Geothermal Capacity Building Program Indonesia - Netherlands

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Plan of approach
Kertamanah Tea Drying

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1 PREFACE

1.1 INTRODUCTION

Based on a geothermal resource assessment and market survey, promising target for development has been identified. The focus for identification was on direct use projects. The identified target is Tea drying plant in Kertamanah, West Java. This case is worked out in more detail in this study. Tea drying plant in Kertamanah, West Java, is used as an object of Plan of Approach because of some reasons (referring to WP 3.06):

1. Old tea processing technology needs to be revamped to modernize so that its business sustainability can be insured.
2. Technically, short distance between heat source and heat user, and heat-bearing brine to transport heat from geothermal waste with temperature above the tea drying temperature can be proposed
3. Economically, if the plant is revamped to accommodate the use of geothermal waste, the plant will still acquire profit if capital cost is covered by green fund or a corporate social responsibility (CSR).

At the current operation, the energy cost of tea drying is cheap because the plant is using forest wood as fuel. With deforestation becomes worldwide issue, the current manner of using forest wood sooner or later is considered not environmentally friendly and people will consider this issue in commodity transaction

1.2 OBJECTIVE

In this study, a case specific analysis is carried out for Tea drying plant in Kertamanah. The objective of the plan of approach is to propose actions of revamping the tea drying process using geothermal waste heat to modernize the tea drying technology and replace the current usage of forest wood.

2 CASE DESCRIPTION

2.1 INTRODUCTION

Under Geocap scheme, a quick scan has been carried out for the tea drying plant. This chapter gives a summary of the quick scan. For more details, the reader should refer to the quick scan report[1]. By analysing several potential markets, the most potential market to utilize the waste heat from geothermal power plant is tea drying (Kertamanah Unit) (see Figure 1).

Tea processing is using CTC (cut, tear and curl) method as shown in Figure 2. After picking up the tea leaves from plantation, the leaves are withered at atmospheric condition. The purpose of withering is to reduce moisture content from 80% to 68%. In this stage, an air flow is passed on the surface of tea leaves. The withering process takes 12 hours with leave reversal after 6 hours, durations of which depend on outdoor condition. During this process, biochemical process is occurring naturally to attain better aroma and taste. At the end of this process, the leaves become weak and ready to be cut down.

[1] W. Purwanto & D. Supramono, Low-Enthalpy Geothermal Waste Heat Utilization for Tea Drying Process, Feasibility Study and Project Financing, GEOCAP, may 2017

After withering, the tea leaves undergo rolling. In CTC rolling method, they are sent to a CTC machine to undergo cut, tear and curl processing. Leaving 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, colour and strength of 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 orthodox one, which relies on a cap applying pressure to the tea leaf mass during rolling, imparting the proper twisting and brushing action.

After being fermented, tea leaves are sent onto a back-and-forth conveyer where they are 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 its low moisture content, the fermentation stage is halted. The dried tea is ready for sorting before being packed and sent to market.

Figure 1. Tea processing in Kertamanah tea plantation.

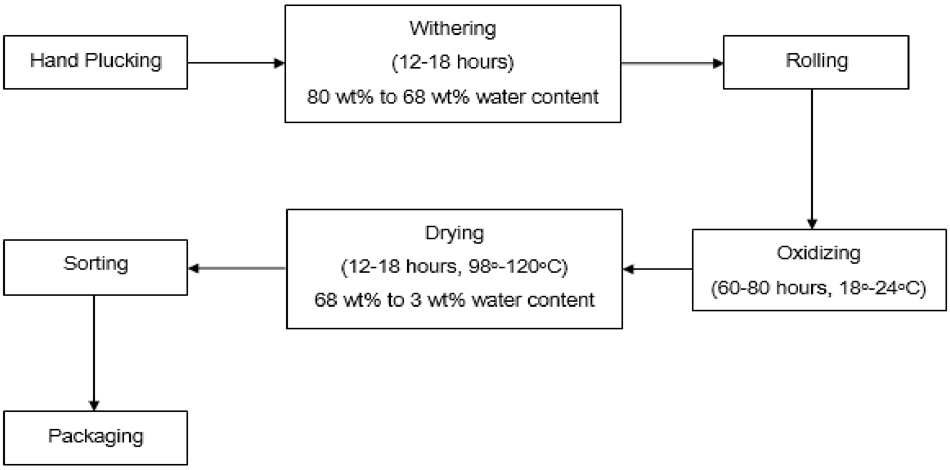

Figure 2. Tea processing diagram

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. It 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 Certificate of Quality Management System ISO 9002 and in 2005 certificate of HACCP (Hazard Analysis and Critical Control Points) to ensure that the processing is hygienist 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 in manufacturing, distribution and consumption of the finished product.

