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Plan of Approach Development Small Scale Power Plant Using Low-Medium Enthalpy

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SUMMARY

The studies in Work Package (WP) 3 low-medium enthalpy geothermal continue to an approach plan for development phase based on previous report. Part of WP 3, WP 3.07 focuses on the plan of approach for project development small scale power plant using low-medium enthalpy geothermal resources using Cisolok hot spring as study case. The geothermal fluids from Cisolok Hot springs with parameter used for assumption is temperatures of 95°C with flow rate of 5 kg/s are used in design of small scale based in technical and financial approach. Main components of a basic geothermal binary cycle power plant are preheater, evaporator, turbine, condenser, and feeding pump. The binary cycle is divided into two cycles: the primary cycle which contain the geothermal fluid and the secondary cycle which enclosed system contain an organic working fluid. Preferable working fluid is Pentane. The selection of turbine pressure design that used in this system is 3 bar based on the optimization maximum power output. The net cycle power that can be achieved by this system is 24 kWe. The heat exchanger and pump type that used in this case is shell and tube heat exchanger and centrifugal pump. Required investment for small scale geothermal power plant is 31,840 USD. Electricity price vs IRR sensitivity shows that 7.5 USD cent/kWh, IRR is 6.21% and 9 USD cent/kWh is 9.01%.

Social matters in geothermal has been an issue from time to time regardless the location. Every geothermal area has different social characteristic and should be defined before every project starts. It is also will surely affecting even a small scale geothermal development. To minimize potential social barrier in a small scale geothermal development, the developer should conduct social mapping procedure, collaborating with related party. Social mapping can be divided by two procedures which are qualitative and quantitative approach. Those approaches will result on escalation issues and re-surfacing social problems finding. Developer should be prepared for any result of this social studies, including rejection from the society regarding of the project. The social resistant towards the geothermal development can be defined in the social mapping result. The next step to overcome the rejection is by conducting social engineering. Social mapping is not only able to define problems but also able to create a possibility pathway on how to countermeasure the problems. Good understanding of social mapping result and local regulation are needed to define the right solution of social engineering, for the benefit of the society and for the developer.

There are several steps to develop small scale geothermal project. Prior implementation in the prospective resources, the project can be started by pre-feasibility study. Pre-feasibility study will be continued by feasibility study which is more detailed in technical, financial and social aspect. This document is important to ensure the project bankable. In feasibility study, the project concluded as feasible or not to proceed. Afterwards, feasible project continued with business case to obtain market assessment, financial model, and approach of related stakeholder including investor, government, and developer. The project continues with implementation consist of detail engineering design, procurement, construction and commissioning.

Using simple chart of scheduling, the small scale geothermal project at least need 6 years to end the development project and begin the operation stage. These 6 years divided into several project stages as mentioned in previous paragraph. Besides the schedule, based on project management basic theory, manpower also important point to be considered. Related stakeholder is mapped which is consist of small scale developer, local government, geothermal field developer, public and academic institution. Each stakeholder has some roles in the project to achieve mutual goals. Win-win solution in every phase of development stage considered to be achieved.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 SMALL SCALE GEOTHERMAL

Conclusion on picking the most suitable resources for small scale geothermal power plants has been decided in Work Package (WP) 3. The studies continue to an approach plan for development phase based on previous report which is quick scan of small scale geothermal power plant using low-medium geothermal resources. According to Vimmerstedt (1998), small geothermal projects are less than 5 MWe. While others (Entingh, et al., 1994 and Pritchett 1998) refer to a range of 100 to 1000 kWe as small scale. The source for small scale geothermal power plants can come from hot spring with adequate flow rate; well head generating unit of a high enthalpy well; waste brine from a high enthalpy power plant; low-medium enthalpy wellbore in a volcanic hydrothermal system; and low-medium enthalpy wellbore in a sedimentary basin system.

Small scale geothermal power plants could use flash system or binary cycle technology. Flash steam power plant in small scale applications are low cost, relatively simple, and require no secondary fluid. However, compared to binary plant, flash steam plant operates at higher temperatures. Binary plants operate at lower temperatures and use a second working fluid. Binary geothermal power plants use chemical fluids known as a secondary fluid that boils at a lower temperature than water.

The small scale geothermal power plant can be inferred to more remote areas which are currently powered by diesel generators. Although the market demand in this area has yet been identified, they offer prospective outlook for small scale geothermal development. The Cisolok Hot springs have temperatures of 95 ^{O}C and measured flow rate is 5 kg/s.

As a clean energy, there should be an added value of geothermal energy for the local community and all. There is an opportunity to use the excess energy for other purposes. It all depends on the local needs, but having energy available means there are a lot of options to expand the local economy.

1.2 OBJECTIVES

The report will be able to define and explain from the start of the project to finish line. In doing so, qualification and quantification of the project can be mapped and well-informed. The tools to undergo the process are by conducting technical, financial and social aspect study. Technical aspect can design power input and output based on fluid properties and availability. Financial aspect can generate sensitivity on project cost versus IRR value as a function of parameters that been used, such as equipment prices, tax rate, etc. Social aspect can describe key factors to elevate the project. All aspect result will be used for arranging related stakeholders function and a feasible time schedule.

2 ASSESSMENT

2.1 TECHNICAL ASPECT

Binary cycle power plants have been widely applied to several fields that are categorized as low-medium enthalpy. In water dominated high enthalpy geothermal field, binary cycles have also been applied to extract the energy from brine to generate electricity. The main components of a basic geothermal binary cycle power plant are the preheater, evaporator, turbine, condenser and feeding pump. The schematic process of a binary cycle is shown in Figure 1. Other equipment is a cooling tower to cool down working fluid in the condenser.

