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A Techno-Economic Analysis of Geothermal Energy in West Java

Allen Haryanto Lukmana, Mia Ferian Helmy

Universitas Pembangunan Nasional Veteran Yogyakarta
E-mail address allenharyanto@upnyk.ac.id; E-mail address mia.ferhel@gmail.com

Abstract

Geothermal energy is a source of heat energy contained within the earth. The utilization of geothermal energy can be done in two ways, direct use and indirect use. The utilization of geothermal energy directly for non-electric purposes naturally tends to utilize thermal energy on-site rather than converting it into electrical energy. The utilization of geothermal energy directly for non-electric purposes naturally tends to utilize thermal energy on-site rather than converting it into electrical energy. The basis for the analysis of the plan to develop the direct use of geothermal areas and its surroundings is carried out in stages: Formulation of the problem, Formulation of Analysis Assumptions, Data collection, Available Geothermal Source Classification, Classification of Economic Activities, Integration of Available Geothermal Resources and Economic Activities. The analysis is used in the calculation of the energy requirements of the tea drying process in Malabar. Direct utilization of geothermal in the case of the Malabar tea factory is Recommended with Capital Cost of direct geothermal utilization can be paid off within a period of 20 years, then the production cost per year is 7.112 billion / 20 = 355.6 million rupiah.

Keywords: geothermal, Techno, Economic, Analysis, heat energy

I. INTRODUCTION

Geothermal energy is a source of heat energy contained within the earth. The utilization of geothermal energy can be done in two ways, direct use and indirect use. The utilization of geothermal energy directly for non-electric purposes naturally tends to utilize thermal energy on-site rather than converting it into electrical energy. The utilization of geothermal energy directly for non-electric purposes naturally tends to utilize thermal energy on-site rather than converting it into electrical energy. In general, direct use of geothermal can be divided into several groups, namely: swimming pool baths and hot water therapy, heating and air conditioning including heating an area, agribusiness (especially agriculture; greenhouse heating & soil sterilization; some animal husbandry and fisheries), process industry.

In remote areas with relatively small population capacities, it is often difficult to reach by the electricity grid. Therefore, this study discusses other alternative energy sources, namely indirect geothermal utilization using small-scale geothermal power plants.

A small-scale geothermal power plant is a power plant with a capacity of fewer than 5 MWe (Vimmerstedt, 1998). This geothermal power plant can better serve rural residents in developing countries. (Entingh & Easwaran, 1994) estimated the demand for electricity capacity per person in remote locations to be 0.2 kW, in less developed locations of 1.0 kW or more in developed areas. One of the main problems with small-scale PLTPs is the high installation costs and low rate of return on capital, so it needs to be subsidized by the government to generate local economic development. This study aims to analyze the development of direct use in the geothermal area of Malabar; in this case, it is carried out mainly in terms of technology.

II. ANALYSIS OF DIRECT UTILIZATION DEVELOPMENT IN GEOTHERMAL AREA

Analysis of the development of direct use in the geothermal area, in this case, was carried out mainly in terms of technology, but for the potential for geothermal energy to be profitable, economic factors and the function of the role of the government must be increased. For example, in Tunisia, the Kebili area, geothermal use is used for agricultural purposes (78% oases and 17% greenhouses), and (5%) for warm water baths, tourists (hotels and swimming pools), washing, and animal husbandry. In Indonesia, one of the direct uses of geothermal is the development of Champignon mushrooms in the Kamojang Geothermal Field. Technically the fungus has been successfully bred well, but there are problems associated with this use (Sumotarto, 2001):

II.1. Utilization Development Diagram in Geothermal Area

The basis for the analysis of the plan to develop the direct use of geothermal areas and its surroundings is carried out in stages:

1. Formulation of the problem
2. Formulation of Analysis Assumptions
3. Available Geothermal Source Classification
4. Classification of Economic Activities
5. Integration of Available Geothermal Resources and Economic Activities

Some development possibilities are also related to the potential conditions of geothermal available in an area. Usually, the design of a geothermal application for a type of business, both for agriculture and industry, is adapted to the type and type of geothermal fluid, namely the phase conditions, temperature, and chemical composition of the geothermal fluid. (Lienau, 2003).

