ganesha No. 10 Bandung

Feetre@gmail.com, Gugun_Madara@gmail.com

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ABSTRACT

Brine is waste fluid from separator in geothermal power plant system. In electricity generating system, the separator located after geothermal wellhead and will separate brine from high temperature steam. The steam then generates electricity in turbine while the brine flows into injection wells. In Indonesia, brine from separator in geothermal plant system has high temperature, usually more than 100°C. With that level of temperature, brine still has potential as thermal energy source.

Brine with 173°C temperature and flow rate 252 kg/s from a geothermal field in West Java, Indonesia have potential up to 70 MW gross thermal energy. With underground piping strategy, heat loss can be managed to 105 kW for 1000 m distance and still can preserve up to 568 kW of thermal energy in final heat exchanger. The system then can be used for various direct use applications including fish cultivation industry for local people.

Maximizing use of brine will have positive impact for geothermal companies and encourage local economy. The aim of this research is to build a general brine utility system to accommodate brine properties, piping strategy and technical requirement. This paper will limit on brine utilization in maintain optimum temperature for direct use application, and will not cover properties as salinity, chemical contents, humidity and other requirements.

1. INTRODUCTION

Indonesia has huge geothermal energy potential. With most of the resources have medium to high enthalpy; this energy is preferred to generate electricity. With electrification ratio about 80.4% in 2013 (PLN's RUPLT, 2015), this green energy is undeniable an alternative to increase national access to public electricity.

Unfortunately the development of geothermal energy in Indonesia still faces many challenges. One of the biggest challenges related with development of this energy is rejection from local communities. Their refusal not only related with environmental concern but also because there are no significant economic benefit for them.

Geothermal companies need billions of dollars to be able to extract geothermal resource into electricity. In Indonesia, the electricity generated then distributed to national electricity grid. There is no local grid that distributes the electricity for communities' surround the geothermal plant. Local people also could not maximize geothermal energy for direct use application, while only few of them have access to surface manifestation in other's people land.

This research is using literature study with objective to provide alternative in maximizing brine from geothermal plant. Data related with brine properties and characteristics are using brine from a geothermal field in West Java, Indonesia. This paper will calculate thermal energy that extracted from the brine for fish cultivation as local direct use application.

2. BRINE AS WASTE FROM GEOTHERMAL PLANT

In almost all geothermal companies in Indonesia, high temperature geothermal fluid from wells is produced to generate electricity. Geothermal reservoirs of hot water and steam, which is found a few miles or more beneath the earth surface is exploited using geothermal wells. Huge volume of geothermal fluids is drilled to earth surface to generate electricity. In the process, separator located after geothermal wellhead separate steam and hot temperature liquid called brine. High-pressure steam then will flow into turbine, while brine usually injected to subsurface using injection wells. In some countries, brine is treated as waste from geothermal plant because it is not included in the geothermal plant processes to produce electricity.

Although treated as waste, brine injection is one of reservoir management strategy to provide sustainability of the geothermal field. In general, brine injection objective is to make a mass balance of reservoir fluid, and also a common procedure to prevent temperature and pressure drop in geothermal reservoir.

Brine injection needs some strategies to manage its temperature and fluid characteristic, and to prevent the field from problems related with scaling and temperature drop. Brine properties including flow rate, temperature and pressure are unique from each geothermal well in any geothermal field, but in general brine injection process is using schema in Picture 1.

With the scheme, brine from separator usually injected directly into injection wells. It is a closed system. There is no necessity to flow brine out from the system. Using the scheme, there is no added benefit for local people who bear operational risk from geothermal power plant in their area.

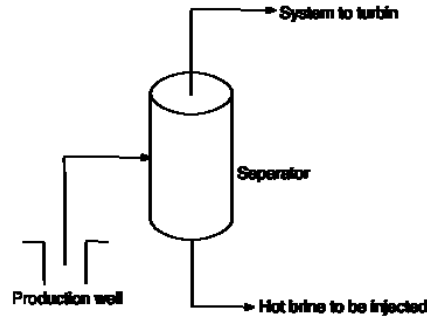


Figure 1: General scheme of brine injection in separator in geothermal plant

Brine temperature in high enthalpy system in Indonesia is more than 150⁰C in average. With that high temperature the brine still have potential as thermal energy source. Treating the brine as a waste by directly injected it into the injection wells is safer and simpler for geothermal companies, but it is wasting the heat energy potential that is contained in the brine.

The heat contained in brine can be utilized as thermal energy source for direct use application for local industries around geothermal plant area. This paper will provide calculation for fish cultivation using geothermal brine as thermal energy source.