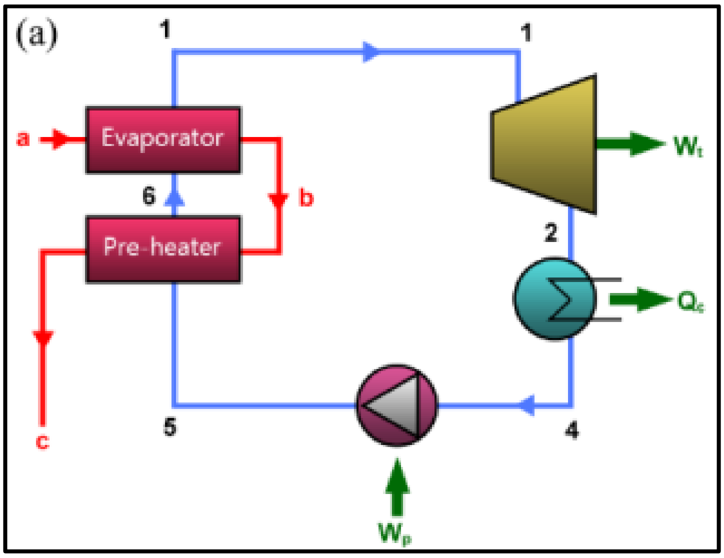


Figure 1 The schematic of binary cycle power plant (Reference: Fuad, 2015)

2.1.1 Resources

This report discusses about the utilization of geothermal manifestation in the Cisolok and brine output from separator in Salak geothermal power plant. Those areas located in West Java. The geothermal manifestation in Cisolok area appears at 106°27’13.4” E and 6°56’0.5” S in the Cisolok River. Based on data from the survey, a temperature of 95 ˚C and mass flow rate of 5 kg/s is used in this study for the Cisolok hot spring. The Awibengkok-Salak geothermal is categorized as two phase geothermal system. The field is generated by single flash system. According to Acuna et al., 2008, Salak geothermal field has been producing the steam required for 110-377 MW of power generation for 16 years, with approximately 14,000 to 18,000 kph of water injected in the production area during this time. Production well produces steam with 10-20% of steam fraction, the total brine production is approximately 1900 kg/s. The wellhead pressure is around 11-12.4 barg. While fluid flows to the separator, the pressure decreased to 8.27-8.62 barg and fluid is separated from brine in water phase, steam directed to the inlet of the turbine. The brine temperature out from separator is 170^{O}C and the pressure is almost same with separator pressure, then the brine is re-injected through reinjection well.

The concept of binary cycle power plant refers to an organic working fluid used in a secondary, closed loop. The organic working fluid has a lower boiling point and higher vapor pressure than water or brine (primary fluid). The binary cycle is divided into two cycles: the primary cycle which contain the geothermal fluid and the secondary cycle which contains an organic working fluid. The concept of binary cycle power plant refers to an organic working fluid used in a secondary, closed loop. The organic working fluid has a lower boiling point and higher vapor pressure than water or brine (primary fluid). Hot spring water passes through a heat exchanger and heats up the secondary fluid in a closed loop. Heat from the geothermal water causes the secondary fluid to flash to vapour, which then drives the turbines, and subsequently the generators. The vapour is condensed back to liquid, closing the cycle.

In preparing the plant design, a selection of working fluid for the system is one of the most important considerations. Several criteria must be considered during the working fluid selection: a good thermodynamic property, a compatibility with fluid characteristic used, especially in medium-high temperature ranges. Other important considerations are critical temperature and pressure and safety (non-flammable, non-toxicity, ozone depleting potential). Hydrocarbons such as butane, pentane and propane are good working fluids, in addition to some refrigerants. An appropriate selection of working fluid will result in a high efficiency system, as well as safe and economical operation. The WP 3.06 study concludes n-pentane as a working fluid.

Table 1 The parameter comparison of working fluid

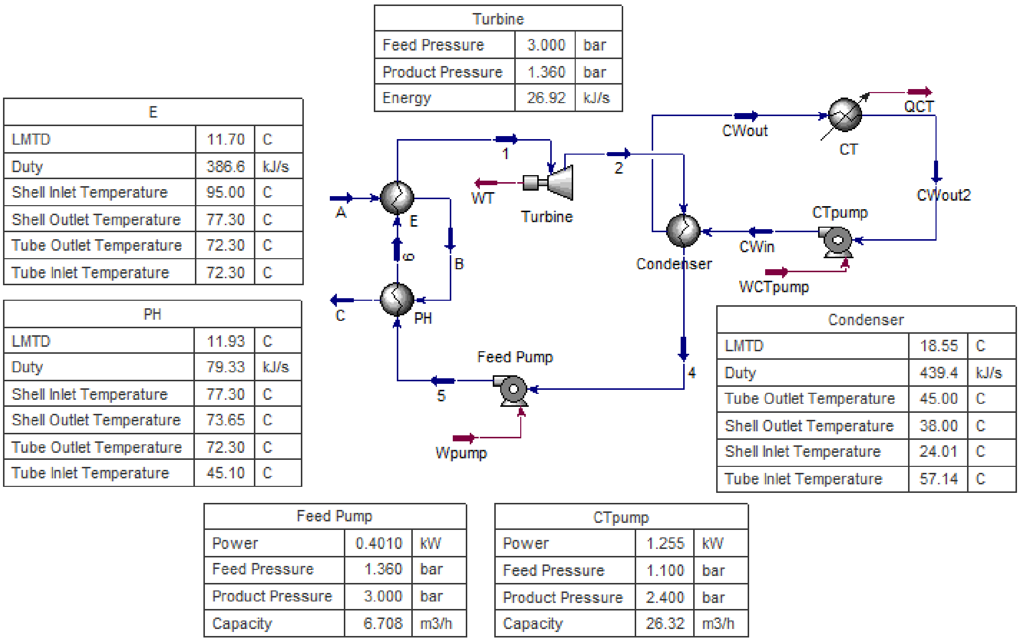
Fluids	Pcritical (bar)	Tcritical (°C)	ODP*	GWP**	Flamm-ability	Toxicity	Price (USD/kg)	Avail-ability
n-pentane	3.37	196.4	0	20 (low)	High	High	1-3	High

Notes

* ODP : Ozone Depletion Potential

**GWP: Global Warming Potential

Figure 2 shows the process flow diagram of Cisolok binary cycle which built in HYSYS v8.8 software. The flow diagram describes the hot water, working fluid cycle, and cooling water line. The selection of the turbine pressure design that is used in this system is 3 bar for n-pentane based on the optimization maximum power output. In this case, the additional feed pump is needed to transport the manifestation fluid to the plant. The parasitic load energy is described in Table 3.