II.1.1. Formulation of the problem

Apart from the difficult details of each well in the four areas, the condition of the reinjection well around the PLTP in the field is very different from the initial image of the fluid temperature in the reinjection well. In fact, the temperature of the fluid entering the reinjection wells in these four areas is very low, ranging between 29-44ºC, and this results in a low utilization temperature.

This can be done as a solution by taking hot water from the separation of the separator and not from the reinjection pipe. The temperature of the hot water resulting from this separator separation will be the same as the temperature out of the production well at saturation pressure, so it is high enough to be used in direct use. The saturated steam pressure exiting the wells in these four regions is usually in the range of 10-15 bar, which means that the temperature ranges from 180-200ºC.

II.1.2. Formulation of Analysis Assumptions

The assumption is the use of geothermal fluid in the form of water in the saturated liquid phase as a result of separating the separator. The mass flow rate of the geothermal fluid used can be calculated from the quality of the steam produced. For vapor-dominated geothermal areas such as Kamojang, due to its saturated state, the mass flow rate of hot water is assumed to be 20% of the total steam flow rate. For geothermal areas dominated by superheated steam such as Drajat, the mass flow rate of hot water is assumed to be 10% of the total steam flow rate obtained using a downhole heat exchanger. Example of a dominated vapor well piping scheme design Figure 1.

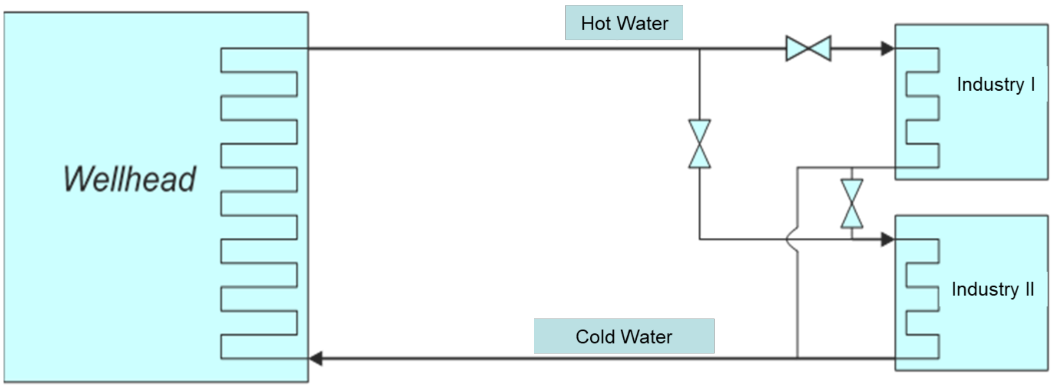

Figure 1. Design of The Piping Scheme for Dominated Vapor Wells

The temperature along the pipeline will drop exponentially, as seen in Figure 2,

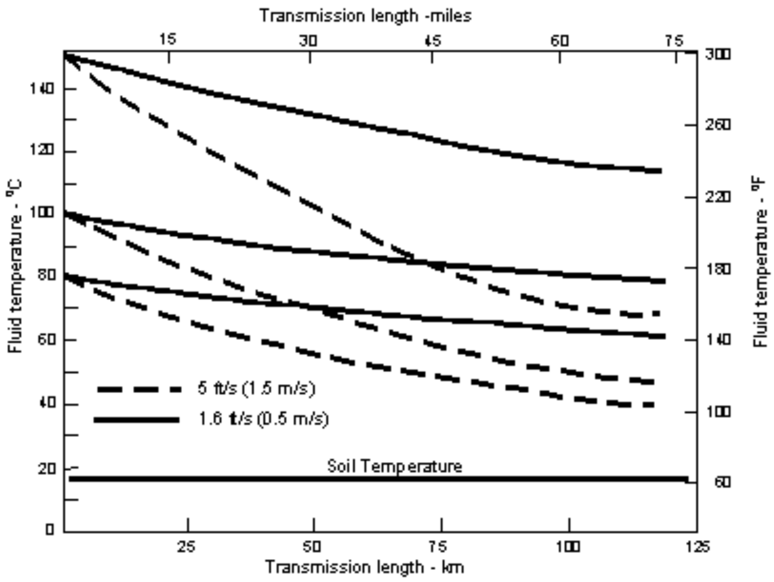

Figure 2. The decrease in The Temperature of Geothermal Fluids While in The Pipeline [Lund, 1998a]