3. USING HEAT EXCHANGER TO EXTRACT HEAT FROM BRINE

With few modifications, the general scheme of brine injection as in Figure 1 can be used as thermal energy source for direct use application. In the previous scheme, high temperature brine from separator is flowed to injections wells through insulated pipes. In this paper we propose a scheme to extract thermal energy from brine using two heat exchangers (HE) and non-insulated part of pipes to manage heat loss. The non-insulated part of pipe is designed to transfer heat from brine inside the pipe into the first heat exchanger (HE1).

HE1 will be using fresh water as heat extraction media, and it is adhere to the non-insulated part of the pipes. The heat from the brine then will increase the fresh water temperature. The heated water then carried into utilization area.

The fresh water need for heat circulation in HE1 can use any water with colder temperature from any source (pond, river, water tank).

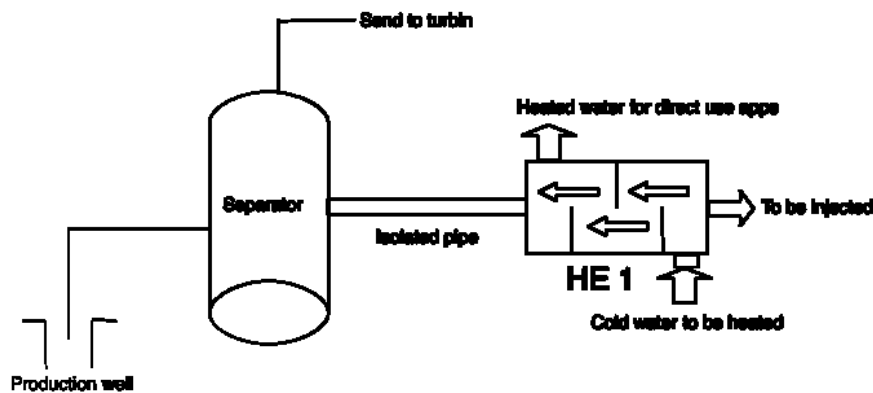


Figure 2: Heat Exchanger scheme to extract brine

Brine properties that are used for calculation in this paper come from a geothermal field in West Java, Indonesia. Brine temperature from wells is 173⁰C and flow rate 252 kg/s. With enthalpy about 732,4 kJ/kg, brine with those properties could produce 184.6 MW thermal energy.

$$H_{brine} = m h_{brine} \tag{1}$$

$$H_{brine} = 252 \frac{kg}{s} * 732.4 \frac{kJ}{kg} = 186.4 MW_{thermal}$$

Where H_{brine} , m , h are thermal energy brine, mass flow rate brine and brine enthalpy.

Brine final temperature out of HE1 needs to be set in certain temperature to avoid silica scaling and temperature drop in reservoir. Geothermal companies usually have specific requirement regarding brine temperature to be injected into injection well. In this paper, we specified brine output temperature from heat exchanger is 100°C.

A hundred Celsius degree brine will be hot enough to flow into injection well and the temperature drop from 173°C can provide sufficient thermal energy as heat exchanger output with low scaling risk. Heat extraction in HE1 from 173°C to 100°C has potential to generate up to 70 MW thermal energy (with 80% efficiency)

An output temperature from heat exchanger is 100°C and heat capacity brine 4.2 kJ/kg °C will produce 77.3 MW thermal energy. Using heat exchanger with 80% efficiency (cross flow type), the thermal output will be 46.36 MW thermal.

$$Q = m C_p \frac{(T_{in}-T_{out})}{1000} * efficiency MW_{thermal} \quad (2)$$

$$Q_{brine} = 242 \frac{kg}{s} * 4.2 \frac{kJ}{kg \text{ } ^\circ C} * \frac{(173-100) \text{ } ^\circ C}{1000} * 80\% = 70.28 MW_{thermal}$$

Where Q_{brine} , C_p , T_{in} , T_{out} are thermal energy extracted from the brine, brine heat capacity, input and output temperature to heat exchanger. The HE1 then will produce 70.28 MW thermal energy output.

4. FROM HE1 TO UTILIZATION AREA

The HE1 located near the geothermal plant area. From calculation above, it could produce about 70.28 MW thermal energy output. We suggest using the second heat exchanger (HE2) outside the geothermal plant area, which duty is to extract thermal energy for local direct use necessity.

HE1 and HE2 will be connected using underground pipe and pump for circulating the heated water. There are some advantages using this scheme as:

1. Using ground insulation would be cheaper and safer. There are no cost needed for the insulation from HE1 to HE2, and buried hot pipe would reduce hazard potential.
2. Using PVC pipe to transport brine from HE1 to HE2 is cheaper and efficient. Easy installation and cost effective pipe would make the investment to apply this scheme is more interesting.