Turbine		
Feed Pressure	3.000	bar
Product Pressure	1.360	bar
Energy	26.92	kJ/s

E		
LMTD	11.70	C
Duty	386.6	kJ/s
Shell Inlet Temperature	95.00	C
Shell Outlet Temperature	77.30	C
Tube Outlet Temperature	72.30	C
Tube Inlet Temperature	72.30	C

PH		
LMTD	11.93	C
Duty	79.33	kJ/s
Shell Inlet Temperature	77.30	C
Shell Outlet Temperature	73.65	C
Tube Outlet Temperature	72.30	C
Tube Inlet Temperature	45.10	C

Condenser		
LMTD	18.55	C
Duty	439.4	kJ/s
Tube Outlet Temperature	45.00	C
Shell Outlet Temperature	38.00	C
Shell Inlet Temperature	24.01	C
Tube Inlet Temperature	57.14	C

Feed Pump		
Power	0.4010	kW
Feed Pressure	1.360	bar
Product Pressure	3.000	bar
Capacity	6.708	m3/h

CTpump		
Power	1.255	kW
Feed Pressure	1.100	bar
Product Pressure	2.400	bar
Capacity	26.32	m3/h

Figure 2 Process flow diagram of Cisolok binary cycle

Table 2 The operational conditions of binary cycle using Cisolok Hot Spring

Parameter	Symbol	Units	
Working Fluid	Pentane		
Hot Water Flow	M_A	5	kg/s
Hot Water Temperature	T_A	95	^{o}C
Pinch Point	ΔT_{pp}	5	^{o}C
Cp Hot Water	Cp_{hw}	4.2	kJ/kg-K
Turbine Inlet Pressure	P_1	3	bar
Turbine Inlet Temperature	T_1	72.3	^{o}C
Condenser Temperature	T_4	45	^{o}C
Condenser Pressure	P_C	0.14	MPa
Turbine Efficiency	η_t	80%	
Generator Efficiency	η_{gen}	95%	
Pump Efficiency	η_{pump}	80%	
HE Effectivity	ε_{HE}	95%	

Table 3 The power generation and the utilization energy requirement in Cisolok power plant.

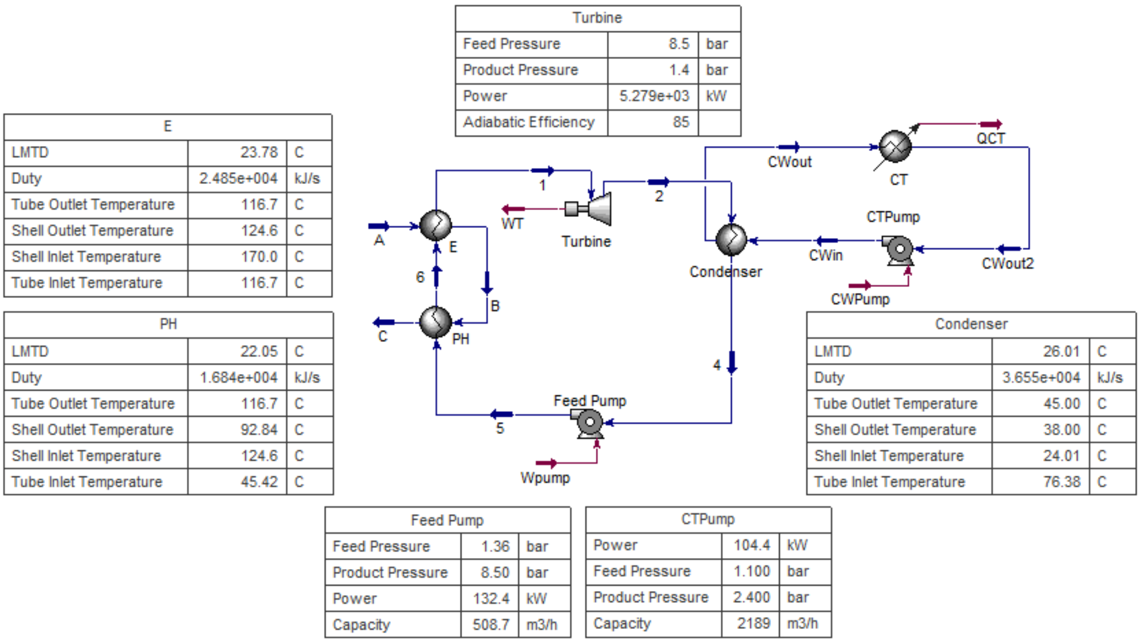
Fluids	Mwf	Net Power	ηthermal	Gross Power	Working Fluid Pump	Cooling Tower Pump	Manifest Pump
	kg/s	kWe	%	kW	kW	kW	kW
n-pentane	1.2	22.7	5.4	26.9	0.8	1.4	2

The net cycle power that can be generated by Cisolok system is 23 kWe for n-pentane.

Salak Power Generation

The power generation in Salak is generated by utilizing the brine separation result from the separator. By simulating the binary cycle output using HYSYS software, the total power that can be extracted from the total brine output from the separator is approximately 13 MW, however, by referring to the small-scale project that we discussed, so the maximum power generation for this case is adjusted to 5 MW. The process flow diagram of Salak binary cycle is shown in Figure 3. The operational condition and several assumptions that we use to calculate the binary power cycle are showed in Table 4 and Table 5. The selection of the turbine pressure design that is used in this system is 8.5 bar for n-pentane and 12 bar for

R 245 fa, based on the maximum 5 MW power output. The pressure of brine output from the separator is still high around 8 bar, therefore in this this case is no need to use the feeding pump to transport brine to the plant.