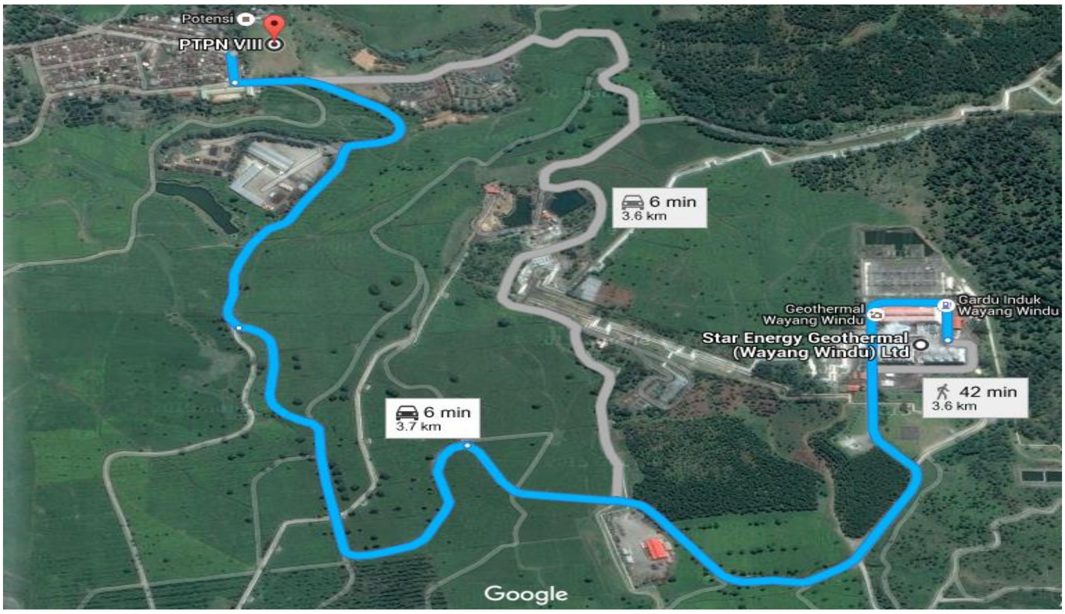

Figure 3. Map Showing the Distance of Kertamanah Unit from Wayang Windu Geothermal Power Plant

This plant is crossed by a geothermal injection pipe of Wayang Windu geothermal power plant. The plant was established in 1926 inhabiting 4 villages, i.e. Margamukti, Pangalengan, Margamulya and Tarumajaya. The plantation area locates 60 km south of

Bandung at altitude 1400-1600 meters above the sea. By taking a straight line, Kertamanah unit locates about 1.08 km from the Wayang Windu Geothermal Power Plant (see Figure 3).

2.2. HEAT DEMAND AND GEOTHERMAL POTENTIAL

The data for heat demand for user are:

1. Dried tea production is 0.5 tons/hr
2. Energy demand to fulfil the drying heat demand is 5.58 kWatt
3. Level temperatures in drying is 100^{o}C.

Near the location of Kertamanah tea drying plant, Wayang Windu geothermal plant is potential to supply geothermal waste heat.

The data for geothermal waste heat potential:

1. Wayang windu waste heat duty (brine) is 7.03 kWatt
2. Wayang Windu waste heat level of temperature is 160^{o}C

2.3. DIRECT USED ENERGY CONCEPT

Based on heat demand by the tea drying plant and heat potential from the geothermal plant, heat recovery simulation between these two plant and drying and air dehumidification simulations at the tea drying plant have been carried out.

Heat Recovery Simulation

Figure 4 shows a simulation result of flowsheeting performed on Unisim Software to describe the process of heat removal from the geothermal plant brine flow in the Wayang Windu Geothermal field to the Kertamanah Unit. The heat exchange between brine and pressurised water generates steam at the steam generator. Steam then is brought as far as 2 km to Kertamanah through sections of the pipeline route to consider barriers through the people’s homes and road. The steam has temperature of about 130°C with a 100% quality steam at the point of steam generator. The brine has a temperature of 160°C with a pressure of 6 bars at the point of steam generator. Brine out of the steam generator will then be injected back to keep the geothermal heat cyclic system.