There will be temperature drop through the pipe, from HE1 output temperature (T_s) to HE2 input temperature (T_a). Using 1000 meters pipe with 3-inch diameter, buried 1.5 meter below surface, air temperature 18°C with ground conductivity 0.8 W/m °C, flow rate fluid 1 m/s and fluid density 953.708 kg/m³ we can calculate the final temperature entering the HE2.

$$r_{pipe} = \frac{d}{2} * 0.0254 = 0.0381 m$$

$$A_{pipe} = \frac{r_{pipe}^2}{2} * 3.14 = 0.0046 m^2$$

$$S = 2\pi * L / \ln(D/r_{pipe}) = 1710 m$$

With T_s (surface temperature) specified at 105°C the input temperature to HE2 would be 101.9°C.

$$Q_{loss} = k_{ground} * S * (T_s - T_\infty) \quad (3)$$

$$Q_{loss} = 0.8 \frac{W}{m \text{ } ^\circ C} * 1710 m * (105 - 18) \text{ } ^\circ C = 105.38 W$$

$$m_{fluida} = \rho v A \quad (4)$$

$$m_{fluida} = 954.708 \frac{kg}{m^3} * 1 \frac{m}{s} * 0.0046 m^2 = 4.4 kg/s$$

$$T_a = T_s - \left(\frac{Q_{loss}}{m_{fluida} * 4.2} \right) = 89.3 \text{ } ^\circ C \quad (5)$$

Where $L, d, r, A, D, D/r, S, T_{\infty}, k_{ground}, Q_{loss}, v_{fluid}, \rho, m_{fluid}$ are distance from HE1 to HE2, pipe radius, pipe section area, depth of ground insulation, depth to pipe radius ratio, shape factor, air temperature, ground conductivity, heat loss, velocity of fluid inside the pipe, fluids density and flow rate.

Figure 3 showed proposed scheme using two heat exchangers.

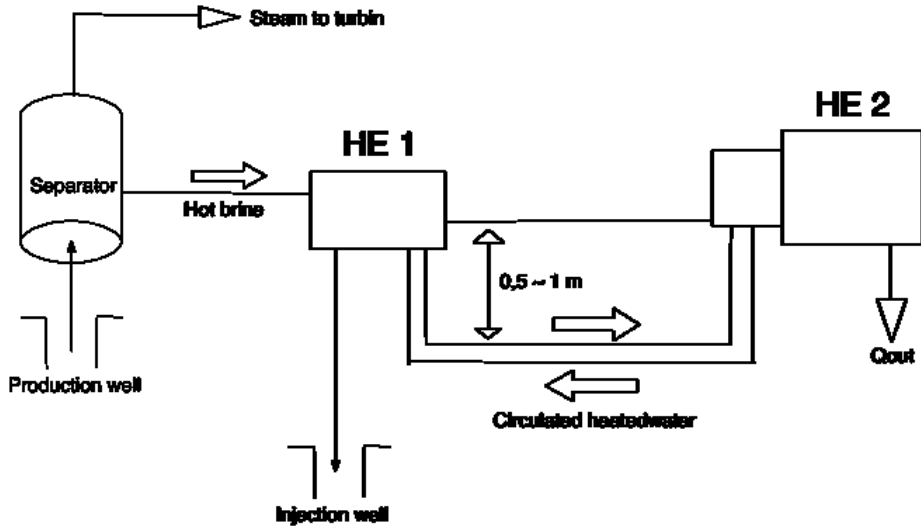


Figure 3: Temperature Drop between 2 heat exchangers

Input temperature in HE2 is 89.3°C and its output temperature 45°C. With 80% efficiency, the thermal energy produced by HE2 is 568 MW thermal.

5. DIRECT USE

Thermal energy produced from HE2 can be used for any industry purposes with range temperature below 45°C. In this paper we use it as thermal energy source for fish cultivation that needs warm pond.

Fish cultivation is common in West Java area. Local people there usually use ground water and rain drop to fill the pond without any temperature control. Maintain the pond into optimal temperature could optimize the growth and increase the quantity and quality of fish produced.

Nile Tilapia (Ikan Nila or *Oreochromis niloticus*) is popular freshwater in Indonesia. In West Java, this kind of fish is one of superior commodity of fishing cultivation program (Fisheries and Marine Department West Java Province, 2013). Tilapias are widely cultured in the tropical and subtropical regions of the world and constitute the third largest group of farmed fish (El-Sayed, 1999). The fish prefer to live in shallow water and the preferred temperature ranged from 31°C to 36°C (FAO, 2010). In this paper we design pool temperature in 33°C with tolerance (+/-) 3°C.