E		
LMTD	23.78	C
Duty	2.485e+004	kJ/s
Tube Outlet Temperature	116.7	C
Shell Outlet Temperature	124.6	C
Shell Inlet Temperature	170.0	C
Tube Inlet Temperature	116.7	C

PH		
LMTD	22.05	C
Duty	1.684e+004	kJ/s
Tube Outlet Temperature	116.7	C
Shell Outlet Temperature	92.84	C
Shell Inlet Temperature	124.6	C
Tube Inlet Temperature	45.42	C

Turbine		
Feed Pressure	8.5	bar
Product Pressure	1.4	bar
Power	5.279e+03	kW
Adiabatic Efficiency	85	

Condenser		
LMTD	26.01	C
Duty	3.655e+004	kJ/s
Tube Outlet Temperature	45.00	C
Shell Outlet Temperature	38.00	C
Shell Inlet Temperature	24.01	C
Tube Inlet Temperature	76.38	C

Feed Pump		
Feed Pressure	1.36	bar
Product Pressure	8.50	bar
Power	132.4	kW
Capacity	508.7	m3/h

CTPump		
Power	104.4	kW
Feed Pressure	1.100	bar
Product Pressure	2.400	bar
Capacity	2189	m3/h

Figure 3 Process flow diagram of Salak binary cycle

Table 4 The operational conditions of binary cycle using Salak brine separator output

Parameter	Symbol	Value	Units
Working Fluid		Pentane	
Hot Water Flow	M_A	120	kg/s
Hot Water Temperature	T_A	170	°C
Pinch Point	ΔT_{pp}	5	°C
Cp Hot Water	Cp_{hw}	4.2	kJ/kg-K
Turbine Inlet Pressure	P_1	0.85	MPa
Turbine Inlet Temperature	T_1	114	°C
Condenser Temperature	T_4	45	°C
Condenser Pressure	P_C	0.14	MPa
Turbine Efficiency	η_t	80%	
Generator Efficiency	η_{gen}	95%	
Pump Efficiency	η_{pump}	80%	
HE Effectivity	ε_{HE}	95%	

Table 5 The power generation and the utilization energy requirement in Salak power plant

Fluids	Mwf	Net Power	ηthermal	Gross Power	Feed Pump Power	Cooling Tower Pump
	kg/s	kWe	%	kW	kW	kW
n-pentane	89	5042	11.3	5279	132	105

By the power output result of the two system which is almost comparable, the system design using n-pentane as working fluid has lower design turbine pressure and working fluid flow rate requirement. Therefore, the selection of n-pentane as working fluid is more suitable than R-245fa due to less investment cost and the availability stock in the market.

The next step is the process equipment design and selection, which is based on the amount and requirement of heat and mass transfer. From the simulation result which is shown in Table 3 and Table 5, The sizing and design of the equipment is need to rate up to match the design requirement. The equipment that is to be reviewed is heat exchanger (HE) and pump. Table 6 to Table 9 show the equipment design of heat exchanger and pump for each case. The type of HE and pump used in this case are a shell and tube heat exchanger (STHE) and a centrifugal pump. The selection of the STHE is determined by the following aspects:

- Size: STHE has larger heat transfer surface area and has a shorter length due to the presence of multiple tubes.
- Heat Duty: STHE provide higher overall heat transfer coefficient so can handle wide temperatures and pressures.
- Versatility: the number of tubes and pitch can be selected according to the operating conditions and baffle cut and spacing can be used to influence the overall heat transfer coefficients.

Table 6 The design of pump in Cisolok binary cycle

	Feed Pump (working fluid)	CT Pump	Feed Pump (manifest Pump)
Flow rate (m^3/s)	10	30	30
Power (kW)	1	2	2
Quantity	1	1	1

Table 7 The design of heat exchanger in Cisolok binary cycle

	Evaporator	Pre-Heater	Condenser
Type:	HE Shell and Tube 1-2 Pass	HE Shell and Tube 1-1 Pass	HE Shell and Tube 1-2 Pass
Quantity:	1	1	1
Dimension:			
Heat transfer area:	16 m^2	5.5 m^2	15.5 m^2
Shell:	ID 8 inch	ID 8 inch	ID 8 inch
	Baffle Spacing 0.04 m	Baffle Spacing 0.04 m	Baffle Spacing 0.04 m
Tube:	OD 3/4 inch	OD 3/4 inch	OD 3/4 inch
	ID 0.62 inch	ID 0.62 inch	ID 0.62 inch
	BWG 16	BWG 16	BWG 16
	Triangular pitch 1-5/16 inch	Triangular pitch 1-5/16 inch	Triangular pitch 1-5/16 inch
	Number of tube per pass 32	Number of tube per pass 36	Number of tube per pass 32

Table 8 The design of pump in Salak binary cycle

	Feed Pump (working fluid)	CT Pump
Flow rate (m^3/h)	510	2200
Power (kW)	135	105
Quantity	1	1

Table 9 The design of heat exchanger in Salak binary cycle

	Evaporator	**Pre-Heater**	**Condenser**
Type:	HE Shell and Tube 1-4 Pass	HE Shell and Tube 1-4 Pass	HE Shell and Tube 1-4 Pass
Quantity:	1	1	1
Dimension:			
Heat transfer area:	623	951	473
Shell:	ID 31 inch	ID 37 inch	ID 27 inch
	Baffle Spacing 6.2 inch	Baffle Spacing 7.4 inch	Baffle Spacing 5.4 inch
Tube:	OD 1 inch	OD 1 inch	OD 1 inch
	ID 0.87 inch	ID 0.87 inch	ID 0.87 inch
	BWG 16	BWG 16	BWG 16
	Triangular pitch 1-1/4 inch	Triangular pitch 1-1/4inch	Triangular pitch 1-1/4 inch
	Number of tube per pass 430	Number of tube per pass 632	Number of tube per pass 302

Overall, the study result of brine utilization from surface manifestation or brine separator output is reliable to conduct the generation.

2.2 FINANCIAL ASPECT

The financial calculation for Cisolok is conducted by using several assumptions as Power generated of 22.7 kW (rounded to 23 kW) based on previous analysis, no loan required, no added area required, all equipment is in existing area and no drilling well. Total investments to develop a 23 kW required to build a geothermal binary at the manifestation in Cisolok is USD 1,688,636, including the Value Added Tax 10% as applied in Indonesia. Calculation of this scenario found that the minimum electricity price is more than USD 100 cent/kWh. With electricity price USD 102 cent/kWh the IRR would be 9.79% per year. The price is very high and above the average of electricity price in Indonesia. The high price explains that this project is not feasible.