Where the temperature drop can be calculated by assuming that the pipe acts as a heat exchanger, and the temperature profile along the pipe can be calculated using the Number of Transfer Units (NTU) method with the equation:

$$T_b = T_\infty + \left(1 - \exp\left(-\frac{4.\bar{h}.L}{\rho.C_p.v.D}\right)\right)(T_w - T_\infty) \qquad (1)$$

T_b = Bulk temperature of geothermal fluid at distance L (ºC), T_∞ = Initial temperature of the geothermal fluid (ºC), T_w = Pipe wall temperature (ºC), $\bar{h}$ = Convection coefficient in the pipe (W / m2K), L = Length of pipe analyzed (m), ρ = Density (density) of geothermal fluid (kg / m3), C_p = Specific heat constant of geothermal fluid (J / kg K), v = Velocity of geothermal fluid in the pipe (m/s), D = Inner diameter of the pipe (m). The amount of Capital Cost required for conversion from past studies with estimated costs is as shown in Table 1:

Table 1. Assumption of Estimated Cost of Each Tool

Tool	Price/Tool's Capacity Unit
Pipe	Rp. 180 million / km
Insulation	Rp. 170 million / km
Aluminum Cladding	Rp. 100 million / km
Support, Turns, Valve	Rp. 100 million / km
Civil Work and Installation	Rp. 130 million
Heat Exchanger	Rp. 40 million / 25 ton capacity per month
Pump	Rp. 50 million
Blower	Rp. 1 million / unit

Note: due to lack of data, the calculation of the cost of pumps and blowers is not included.

Other assumptions used in this analysis are the use of the Industrial Diesel Oil (IDO) price of Rp. 1650, - / liter, the price of oil is Rp. 1200, - / liter, the price of LPG is Rp. 155,000, - / tube, and the average PLN electricity price is Rp. 600, - / kWh.

II.1.3. Basic Classification of Available Geothermal Sources

The available geothermal sources can be calculated based on the following considerations:

1. Mass flow rate steam out reinjection pipe
2. Steam pressure out reinjection pipe
3. Reinjection pipe out the steam temperature
4. Chemical composition of vapor out reinjection pipe

Considerations 1, 2, and 3 can be combined into a large classification of available energy, while consideration three can be an independent temperature parameter and parameter four can be an independent parameter of the scaling process so that the classification of available geothermal sources can be :

1. Amount of energy available
2. Steam temperature available
3. Possible scaling

The above classification is based on the piping distance between the available geothermal sources (PLTP or well/injection pipe) and the location of economic activity, as shown in Figure 2 above.

II.1.1.4. Basis of Clarification of Economic Activities

The economic activities that result from data collection can be classified according to:

1. Required steam temperature
2. The mass flow rate of steam per commodity according to specific energy requirements
3. Level of complexity in applying technology.

For the record, the economic activities considered in this classification are economic activities that require geothermal energy in the process, so that traditional agricultural activities are temporarily not included in this classification.

II.2. The basis for Integration of Available Geothermal Resources and Economic Activities

Based on the classification of available geothermal sources and economic activities requiring geothermal energy, the integration of available geothermal sources and economic activities can be carried out, and this depends on the two factors below, which are based on the distance of economic activity to geothermal energy sources.:

1. Lindal diagram temperature correlation
2. Amount of energy required by the available amount.

From the classification explanation above, it can be concluded that the distance of economic activities to energy sources is a very influential factor, so it is necessary to map the distribution of the potential distribution of geothermal production and the potential use of energy by economic activities, which has the following parameters :

1. Temperature compatibility based on the Lindal chart (classified as POSSIBLE and IMPOSSIBLE)
2. The match of the amount of energy required to the availability (classified as FIT and NOT SUITABLE)
3. The potential energy that can be saved by using geothermal
4. Capital Cost of the cost of piping, pumps, and heat exchangers
5. Maintenance Cost of the scaling factor at temperatures below 150ºC (classified as LOW and HIGH)
6. Comparison of operational costs before and after using geothermal utilization with the assumption that the Capital Cost is paid within 20 years.

