Geothermal Capacity Building Program Indonesia - Netherlands

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Low-Enthalpy Geo-thermal Waste Heat Utilization for Tea Drying Process, Feasibility Study and Project Financing

Authors: W. Purwanto, D. Supramono

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1 INTRODUCTION

1.1 OVERVIEW OF TEA PROCESSING

At present in Indonesia most of the tea processing uses CTC (Cut, Tear, and Curl) method. This is one of the two available methods. The other method is the orthodox method. In the orthodox method, the breakage of tea leaves is carried out by rolling of the leaves so that the leave size remains wide. On the other hand, CTC method uses one machine to reduce leave size into small size. The size of tea using CTC method can be as small as 0.75 mm (Temple & van Boxtel, 1999).

The tea processing block diagram using the CTC method is shown in Figure 1. After picking up the tea leaves from the plantation, the leaves are withered at atmospheric condition. The purpose of withering is to reduce moisture content from 80% to 68%. In this stage, air is passed on the surface of tea leaves. The withering process takes 12 hours with leave reversal after 6 hours. The durations depend on the outdoor condition. During this process, there is also a biochemical process occurring naturally to attain better aroma and taste. At the end of this process, the leaves become weak and ready to be broken down.

After withering, the tea leaves undergo rolling. In the CTC rolling method, they are send to the CTC machine to undergo cut, tear and curl processing. Exiting the CTC machine, the curled tea leaves are brought onto a moving conveyer where they undergo fermentation in which the enzymes in tea leaves are in contact with air for oxidation. This fermentation improves taste, color and strength of the tea. This process is controlled by the speed of the conveyer. The fermentation process may take 60 to 80 minutes. The other rolling method is the orthodox one, which relies on a pressure cap applying pressure to the leaf mass during rolling, imparting the proper twisting and brushing action.

After being fermented, tea is sent on a back-and-forth conveyer where it is dried by a hot air flowing perpendicular to the tea layers on the conveyer. This drying process reduces the moisture content to 2% (Surana et al, 2010). Due to its low moisture content, the fermentation stage is halted. The dried tea is ready for sorting before being packed and sent to market.

1.2 TEA DRYING FACTORY

One of the potential tea plantations to use heat from geothermal brine is Kertamanah plantation (see Figure 2). This plantation is passed by a geothermal injection pipe of the Wayang Windu geothermal power plant. The Kertamanah Unit is located 1.08 km from the Wayang Windu Geothermal Power Plant (see Figure 3). The plantation was established in 1926 covering 4 villages, i.e. Margamukti, Pangalengan, Margamulya and Tarumajaya. The plantation area locates 60 km south of Bandung at altitude 1400-1600 meters above sea level.