The financial calculation for Salak was conducted as power generated 5 MW based on previous analysis by using similar assumptions of Cisolok calculation: no loan required, no added area required, all equipment is in existing area and no drilling well. The total investment to develop a 5 MW geothermal binary plant that utilizes the manifestation in Salak is USD 16.6 Million, including the Value Added Tax 10% as applied in Indonesia. Calculation using above assumptions found that the minimum electricity price for this scenario is USD 23.8 cent/kWh. The IRR on Equity would be 9.70% for 30 years project time.

2.3 MARKET AND SOCIAL ASPECT

Based on government projection (RUPTL PLN 2018-2027) in Figure 4, geothermal can generate electricity up to 4,583 MWe (8% of total produced electricity on national scale). If implemented, the Cisolok small scale power plant will partly replace fossil energy of the Jawa-Bali Interconnection. Fuel demand and greenhouse effects could also decrease from this energy diversification. There is even a possibility to increase revenue from carbon trade regulation, as it is in line with president commitment at the G20 meeting.

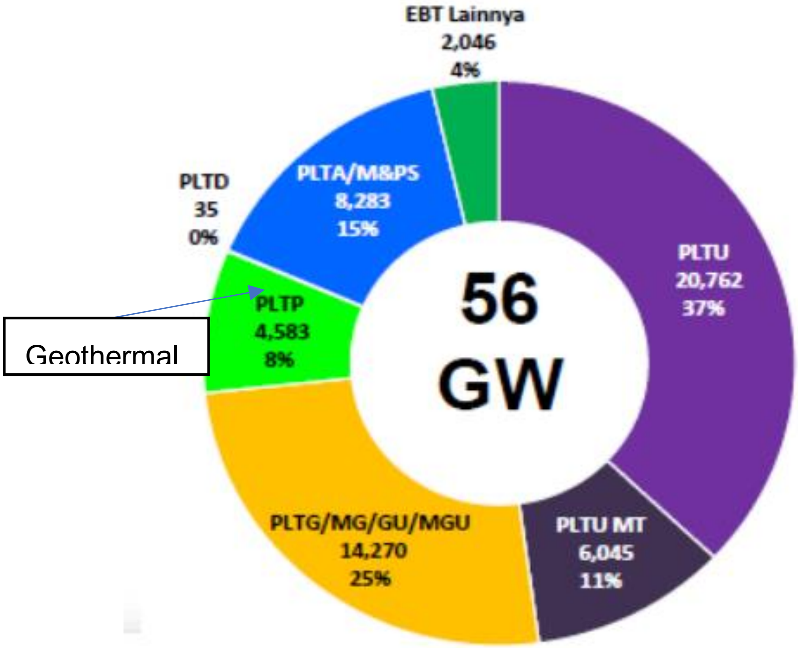


Figure 4 Government plan (RUPTL PLN 2018-2027)

The geothermal market basis for electricity is created by society needs. The society needs electricity to increase their life quality but on the contrary, there are many existing social matters in the geothermal area, such as rejection from the people, demonstration to resist geothermal development, etc. Social matters in geothermal has been an issue from time to time regardless the location. This causes many rejections to happen in certain geothermal locations due to limited knowledge on social behavior in the geothermal area and its surrounding. It will also affect small scale geothermal development. Social aspects are never a single (and simple) topic. It will always be accompanied with environmental issues as a thoughtful worry. Many geothermal developments had to struggle in confronting those problems because they lack understanding of the local people behavior or they are even not interested in this matter.

Geothermal areas are a social site-specific type. It means every geothermal area has different social characteristic and should be defined before every project starts. To minimize potential social barriers in a small scale geothermal development, the developer should conduct a social mapping procedure, collaborating with local parties. Social mapping can be divided by two procedures which are a qualitative approach and a quantitative approach. A qualitative approach is conducted by interviewing key figures in the local area. A quantitative approach is conducted by creating some questionnaires to target social behavior in the local area. Those approaches will result in an identification of potential escalating issues and re-surfacing social problems.

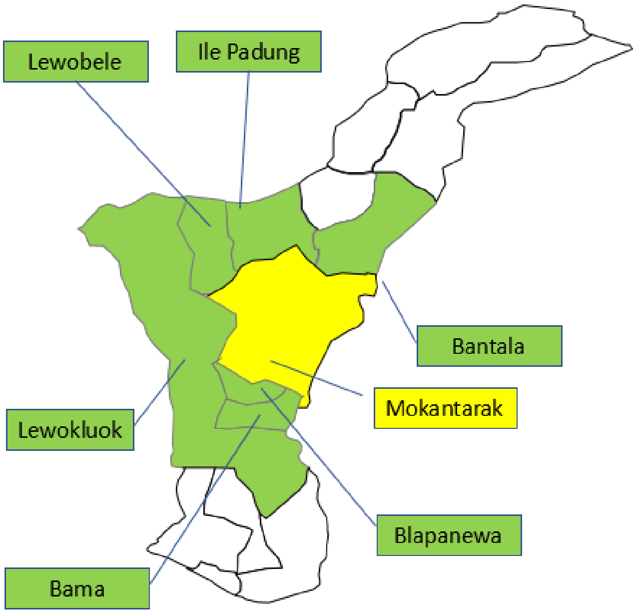


Figure 5 Example of villages area mapping, Oka-Ile Ange Geothermal Area (Guwowijoyo, F.X. et al., 2017 – unpublished paper of IIGCE2016)

Figure 5 is an example on how to divide affected area by villages in a geothermal development. From the distribution, questionnaires can be distributed on each area with determined samples. This include acquiring key figures on each village by qualitative approach. Both approaches can be used to elaborate social needs and expectation from the small scale geothermal development. The developer should be prepared for any result of this social studies, including rejection from the society regarding the project. The rejection can be defined in the social mapping result. The next step to overcome the rejection is by conducting social engineering. Social mapping is not only able to define problems but also able to create a possible pathway on how to countermeasure the problems. Good understanding of social mapping results and good knowledge of local regulations are needed to define the right solution of social engineering, for the benefit of the society and also for the small scale developer.