The schematic illustration of technological aspects can be seen in Figure 3.

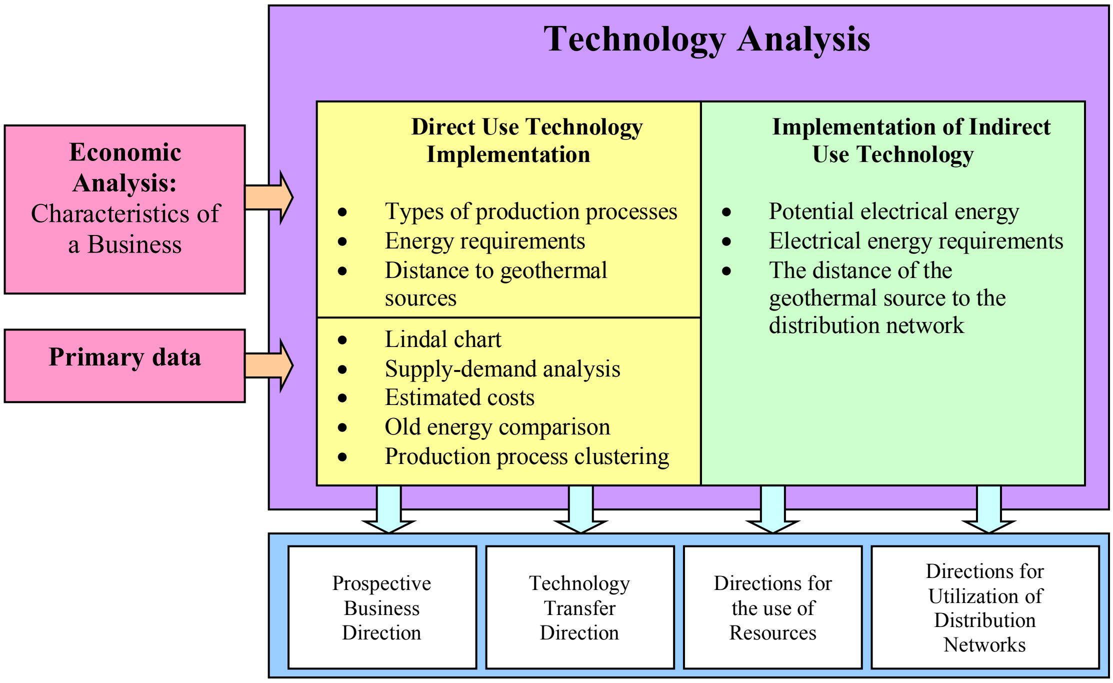

Figure 3. Mindset Illustration of Technological Aspects

II.2.1. Analysis

Analysis of the analysis carried out is the calculation of the energy requirements of the tea drying process in the Malabar tea factory and availability of energy from the nearest well, namely Wayang Windu. The main equation used is the law of conservation of energy from the well to the heat exchanger in the dryer so that this energy results in the evaporation of water content in the tea, which produces dry tea, illustrated in Figure 3.