From the simulation results, the water vapour consumes 724 kg/hour of water. To transport the water vapour carbon steel pipe with a diameter of 6 inches is used. This pipe is insulated by calcium silicate with a thickness of 1 inch. Along the pipeline approximately 13% of heat loss occurs. This results in a decrease in water vapour temperature of 3°C/km, so that when reaching the tea factory Kertamanah temperature water vapour drops to 124°C with 23% quality steam. From these results it can be seen that the temperature of the water vapour at the tea factory Kertamanah is still 20°C above the drying temperature, so technically the use of brine as a heat source can be done.

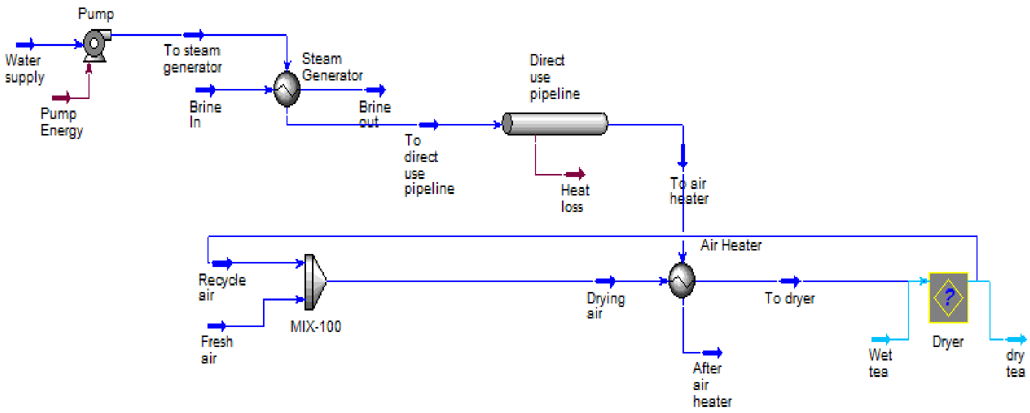

Figure 4. Tea drying using brine simulation

Drying Simulation

From the simulation results, it is known that the dryer efficiency reached 46.32%, with the rate of evaporation of water per hour of 54.73 kg/m^2. The drying requires is about 24 minutes. The heat energy required to dry the tea is about 1.61 kW/kg tea.

Dehumidification simulation

One of the factors that affect the drying process is air humidity to the tea dryer. The humidity will affect the equilibrium moisture content in tea drying. The equilibrium moisture content will increase with increasing relative humidity of air. The relative humidity also will 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, the tea factory has no an air dehumidifier unit before the air flows to the tea dryer. Currently, ambient air flows directly into the tea dryer using a fan. Therefore, the performance of the tea dryer is strongly influenced by the condition of the ambient air. The adsorber can reduce the air humidity before it enters the tea dryer. Thus, the condition of the air entering the dryer can be arranged so that the performance of the dryer is maintained. System of tea drying with the addition of the adsorber can be seen in Figure 5.

The graphs of Figure 6 shows that along with a reduction in humidity, dryer efficiency will increase and energy consumption will decrease. If the water content in the drying air is reduced by 50%, dryer efficiency is up to 49.15%. In addition, the required specific energy consumption is down 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 adsorber unit must be added which adds to the cost of capital.