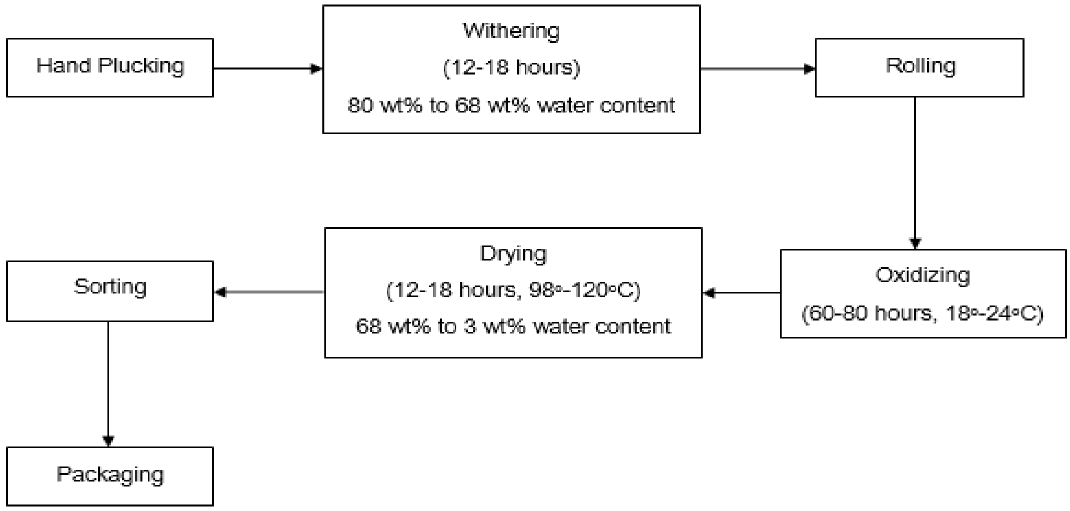

Figure 1. *Tea processing diagram*

Kertamanah tea processing produces high quality tea and has two concurrent rolling methods in one factory, i.e. CTC and orthodox methods. This plantation is the only plantation using both methods and operates under management of PTPN VIII. Its tea processing can process up to 50 tons wet top-picked tea leaves in one day with production capacity of 4.5 tons per day. In 1999, this plantation was awarded the Certificate of Quality Management System ISO 9002 and in 2005 the certificate of HACCP to ensure that the processing is hygienic and consumable. HACCP is a management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product.

Figure 2. Tea processing in Kertamanah tea plantation.

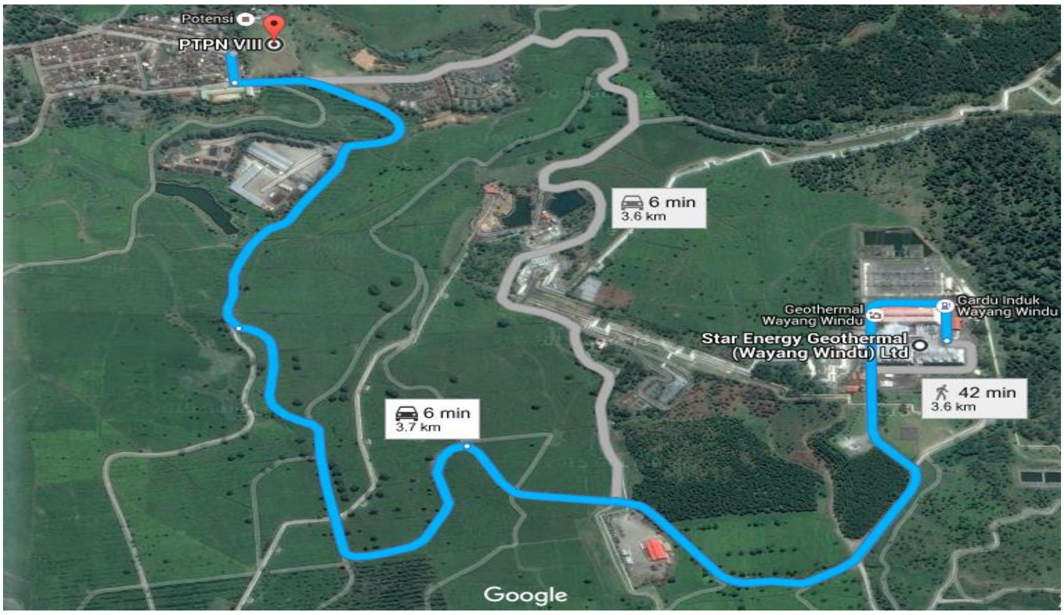

Figure 3. Map Showing the Distance of Kertamanah Unit from Wayang Windu Geothermal Power Plant

2 TECHNICAL EVALUATION

2.1 HEAT RECOVERY SIMULATION

Figure 4 shows a simulation result of flowsheeting performed on Unisim to describe the process of heat removal from the brine. A pump is used to supply water to the steam generator. Hot brine is supplied to the steam generator so that the water will evaporate at a temperature of about 130°C with a 100% steam quality. The brine used is sourced from the separator on the Wayang Windu Geothermal Field at a temperature of 160°C and a pressure of 6 bar. Brine out of the steam generator will then be injected into the injection wells.

Water vapor will then be transported to the tea factory Kertamanah using a direct pipeline. From the simulation results, the water vapor that is required is 724 kg/hour. To transport the water vapor, carbon steel pipes are used with a diameter of 6 inches. This pipe is insulated by using calcium silicate with a thickness of 1 inch. Along the pipeline, approximately 13% of heat loss will occur. This results in a decrease in water vapor temperature of 3°C/km. At the tea factory Kertamanah, the water vapor temperature has dropped to 124°C and the steam quality has dropped to is 23%. From these results it can be seen that the temperature of the water vapor at the tea factory Kertamanah is still above the drying temperature, so technically the use of brine as a heat source can be done.