Thermal energy produced from HE2 can be utilized to provide a stable and optimum temperature for Tilapia cultivation. Using Equation 2 and 4 we can calculate maximum size of pond to be heated by thermal energy from HE2.

$$Q = m C_p \frac{(T_{in} - T_{out})}{1000}$$

$$m = \frac{Q}{(C_p * (T_{in} - T_{out}))} = 568 \frac{kJ}{s} * 3600 \frac{s}{hour} * 24hour / (4.2 \frac{kJ}{kg \cdot ^\circ C} * (33 - 18) ^\circ C) = 782,740kg$$

Then water volume that can be heated is 782.74 m³. With 1 m depth, we can have different combinations length and width, as about 20m X 39 m, or 15m x 52m or other size combinations.

Beside fish cultivation, there are some other direct use applications to utilize thermal energy potential from the brine. Lindal Diagram provided range of direct use applications for geothermal resource depending on the temperature. For range temperature between 31°C to 36°C that we calculate in this paper, some possible applications are soil warming, warm swimming pool, biodegradation and fermentation.

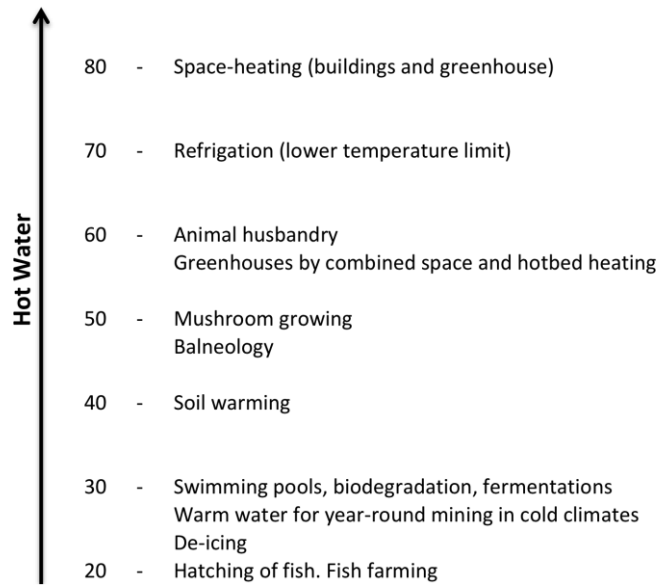


Figure 4: The Lindal Diagram for direct use of geothermal energy in 20°C to 80°C (Gudmundsson, 1985)

5. CONCLUSION

The objective of this paper is to provide an idea about how to maximize the use of brine from geothermal plant. Brine from separator that usually treated as waste, and flow directly to injection wells can be used to give more benefit for local industries near geothermal plant.

The proposed scheme in this paper using two heat exchangers, one (HE1) in plant area and the other outside company's area. The second heat exchanger (HE2) will provide thermal energy for local industries and will be their responsibility. The geothermal company will have to do nothing but to peel out insulation in slight area of their injection pipe. The non-insulated pipe will act as source of thermal energy for the first heat exchanger (HE1).

This scheme use ground insulation for PVC pipe that will transport brine from HE1 to HE2. The ground insulation will prevent from hazard and will provide enough insulation with cheaper prize. The local communities need to operate the HE2 t maintain the pipes from boundary of company's area. We recommend that the local people create working unit to make sure the pipes always in good condition and the heat exchanger (HE2) outside the company's area always working properly to be able to provide thermal energy for their direct use operations.

For the geothermal company, this scheme is relatively safe. Brine temperature from the heat exchanger (HE1) is maintained above scaling temperature. There is no reducing volume of brine to be injected, because the heat exchanger (HE1) using fresh water from outside the system to extract only heat from the brine. Also, the company does not have to responsible with pipes and heat exchanger outside their area; they only need to monitor the non-insulated pipe in HE1. With only small alteration in the scheme, the company can provide alternative energy for local people and that will be a positive value for both of them.

For this research we use sample brine characteristics from a geothermal field in West Java, Indonesia. Heat energy potential from brine is used to stabilize optimum temperature for Tilapia fish cultivation. With the proposed scheme, brine with 173°C temperature and 252 kg/s flow rate can provide up to 430 kW thermal energy that can be used to heat up a 8.6 m³ volume and maintain its temperature in 30°C.

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Purwaningsih and Abdurrahman

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