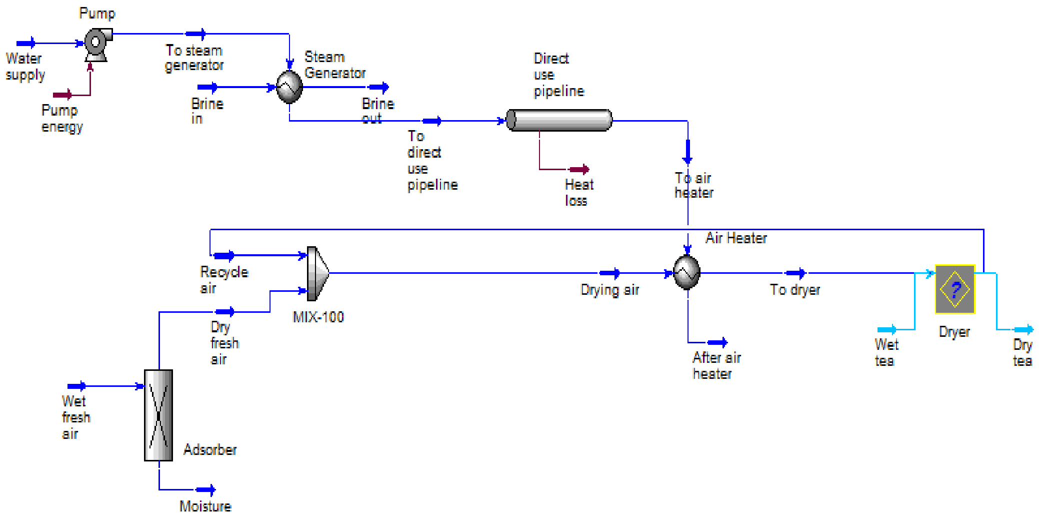

Figure 5. Tea drying using brine simulation with an adsorber

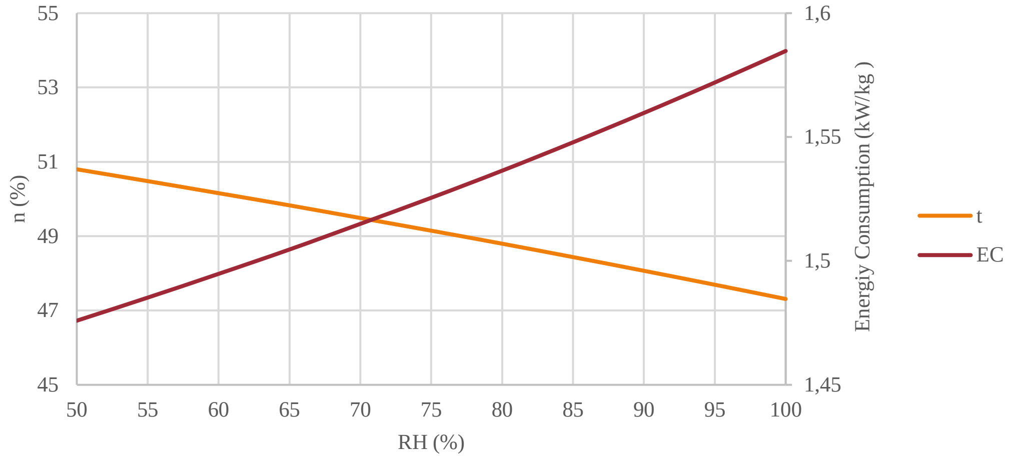

Figure 6. Dryer performance with decreasing air humidity

Dryer performance comparison

Comparison of the performance of dryers using firewood and utilizing the brine as sources of heat is shown in Figure 7. It can be seen that using the brine can increase efficiency twofold and decrease energy consumption 7 times lower. If the adsorbed is added, comparison between the use of adsorber or not shows that adding adsorber will have a 3% higher efficiency and 0.09 kW/kg lower energy consumption.

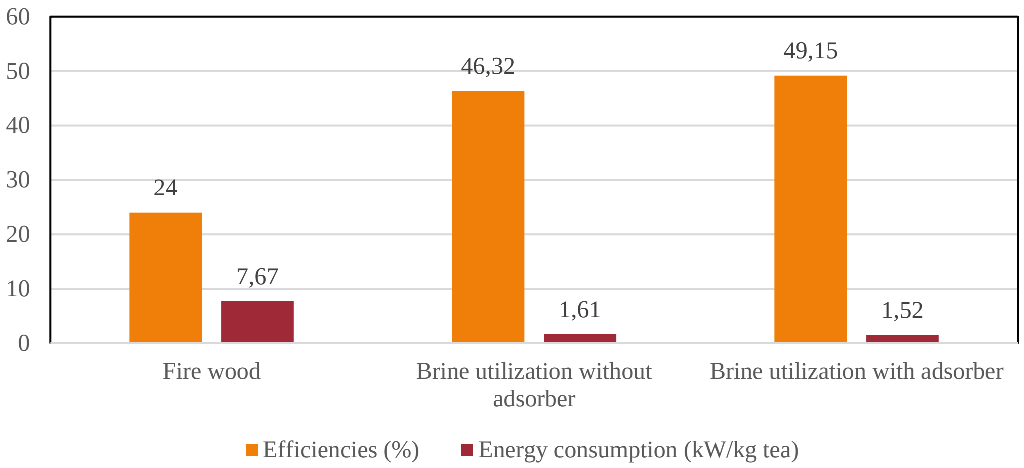

Figure 7. The comparison of dryer performance due to the use of different energy sources

2.3. SUSTAINABILITY

Even though the substitution of forest wood by geothermal energy waste requires an added capital cost, but this substitution will reduce CO_2 emission. By using the forest wood, the emission corresponding to the tea drying energy consumption reaches 10,835 ton of CO_2/year, which equivalent to 2.74 ton of CO_2/ton of dried tea. If the heat source comes from IDO combustion, CO_2 emitted reaches 10,072 ton CO_2/year or equivalent to 2.54 ton of CO_2/ton of dried tea. If the heat source comes from LPG combustion, CO_2 emitted reaches 3,834 ton of CO_2/year or equivalent to 0.97 ton of CO_2/ton of dried tea. However, the use of IDO or LPG will incur more operating cost of the tea drying plant. By utilising geothermal energy waste, then the CO2 emission is avoidable. Comparison of CO_2 emission due to the use of different energy sources is described in Figure 8.