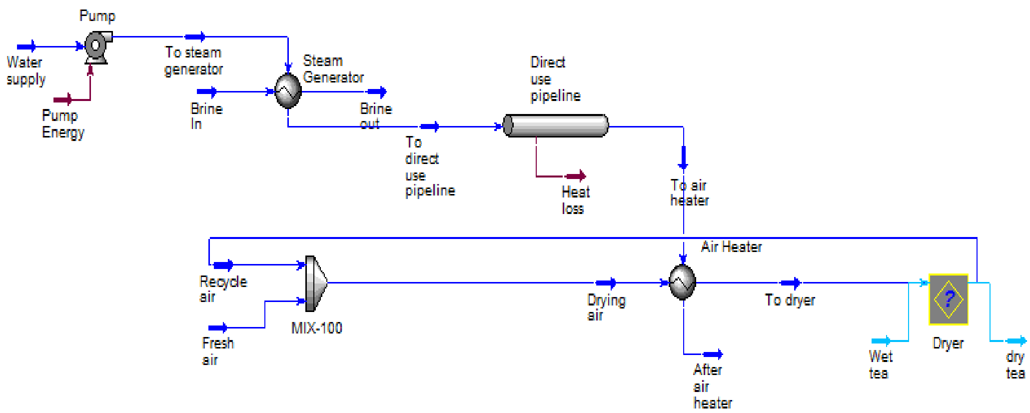

Figure 4. Tea drying using brine simulation

2.2 DRYING SIMULATION

Equations of the drying processess are summarized in Tabel 1.

Table 1. Models of drying processess

Equation	No.
Psychometric Equations	
$P_s = \exp(A - B/(C + T)$	(1)
$Y = \mathrm{m}a_w P_s/(P - a_w P_s)$	(2)
Drying Kinetics	
$X^* = (a_w X_m ck)/((1 - ka_w)(1 + cka_w - ka_w))$	(3)
$t = (\ln(X - X^*)/(X_0 - X^*)/(-k))$	(4)
Mass Balance	
$W = F(X_0 - X)$	(5)
$F_a = W/(X_0 - X)$	(6)
Heat Energy	
$Q_{we} = F(X_0 - X)(\Delta H_0 - (C_{PL} - C_{PV})T)$	(7)
$Q_{sh} = F(C_{PS} + C_{PL}X_0)(T - T_0)$	(8)
$Q_{ah} = F_a(C_{PA} + C_{PV}Y_0)(T - T_0)$	(9)
$Q = Q_{we+}Q_{sh} + Q_{ah}$	(10)
Dryer Specifications	
$M = tF(1 + X_0)$	(11)
$H = M/(1 - \varepsilon)\rho_s$	(12)
$A = H/Z_o$	(13)
$L = A/D$	(14)
$v_b = L/t$	(15)
$E_b = eL(1 + X_0)F$	(16)
Dryer Performances	
$n = Q_{we}/Q$	(17)
$r = W/A$	(18)
$SE = Q/F$	(19)
Fan Specifications	
$\Delta P = f_{we} Z_0 V^2$	(20)
$F_f = \rho_a VDL$	(21)

The simulation show a dryer efficiency of 46.32%, with an hourly rate of evaporation of water of 54.73 kg/m^2. The required drying time is about 24 minutes. The heat required to dry the tea is about 1.61 kW/kg tea.

2.3 DEHUMIDIFIER

One of the factors that affect the drying process is the humidity. The humidity will affect the equilibrium moisture content. The equilibrium moisture content will increase with increasing relative humidity of air. A high relative humidity will also cause a decrease in air temperature. Therefore it takes more energy to obtain the desired drying air temperature.

Reduction of air humidity can be done using an adsorber. At the moment, there is no air dryer unit at the tea factory. Ambient air flows directly into the dryer using a fan. Therefore, the performance of the dryer is strongly influenced by the conditions of the air. An adsorber will reduce the air humidity before it enters the dryer. Thus, the condition of the air entering the dryer can be controlled so that the performance of the dryer can also be controlled. The scheme for drying tea with the addition of an adsorber can be seen in Figure 5.