Social mapping activities proofed to be one of the effective solutions in terms of people rejection of geothermal activities. On the other hand, it is a time consuming and costly study to be implemented. It takes time. Some developers will assume this activity as a local government responsibility, others will take it as a developer responsibility. It is not some parties' responsibility, but a good action is a must for all of the related stakeholders. Good collaboration effort needs to take place for mutual benefit and to successfully implement a small scale geothermal development. Individual interests should be eliminated in the collaborative work, so the result would be good as well. This method can be applied in the Cisolok area prior to or at the start of the project. At least a literature study should be conducted to get a general picture of the area.

The Cisolok area conditions need to be described, especially demography background. Demography conditions at Cisolok are collected by Statistics Indonesia (Badan Pusat Statistik). The Cisolok area is stated as a district inside Sukabumi Regency, West Java. It has 68,306 population with 18,395 families and a population density of 4.3 persons/ha. The main income for the people in Cisolok is farming, with paddy as a main commodity. Peoples education background in Cisolok consist of Elementary (9,056), Middle School (3,812), High School (770) and Diploma to Doctoral (552). There is no large and medium industry, only 21 small industries and 371 home industries existing in Cisolok. One local union exists around the district. State Electricity Company (PLN) electricity is used by 17,461 families, 920 families consume electricity from non-PLN sources and 14 families are still off grid. All the data is taken from BPS, 2016.

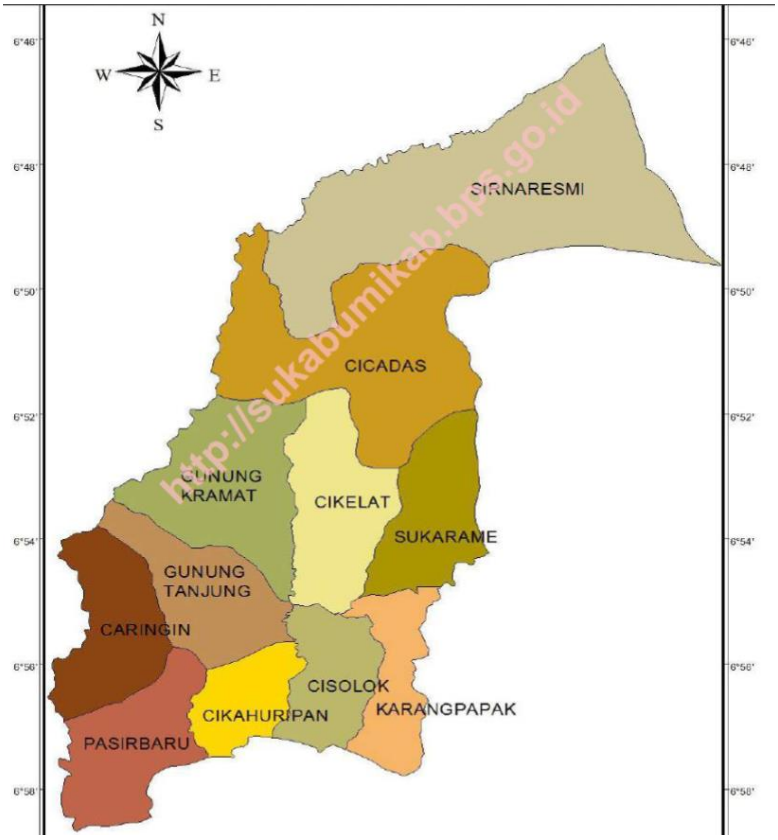


Figure 6 Village distribution in Cisolok District (BPS, 2016)

2.4 PROJECT STAGES

There are several steps to develop small scale geothermal projects. Prior to the implementation of the prospective resources, the project can be initially started by a pre-feasibility study. The pre-feasibility study is followed up by a feasibility study which has more detailed technical, financial and social aspects. This document plays an important role as it has the capability to check if the project is bankable. In the feasibility study, it is concluded whether or not it is feasible to proceed with the project. Feasible projects can be continued with a business case to obtain market assessment, financial model, stakeholder and investor approach and permit application. An optional stage for innovative projects is a building a pilot plant. In case of a pilot project, next steps should consist of engineering design, construction prototype, and initial testing. After finishing the construction and testing of the pilot plant, the project continues with the implementation stage which covers detailed engineering design, mutual agreement between shareholders, procurement, construction, and commissioning.