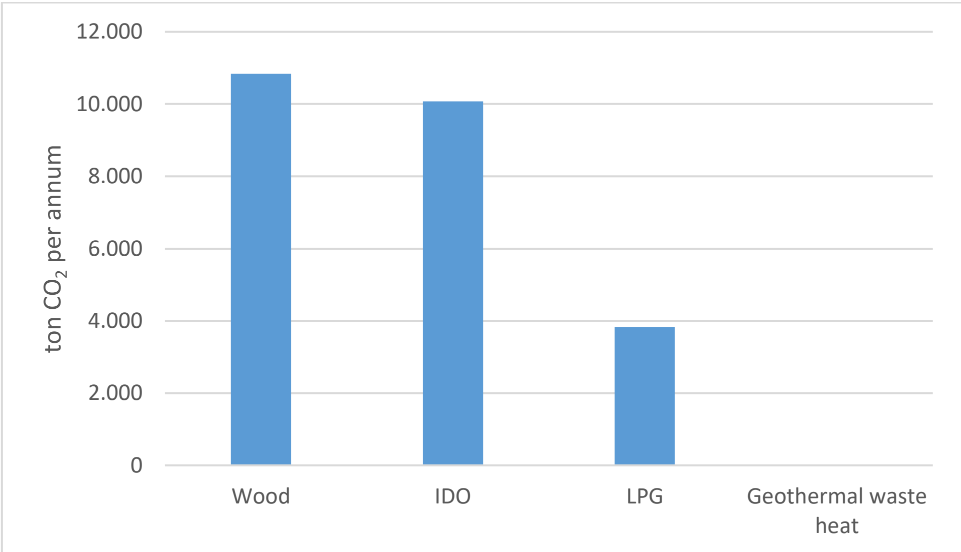

Figure 8. Comparison of CO_2 emission per annum in the tea drying plant due to the use of different energy sources

2.4. FINANCIAL ANALYSES

This section will provide the capital and operational costs required to implement the investment related to the utilisation of geothermal waste heat. Profitability of this investment will be shown later obtained through calculations of some economic parameters such as Internal Rate of Return (IRR), Net Present Value (NPV) and Payback Period (PBP).

There are four financing schemes proposed in this study to fund this project, i.e.

a. **Scheme 1**: Capital (investment) is earned from the bank loan to cover a much as 100% of total capital cost. The interest rate on this loan is set at 10% which is common used in Indonesia banks. Meanwhile, the tax component used in the calculation is income tax accounting to 25%.
b. **Scheme 2**: The source of capital is the same as 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, the government provides 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**: Total investment cost of the project is charged to the producer (waste heat provider), which means that the capital cost is fulfilled by the producer as much as 100% of total capital cost in the form of CSR funds without interest rate. The tax component used in the calculation is income tax accounting to 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. The institution may be International Finance Corporation (IFC). The Loans can be 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.

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 a formula given by Seider et al (2003) and Ulrich and Vasudevan (2006). The capital cost consists of total process equipment cost and other capital cost for installation of equipment in the field such as pipe ROW (Right of Way), contingency and wage contractors, start-up and working capital cost. The total capital cost for this investment is $963,410.00. Details of the cost of each component can be seen in Table 1.

Table 1. 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)].

Table 1 shows that the largest portion of capital cost is process equipment cost amounting to $729,250. Of 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 drying plant. Therefore, the pipeline cost becomes a determinant of the feasibility of this investment. In addition to the pipeline cost, the other largest contribution is the adsorber and steam generator capital cost contributing 13% and 23% of the total process equipment cost.