In Figure 6, it can be seen that along with a reduction in humidity, it will increase dryer efficiency while the energy consumption will decrease. If the water content in the drying air is reduced by 50%, the dryer efficiency will increase to 49.15%. In addition, the required specific energy consumption will drop to 1.52 kW/kg tea. The flow rate of the steam used also decreases to 690 kg/h. However, to obtain the necessary efficiency improvements, an additional adsorber unit is required, increasing the required capital costs.

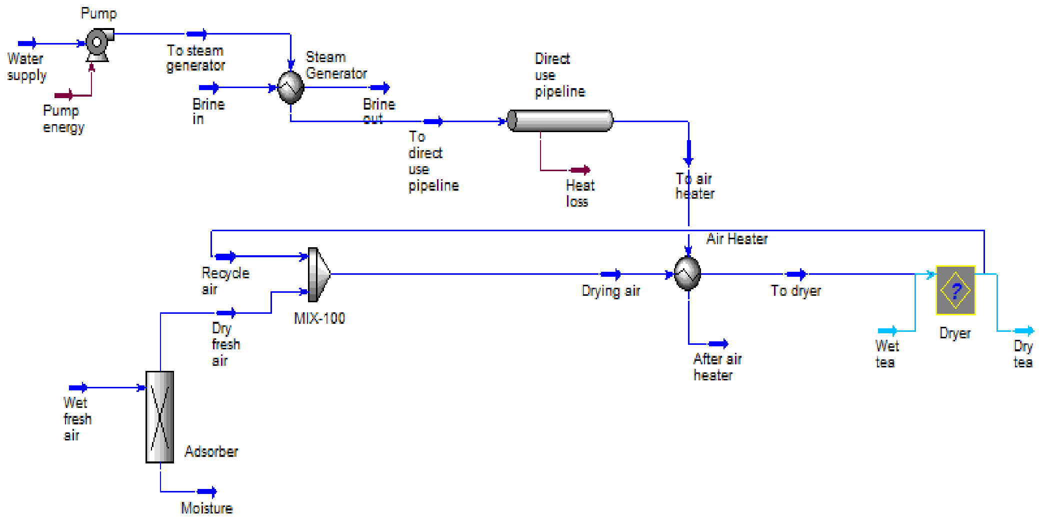

Figure 5. Tea drying using brine simulation with adsorber

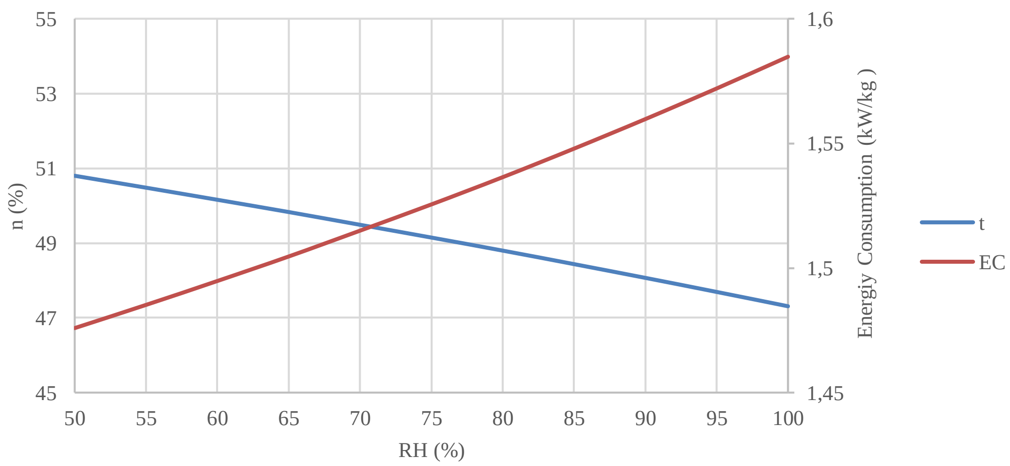

Figure 6. Dryer performance with decreasing air humidity

2.4 DRYER PERFORMANCE COMPARISON

A comparison of the performance of dryers using firewood and brine is shown in Figure 7. It can be seen that when using brine, the efficiency will increase a twofold, while the energy consumption will decrease sevenfold. This is because a fin and tube heat exchanger is used with brine instead of a furnace with wood. An absorber will further increase the efficiency by 3% while also lowering the energy consumption by 0.09 kW/kg.