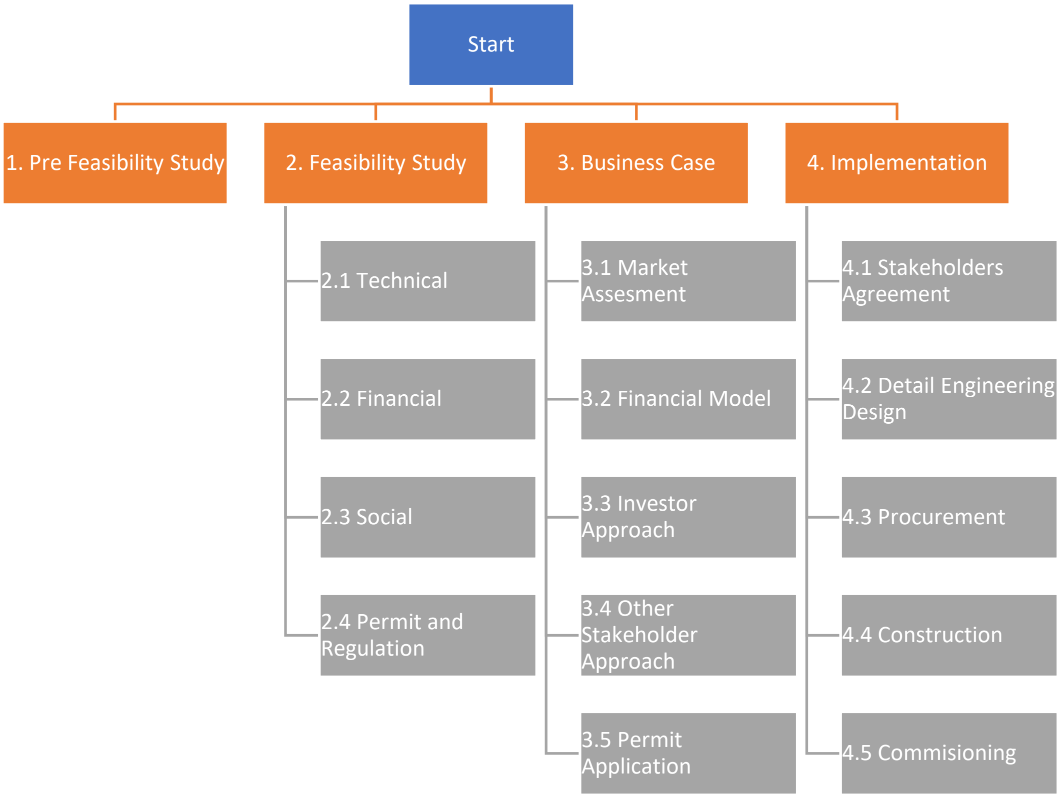


Figure 7 Project stages

2.4.1 Time Schedule

The estimated time schedule of small scale geothermal project is shown below. For the project development, at least 6 (six) years are needed from the start to end of the operation stage. These 6 (six) years are divided into several project stages as mentioned in the previous section.

Table 10 Estimated Time Schedule (1)

NO	Year	1												2												3											
	Stages Month	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
1	Start	🟧																																			
2	Permit and Lisence for Exploration and Exploitation	🟧	🟧	🟧	🟧	🟧	🟧																														
3	Pre-Feasibility Study							🟧	🟧	🟧	🟧																										
4	Exploration											🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧																	
5	Feasibility Study																				🟧	🟧	🟧	🟧	🟧	🟧											
6	Technical Assessment																				▨	▨	▨														
7	Financial Assessment																					▨	▨	▨													
8	Social Assessment																						▨	▨	▨	▨											
9	Permit and Regulation Assessment																							▨	▨	▨											
10	Business Case																										🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧
11	Market Assessment																										▨										
12	Financial Modelling																										▨	▨	▨	▨	▨	▨					
13	Stakeholder Approach																														▨	▨	▨	▨	▨	▨	
14	Permit Application																																▨	▨	▨	▨	▨
15	Implementation																																				
16	Stakeholder Agreement																																				
17	DED																																				
18	Procurement																																				
19	Construction																																				
20	Commissioning																																				
21	Project Development End, Project Operation Start																																				

Table 11 Estimated Time Schedule (2)

NO	Year	4												5												6											
	Stages / Month	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
1	Start																																				
2	Permit and Lisence for Exploration and Exploitation																																				
3	Pre-Feasibility Study																																				
4	Exploration																																				
5	Feasibility Study																																				
6	Technical Assessment																																				
7	Financial Assessment																																				
8	Social Assessment																																				
9	Permit and Regulation Assessment																																				
10	Business Case	🟧																																			
11	Market Assessment																																				
12	Financial Modelling																																				
13	Stakeholder Approach																																				
14	Permit Application	▨																																			
15	Implementation		🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
16	Stakeholder Agreement		▨																																		
17	DED		▨	▨	▨	▨	▨	▨	▨	▨																											
18	Procurement									▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																
19	Construction																▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
20	Commissioning																																				▨
21	Project Development End, Project Operation Start																																				▨

2.5 RISK MANAGEMENT

All projects will be exposed to several risks, consisting of technical and non-technical risks which could be further divided into resource, financial, market and demand, operation, regulation, and environment risk. Overall, risk management consists of risk identification, risk analyses and risk mitigation. Risk identification is a systematic process to identifying, classifying and determining the effect of a risk on the sustainability of a project. The output of risk identification is the list of risks, causes, and effects on the subsequent process. At this stage, the activity undertaken is to analyze previously identified risks.

Below is the matrix of risk analysis and mitigation.

Table 12 Risk identification and mitigation plan

No	Risk Identification	Mitigation Plan
1	Overestimate resource	Exploration or further resources estimation need to be implemented
2	Chemistry of geothermal fluids may be corrosive, high scaling index or high CO_2	Survey for geochemistry and preparation of the proposed binary facilities for example using stainless steel for corrosive fluids
3	Oversizing the power plant capacity	Advance exploration for resources or add other resources
4	Safety issues for secondary fluids	Design the plant to fulfill relevant fire safety and explosion standards in relation to the selected secondary fluid. Develop and implement safety management plan for the operation and maintenance of the plant. Access to the plant should be restricted.
5	Transmission grid issues	Binary power plants are best suited as base load plants connected to a large grid but can also be operated for a small grid in combination with a diesel power plant. Binary power plants are not feasible as the only plant connected to a small grid.
6	Selling tariff vs instability in government and economy	Changes in government and economic development may cause the selling tariff is not proper with financial model. Renegotiation and contract revision may be considered.

No	Risk Identification	Mitigation Plan
7	Unskilled operators and workers that operate and maintain the power plant	Appropriate training for operators and workers. The equipment manufacturers usually provide training and operation assistance for the equipment they supply. Build the Standard Operation Procedure (SOP) to assist operator determine the proper decision to operate or maintain the plant.
8	Regulation about utilization of manifestation is not available	Discuss with related stakeholders.
9	Social resistance due to lack of information about geothermal small scale	Socialization and education to people that may affect the development of small scale power plant.
10	Delay in project implementation	Planning, executing and monitoring in every stage of development by skilled project manager.

2.6 ORGANIZATIONAL CHART

In this section, related stakeholders are mapped, which consist of a small scale developer, local government, geothermal field developer and public and academic institutions. Each stakeholder has some roles in the project to achieve mutual goals. Win-win solutions in every phase of the development stage should be considered and achieved. The small scale developer is assisted by the other related stakeholders, as can be seen in the following picture. Good contribution from each stakeholder could make the project successful.