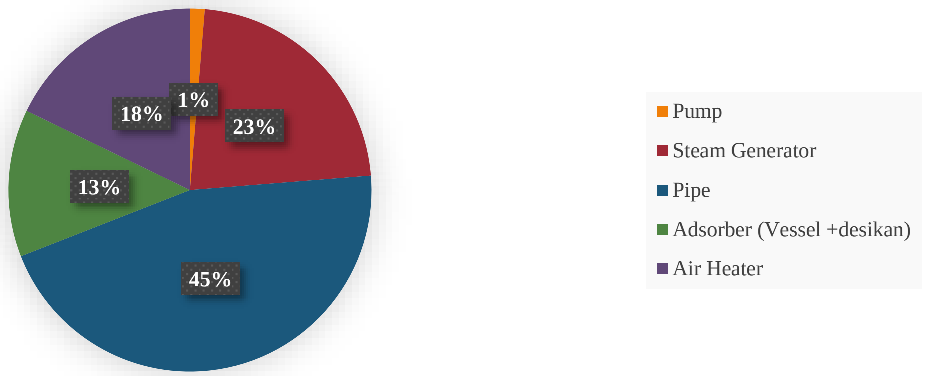

Figure 9. Equipment cost breakdown

Operational Expenditure

The operational expenditures are determined using the rule of thumb that the value of its capital investment is dominated by piping cost. Based on the rule of thumb, the operational expenditure per year is counted as much as 2% of the total of capital cost. The operational and maintenance expenditure for this investment is $19,268.00 per year.

Profitability & Cost Comparisons

The economic viability of the project was determined through three economic parameters calculated for the financing schemes that have been described previously. The three parameters are NPV, IRR and PBP (Payback Period). The results of economic calculation are shown in Table 2.

Table 2. Economic parameters of each scheme 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 worthwhile if the NPV is positive and IRR is greater than the MARR. Table 2 shows that the only favourable financial scheme is the scheme 3 in which all the capital costs are funded 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 energy cost alternative is cheaper than energy cost of firewood currently being used. If we compare the energy cost of each scheme with that of using firewood, it can be seen that only scheme 3 has lower energy cost than that of using firewood (see Figure 10). This proves that only scheme 3 is more profitable and able to compete with firewood as a source of energy for tea drying.

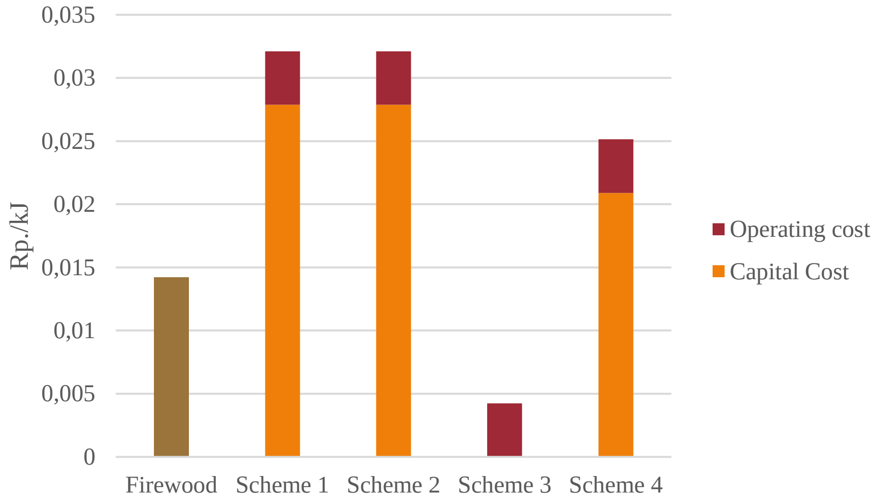

Figure 10. Comparison of **e**nergy cost using geothermal waste heat of each scheme with firewood

This chapter gives a plan of approach on how to possibly realize a geothermal direct use project for Kertamanah tea drying. For a geothermal direct use project, the following phases can be distinguished:

- Phase I: Preliminary Survey
- Phase II: Exploration
- Phase III: Project review and planning
- Phase IV: Realization
- Phase V: Exploitation

3.1 PHASE I: PRELIMINARY SURVEY (SEE QUICK SCAN REPORT)

In the preliminary survey, first steps are made to identify opportunities and work out a case on a quick scan level. Steps performed consist of:

- Quick scan: based on the resource assessment and market survey, high potential projects have been identified. The high potential projects have been worked out in more detail in quick scans. Results of the quick scan for Kertamanah tea drying case are already summarized in chapter 2.
- Stakeholder session: in case of a positive quick scan, important stakeholders will be identified. A quick scan can be considered positive in case of a positive business case and/or improved sustainability. Identified stakeholders will be contacted and a workshop setup to introduce the project. This step has already been done during Geocap (see chapter 4 for more details).
- Data inventory and collection: inventory and collection of available (geothermal) data.
- Update quick scan: using info and incentives directly supplied by the stakeholders, the quick scan will be updated.

3.2 PHASE II: (DETAILED DESIGN OF PIPE FROM HEAT SOURCE TO USER AND ADSORBER)

Pipe design.