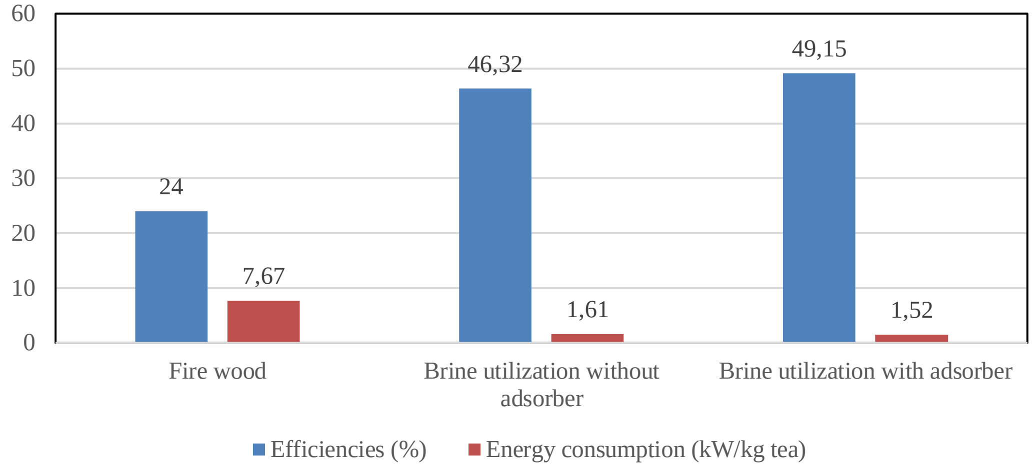

Figure 7. The comparison of dryer performance

3 ECONOMICAL ASPECTS

This section will provide the capital and operational cost that are required to implement waste heat utilization. After that, the profitability of this investment can be shown by calculating economic parameters such as the Internal Rate of Return (IRR), Net Present Value (NPV) and Payback Period (PBP).

There are four financing schemes that have been made in this study. The four schemes used to fund this project are as follows :

a. **Scheme 1**: Capital (investment) is 100% funded by a bank loan. The interest rate on this loan is set at 10%, which is common for Indonesian banks. Meanwhile, the tax component used in the calculation is the income tax (25%).
b. **Scheme 2**: The source of the capital is the same as in scheme 1. However, the tax component used in the calculation is adjusted to the regulation of Finance Ministry (PMK No. 21/PMK.011/2010). Under the regulation, government provides an income tax facility for activities exploiting renewable energy sources in the form of net income reduction by as much as 30% of the amount of investment which is charged for 6 years at 5% per year.
c. **Scheme 3**: The total investment cost of the poject is charged to the producer (waste heat provider), which means that the capital is obtained from the producer by as much as 100% of the total capital cost as a form of CSR funding without interest rate. The tax component used in the calculation is the income tax (25%).
d. **Scheme 4**: Capital is obtained from international institutions that provide funding in the form of green funds for any projects that utilize renewable energy. An example of an institution is the International Finance Corporation (IFC). The loans obtained from IFC are limited to 25% of the total "greenfield" project cost up to maximum of $100 million. The interest rate on the loan is 0.75% (LIBOR). Tax component used in the calculation is the same as the previous schemes.

3.1 CAPITAL COST

The capital cost required for this investment is mainly used for process equipment. The calculation of process equipment cost is estimated by using Seider (2003) and Ulrich and Vasudevan (2006). The component of capital cost consist of total process equipment cost and other capital cost for installation of equipments in the field such as, pipe ROW (Right of Way), contingencies and wage contractors, startup and working capital. The total capital cost for this investment is $963,410.00. Details of the cost of each component can be seen in Table 2.

Table 2. Total capital cost breakdown

Component	Cost ($)
Total process equipment cost[1)]	729,250
Right of way (ROW)[2)]	33,060
Contingency & contractor fee[3)]	137,220
Startup fee[4)]	18,000
Working capital[5)]	45,880
Total capital cost	963,410

TPEC=Total process equipment cost[1)]; ROW=10% of pipe investment cost [2)];
CCF=10%(TEC+ROW)[3)];
SF=2%(TPEC+ROW+CCF)[4)]; WC=5%(TPEC+ROW+CCF+SF)[5)].
Reference : (Seider, et al 2003).