Figure 8 Related Stakeholder

In small scale development, several stakeholders can contribute as shown in Figure 8. There are four main contributors for small scale development, which are local government, public, academic institution, and the geothermal field developer. All of them has specific contribution to the developer. Local government can give advice regarding the location regulation and become controller of the project conformity. Public should able to give input on local people behavior and should act as a mediator towards any issues related geothermal. The academic institution needs to give support on technological aspect and create the right solution to specific geothermal area in situ. Geothermal field developer should, with the agreement of the small scale developer, emphasize good collaboration to make the project successful.

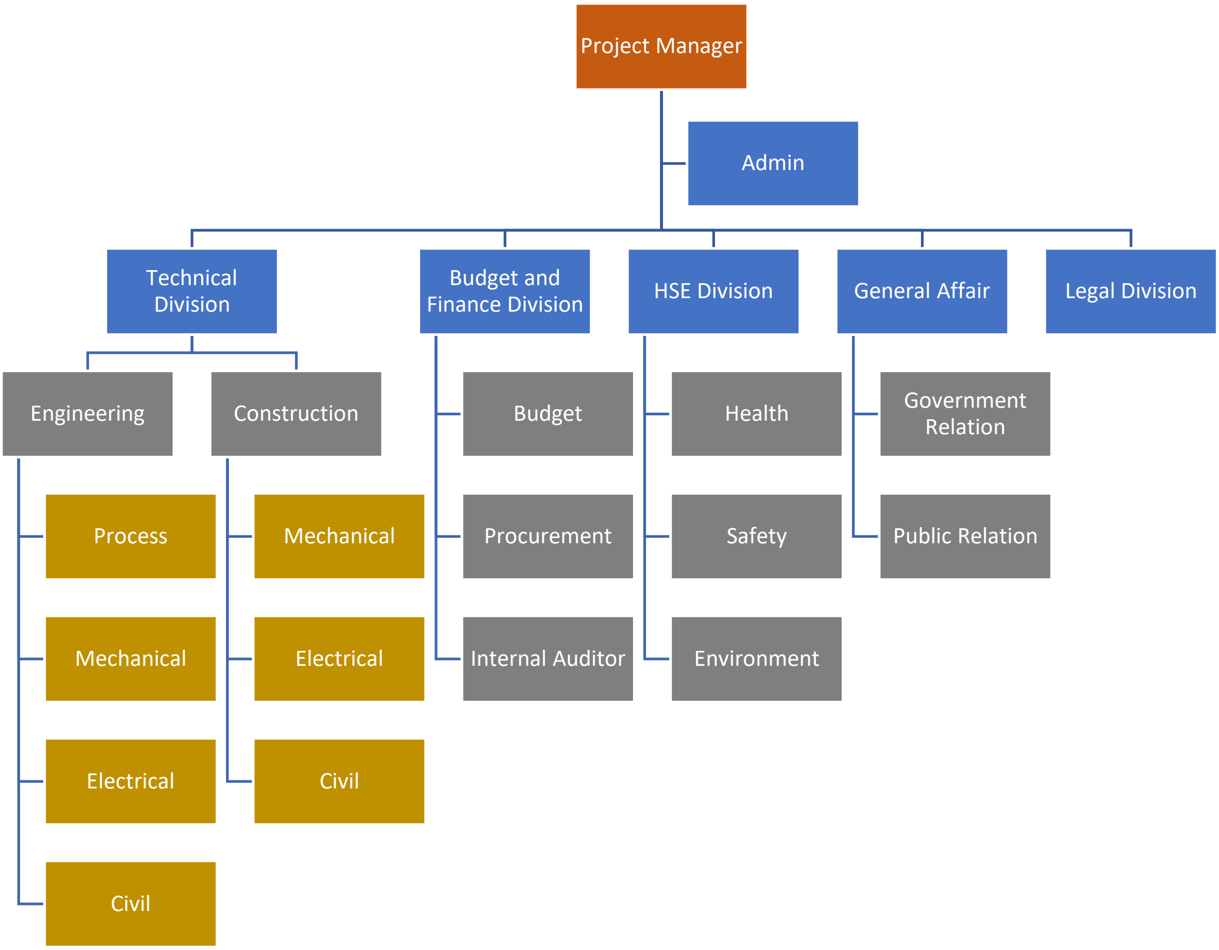


Figure 9 Proposed Organizational Chart

Figure 9 shows the basic diagram on project development needed to develop a small scale power plant. It is based on usual geothermal development at the moment and it is recommended to be applied on small scale as well. The Project Manager can be a geothermal expert and/or may come from project owners. The Admin will assist the Project Manager to arrange business needs. The Project Manager has a responsibility to ensure the project goes according to the plan and is supported by Technical Division and Non-Technical Division, such as Budget and Finance Division, HSE Division, General Affair, and Legal Division. Every division has their functional sub division to segregate specific roles. Specific roles are assigned to make operation processing more effective and efficient.

3 CONCLUSION

The plan of approach for the development of a small scale power plant project using low-medium enthalpy geothermal resources has been successfully studied and an assessment has been conducted. A comprehensive approach from identifying potential resources to develop the resources has been done. Analysis has been made and it is concluded that geothermal manifestations can be used as a source for binary cycles. At Cisolok, hot spring are available with a temperature of 95 ^{o}C and an adequate mass flow rate of 5 kg/s. Technical aspects shown that using Pentane is preferable for small scale power plant and will result in 24 kW of continuous electricity production. Alternative, working fluid R245fa could be used, because it also gives good performance, resulting in 26 kW of continuous electricity production. . Required investment for small scale geothermal power plant is estimated at 31,840 USD. An electricity price of 9 USD cent/kWh will yield an IRR of 9%.

Market and social aspects could support technical analysis to assess the feasibility of a project. Although power generation is limited, a small scale geothermal power plant at Cisolok will replace fossil energy for the Jawa-Bali Interconnection. Fuel demand and greenhouse effects could also decrease from energy diversification. Social mapping and social engineering programmes should be applied on Cisolok (in-situ) conditions to minimize potential social barriers in a small scale geothermal development and find effective solutions to mutual benefit, enabling successful small scale geothermal development.

The estimated time to implement small a scale power plant is 6 years, which consist of pre-feasibility study, feasibility study, business case, development stage, and commissioning. A project organizational chart has been defined. Those are the tools to eliminate barriers and implement effective management in the project development process.