The results of calculations on the piping design consist of setting operating conditions and sizing of the pipe. The conditions set as basis for pipe design are as follows:

1. Input temperature of steam to the pipe is 130oC
2. Input pressure of steam to the pipe is 2.40 bar absolute with vapour quality of 100%.

Sizing data of the pipe are as follows:

1. Length: 2000 meters
2. Diameter: 6 inches
3. Pipe material: carbon steel
4. Design standard: Schedule 40
5. Insulator: calcium silicate
6. Insulator thickness: 1.5 inches

These conditions and sizing data develop some design losses as follows:

1. Heat loss: 119 kW/km
2. Pressure drop along the pipe: 0.178 bar with temperature drop of 6.5^{o}C.
3. Steam quality at the pipe exit: 52% with exit temperature of 123.5^{o}C

Air dryer design

In order to maintain the dryness of the air delivered to the surface of tea leaves in tea dryers, an adsorber unit is required. Inside the adsorber is desicant granules which can adsorb moisture contained in surrounding air. The humidity variation of surrounding air should be kept low by installing the adsorber prior to delivering the air to tea dryers to maintain high drying efficiency. The sizing of the unit is as follows:

1. Length: 4.64 meters
2. Diameter: 1.88 meters
3. Material: carbon steel
4. Desicant type: activated alumina
5. Volume of decicant: 12.93 m^3.
6. Moisture adsorption capacity: 106.11 kg/hr.

3.3 PHASE III: UPDATED BUSINESS SCENARIO

- Proposed business case based on detailed design.
- Detailed economic analysis
- Contracting: initial contracts are made about heat supply and heat off take
- Financing: details about financing are finalized. This may include grants and subsidies.
- Permits: if required, additional permits are secured.

3.3.1 Proposed business case based on detailed design

Figure 11 describes some of relevant stakeholders for one potential candidate. Figure 11 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 a bank which loans the necessary funds. However, in scheme 2, scheme financing 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 provide all the capital costs of the project (project sponsor) without interest rate so that the consumer does not deal with with the bank. In scheme 4, the capital costs are obtained from the international institutions such as the International Finance Corporation (IFC). The Loans obtained from IFC are limited to 25% of the total "greenfield" project costing 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 met by a loan from banks.

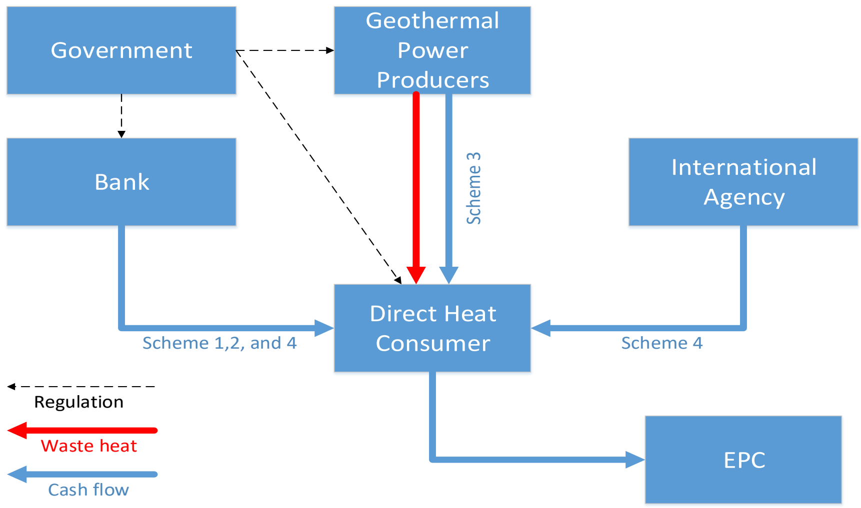

Figure 11. Stakeholders that relevant to the investment

The other arrangement of the stakeholders can be seen in Figure 12. In this scheme there is a project company or a special proposed company (like ESCO) that manages all investment-related activities such as the setting of the funds and the project. Meanwhile, the user will operate after the project finished or depending on project structure agreement (such as BOT, BOOT) between stakeholders involved.