From Table 2, it can be seen that the biggest portion of capital cost is for process equipment ($729,250). From the total process equipment cost, 45% is required for pipeline cost (see Figure 8). The pipeline cost is directly proportional to the distance between the location of the waste heat to the tea processing plant. The pipeline cost will greatly influence the feasibility of this investment. In addition to the pipeline cost, the other biggest contribution is the adsorber and steam generator with a contribution of 13% and 23% of the total process equipment cost.

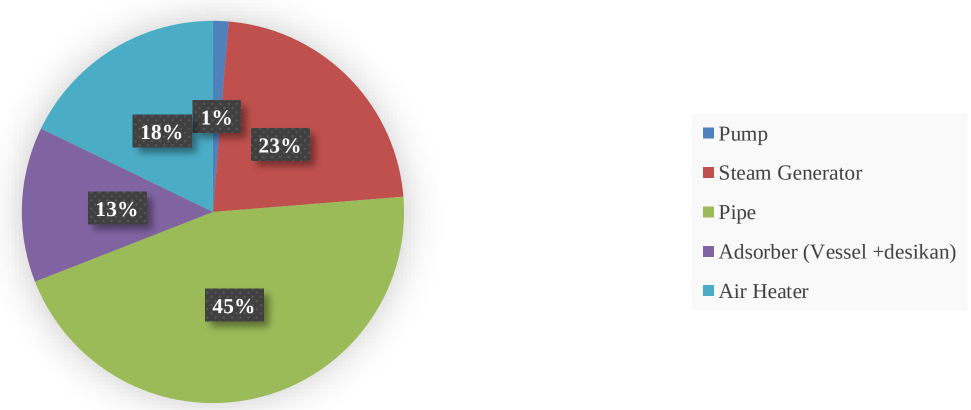

Figure 8. Equipment cost breakdown

3.2 Operational Expenditure

Based on the rule of thumb, the operational expenditure per year is estimated at 2% of the total capital cost. The operational and maintenance expenditure for this investment is $19,268 per year.

3.3 PROFITABILITY & COST COMPARISON

The economic viability of the project was determined by calculating three economic parameters for all four the financing schemes. The three parameters are NPV, IRR and PBP (Payback Period). The results of economic calculation are shown in Table 3.

Table 3. Economic parameters of each scheme of financing

Scheme	NPV ($)	IRR	PBP (years)
1	(426,660.91)	-8.30%	18.50
2	(405,470.36)	-7.77%	17.78
3	506,074.18	342.19%	0
4	(365,576.54)	-7.99%	13.47

The investment will be worth if the NPV is positive and IRR is greater than the MARR (hurdle rate). Table 3 shows that the only favorable financial scheme is scheme 3, when all the capital costs are paid by the Geothermal Power Plant producers. However, the implementation of this scheme will depend on the willingness of the Wayang Windu Geothermal Power Plant to finance all investments related to this project.

The tea factory will be willing to switch to other alternative energy only if the cost of energy is cheaper than energy costs for firewood used today. When the energy cost of each scheme is compared with firewood, it can be seen that only scheme 3 has lower energy costs than firewood (see Figure 9). This concludes that only scheme 3 is profitable and able to compete with firewood as a source of energy for drying tea.