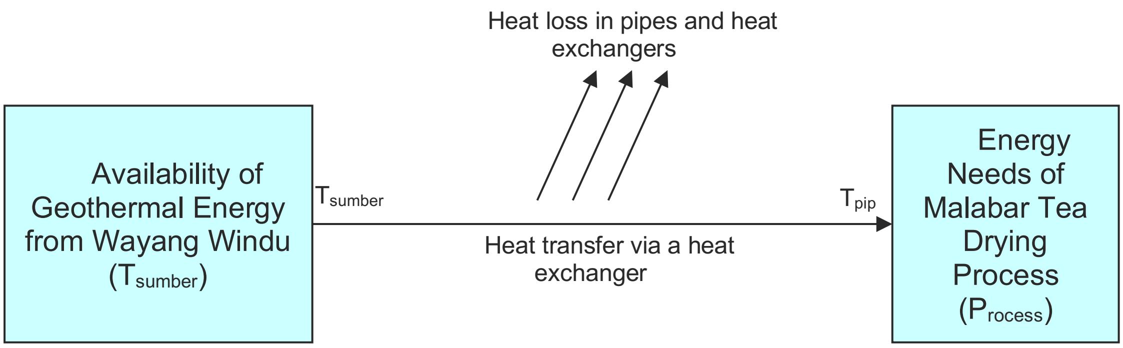

Figure 4. Conservation of energy in the tea drying process

II.3. Classification of Available Geothermal Sources

The closest geothermal source, in this case, is the Wayang Windu geothermal source, which is 8.6 km from the Malabar tea factory. The Wayang Windu geothermal source data in Table 2.

Table 2. Calculation of Energy Availability in the Wayang Windu Area

Distance (km)	T (°C)	Energy (MW)	Piping Price (million rupiahs)
0	180.0	6.470	100
1	177.8	5.990	680
5	169.7	4.232	3000
10	160.8	2.312	5900
15	153.0	0.644	8800
20	146.2	-0.812	11700

Note: The hot water flow rate is 49.5 kg / s, and the vapor pressure is 10.02 bar.

From the calculation of temperature reduction with the NTU method, it is found that the temperature of hot water at a distance of 8.6 km from the source is 163.2 ° C, which means that the enthalpy can be generated is 689.7 kJ / kg. If the lower limit of the temperature inside the pipe is 150 ° C (with an enthalpy of 632.5 kJ / kg) to avoid scaling, then the maximum enthalpy difference in the pipe that can be generated is 57.2 kJ / kg. With a heat flow rate of 49.5 kg / s, the energy available at the tea factory location with piping, which is assumed to be straight, is 2.83 MW.

II.4. Classification of Economic Activities

Economic activities in the Malabar tea factory that has the potential to use direct use applications are the withering and drying process of the tea. The withering process is intended to remove water content up to about 50% and is carried out by blowing air at ambient temperature. In the rainy season, the water content in the tea leaves is relatively higher than the dry season, so that the withering process also takes a longer time, which is around 8-10 hours, while in the dry season, it is only around 2-3 hours. The drying process is carried out by spraying hot air with a temperature of 97-105 ^{0}C, with the aim of reducing the moisture content of the tea powder to less than 2%.

The data from the Malabar tea factory is the production of dry tea leaves as much as 3300.5 tons/year from 15180 tons/year of wet tea leaves so that the amount of energy required in drying Malabar tea is 1,001 MW.

III. CONCLUSION

From the classification of available geothermal sources and their economic activities, the following conclusions are drawn on integration:

1. 1.Temperature based on the Lindal diagram is MAYBE (97-105 ° C)
2. The amount of energy required by the amount available is FIT (2.83 MW available, 1.001 MW required)
3. The potential for energy using geothermal is 1.001 MW
4. Capital Cost is calculated from the cost of piping and heat exchanger:
    - Pipe = Rp. 180 million / km = Rp. 1548 million
    - Insulation = Rp. 170 million / km = Rp. 1462 million
    - Aluminum cladding = Rp. 100 million / km = Rp. 860 million
    - Support, turn, valve = Rp. 100 million,
    - Civil work and installation, etc. = Rp. 130 million / km = Rp. 1118 million
    - Heat exchanger = Rp. 40 million / 25 ton capacity per month = Rp. 2024 million
    - TOTAL = Rp. 7,112 billion
5. Maintenance Cost at 163.2 ° C: **Low**

6. The operational cost before using geothermal is to use IDO as much as 0.38 liters per kilogram of dry tea, so that within a year, the IDO used is 0.38 x 3300 500 liters = 1254190 liters. With an IDO price of Rp. 1650, - / liter, then in a year, the operating cost is Rp. 2.069 billion.

If the Capital Cost of direct geothermal utilization can be paid off within a period of 20 years, then the production cost per year is 7.112 billion / 20 = 355.6 million rupiah, so direct utilization of geothermal in the case of the Malabar tea factory is Recommended.

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