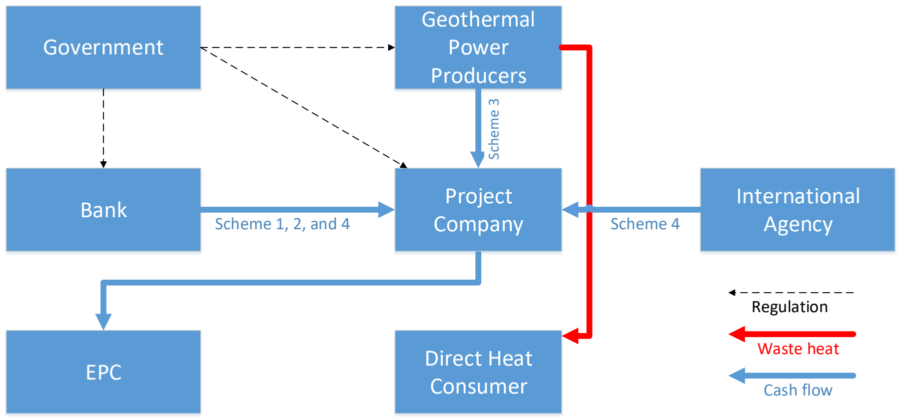

Figure 12. Stakeholders that relevant to the investment with adding project comp

3.4 Phase IV: Development

- Final EIA: the Environmental Impact Assessment is finalized.
- Tendering: all equipment and work will be tendered.
- Contracting: contracts about heat supply and heat off take are finalized
- Financial Closure: A final Investment Decision is made and a funding agreement is signed between all relevant stakeholders.

3.5 PhaseV: Realisation

- Construction of piping system between the geothermal plant and tea drying plant and adsorber in the tea drying plant.
- Start-up and commissioning: in the start-up, the complete system is tested and technical issues have to be solved.

- Performance (efficiency) as a whole is tested.

3.6 Phase V: Exploitation

- Operation and maintenance: during exploitation, all equipment will be operated and maintained. Scheduled maintenance will be carried out. Unexpected technical problems will be resolved on ad-hoc basis.

4 CASE UPDATE

The quick scan for Tea Drying case shows that the payback period varies depending on financing scheme used (see Table 2). Scheme 3 offers the period of 0 years in which total investment cost of the project is charged to the producer (waste heat provider). It means that the capital cost is fulfilled by the producer as much as 100% of total capital cost in the form of CSR funds without interest rate. The tax component used in the calculation is income tax of 25%.

4.1 STAKEHOLDERS

In the preliminary survey, relevant stakeholders are heat off taker, authorities, geothermal operators, project developers and local community. The only heat off taker for tea drying is PTPN 8 (a state-owned company under Ministry of Environment and Forestry Indonesia). Wayang Windu geothermal plant is operated by Star Energy Geothermal (Wayang Windu) Limited. It is managed under Joint Operation Contract with Pertamina to develop geothermal resources within contract area of 12,960 hectares.

Authorities

Relevant authorities can be subdivided into central and local government. In the entire process, many authorities will be involved, but in this case, the most important authorities are as follows.

Central government

- MEMR: The ministry of Energy and Mineral Resources is responsible for the national energy policy.
- EBTKE: The Directorate General of New Renewable Energy and Energy Conservation is responsible for formulating and implementing policies in their sector, as well as preparing norms and standards. They are also responsible for managing the pre-survey activities and tendering of geothermal areas.

Local government

- Bandung regency: Wayang Windu geothermal plant is Bandung Regency. For geothermal direct use projects, both local and central government will be involved. Local government must be involved from the start of the project.
- West Java Geothermal Centre of Excellence: Wayang Windu geothermal plant is situated in West Java. The Geothermal Centre of Excellence can assist other (local) authorities in decision making.

Local community

All nearby citizens should be involved in communicating the project. Important aspects are areas affected by pipeline and pipeline-associated maintenance.

4.2 BARRIERS

During Geocap workshop, important barriers were identified, together with possible solutions in Work Package 3.3. Low energy cost for fossil fuels was identified as an important barrier. One of the reasons for low fossil fuel prices is because of the subsidy scheme applied by the central government. This need to be changed to create a more level playing field for geothermal heat.

5 Conclusions & recommendations

5.1 Conclusions

- Technically, low and medium enthalpy geothermal heat can be used to supply industry with renewable hot water and/or steam.
- Authorities and geothermal developers/operators show interest in geothermal direct use.
- End users have no interest in geothermal heat due to low prices for fossil heat.

5.2 Recommendations

- A first step is the central government should change the subsidy schemes for energy in such a way that a level playing field is created for all energy options.
- Stronger sustainability incentives should be created by the government to stimulate (geothermal) renewable direct use production.
- Another reason for the lack of interest could be a lack of knowledge on geothermal direct use. In that case, a stakeholder session can be of great impact, informing end users about the technique and its advantages. It is recommended that a new attempt is made to set up a stakeholder session, preferably initiated by the central government.

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