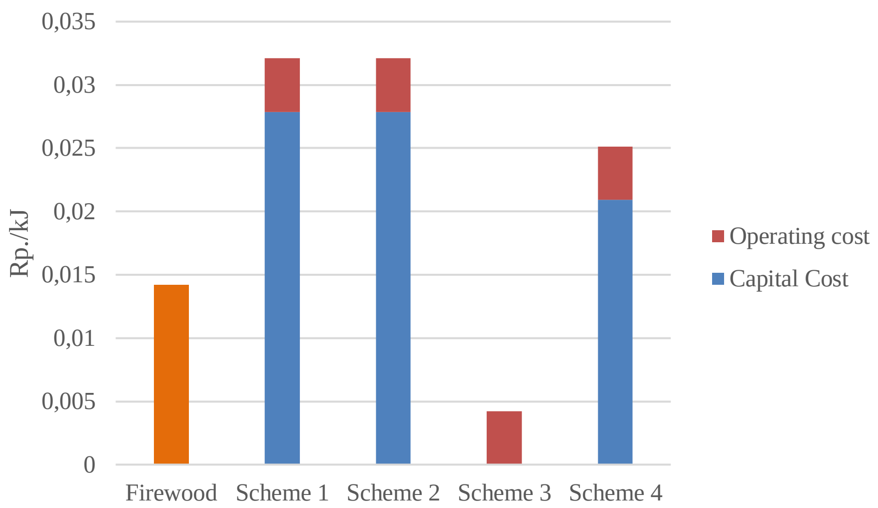

Figure 9. Energy cost comparison of each scheme with firewood

4 PROPOSED PROJECT IMPLEMENTATION

Figure 10 describes some of the relevant stakeholders for one of the potential candidates. Figure 10 shows that all costs are given on each scheme will be managed directly by the direct heat consumers and they will assign EPC to undertake the construction of this project. Geothermal power producers also provide waste heat directly to the consumer. Meanwhile, the project is also limited by the applicable regulations of the government.

In scheme 1 and 2, the user will deal directly with the bank to loan the necessary funds. However, in scheme 2, the financing scheme follows the regulations of the Ministry of Finance (based on PMK No. 21/PMK.011/2010) which provides tax relief for this project. In scheme 3, the Geothermal Power Plant will provides all the capital costs of the project (project sponsor) without interest rate so that no bank loan is required. In scheme 4, the capital costs are obtained from the international institutions such as the International Finance Corporation (IFC). The loans from IFC are limited to 25% of the total "greenfield" project cost up to a maximum of $ 100 million. The interest rate on the loan is 0.75% (LIBOR). Meanwhile, the rest of the capital costs are loaned from banks.

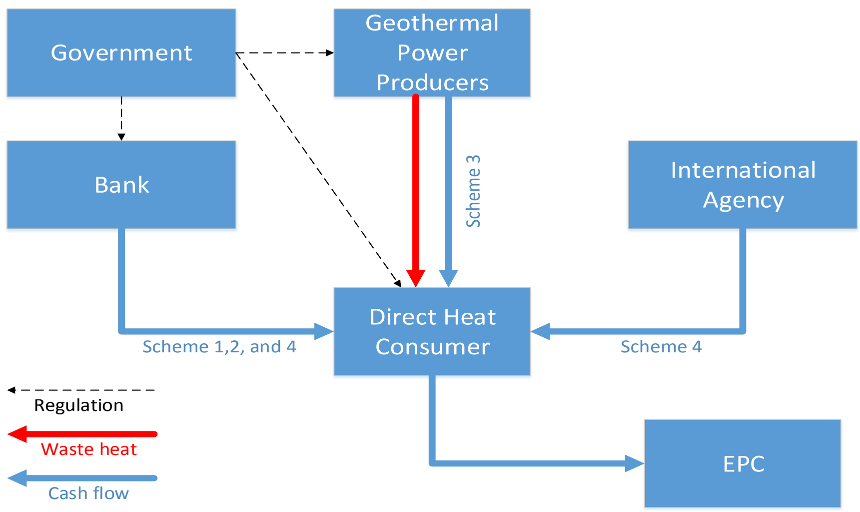

Figure 10. Stakeholders that relevant to the investment

Another arrangement of the stakeholders can be seen in Figure 11. In this scheme, there is a project company or special propose company (like ESCO) that manages all investment related activities, such as the setting of funds and project. The user will operate after the project is realized, depending on the project structure agreement (such as Build-Operate-Transfer or Build-Own- Operate-Transfer) between stakeholders involved.

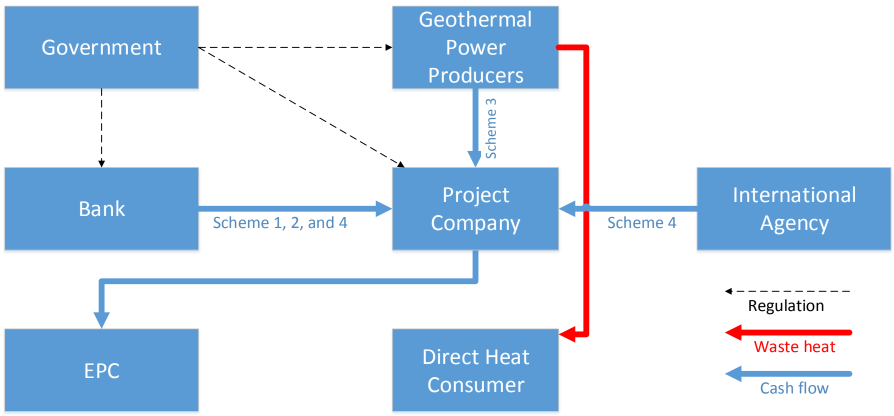

Figure 11. Stakeholders that relevant to the investment with adding project company

5 Solving Barriers

The most important non-technical barriers on direct use of geothermal energy in Indonesia are:

- Knowledge in the society on the utilization of geothermal direct use optimally for local industry is not deep enough.
- Uncertainty on policy regarding the status of ground water with geothermal brine for industrial purpose.
- There is a willingness from users to use geothermal heat source, on the condition that the investment cost is provided by the geothermal producer.
- Lack of information sharing from industrial users and producers because their permission request process is complicated.
- Funds from the government on direct use of geothermal energy are limited. Most funds are for geothermal electricity production.
- There is no fiscal policy (law and regulation) from the central government, such as incentives discount from the government, specifically for geothermal direct used
- Direct-use for agriculture process industry is more expensive than current energy costs.

To solve the most important barriers, actions are needed, such as:

- Improving awareness of society about geothermal direct use through campaign.
- Doing feasibility studies in response to the reluctance by producers and consumers of geothermal direct use.
- Propose to update policy, especially that on geothermal direct use.
- Attracting geothermal producers to use their CSR on geothermal direct use application.
- Recommending feasible financial schemes for projects
- More supportive governmental policies, stakeholders and efforts are needed to speed up the development of geothermal resources for direct use.

6 Conclusions

Geothermal waste heat can technically be used for the tea drying process in the Kertamanah Unit. New equipment needed are a pump, steam generator, pipe and air heater. To increase the efficiencies, an additional adsober can be added. To make this project feasible in terms of economics, compared to the firewood, 100% of the total capital cost must be provided by the geothermal operator as a form of CSR fund, without interest rate.

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8 NOMENCLATURE

A	m^2	Belt area
A, B, C	-	Antoine Equation constants
a_w	-	Water activity
C_{PA}	kJ/kg K	Specific heat of air
C_{PL}	kJ/kg K	Specific heat of water
C_{PS}	kJ/kg K	Specific heat of dry material
C_{PV}	kJ/kg K	Specific heat of water vapor
D	m	Dryer width
e	-	Belt driver power equation constant
E_b	kW	Belt driver power
F	ton/h db	Material flowrate
F_a	ton/h	Fresh air flowrate
F_f	ton/h	Recycle airflow rate
f_{we}	-	Pressure loss equation power
H	m^3	Dryer volume holdup
L	m	Dryer length
m	-	Air-water molecular weight ratio
M	ton	Dryer mass holdup
n	%	Thermal eficiency
P	bar	Drying pressure
P_s	bar	Vapor pressure at drying conditions
Q	kW	Total thermal load
Q_{ah}	kW	Air-heating thermal load
Q_{sh}	kW	Solid-heating thermal load
Q_{we}	kW	Water vaporization thermal load
r	kg/h m^2	Specific rate of evaporation
SE	kW/kg	Specific energy
t	s	Time
T	^oC	Drying temperature
T_0	^oC	Ambient temperature
V	m/s	Air velocity
v_b	m/s	Belt velocity
W	ton/h	Evaporating capacity
X	kg/kg db	Final moisture content
X^*	kg/kg db	Equilibrium moisture content
X_0	kg/kg db	Initial moisture content
X_m	-	Monolayer moisture content
Y	kg/kg db	Drying air humidity
Z_o	m	Loading depth
ρ_a	kg/m^3	Air density
ρ_s	kg/m^3	Dry material density
ΔH_0	kJ/kg	Latent heat of water evaporation at 0^oC
ΔP	bar	Pressure loss of air flowing through belt
c, k	-	GAB equation contains
ε	-	Void (empty) fraction