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Searching for an Opportunity in the Development of Direct Use Geothermal Resources; A Case Study in West Java Province - Indonesia

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ABSTRACT

Collaborative research between local government and Institute Technology of Bandung had been undertaken in two years to delineate the prospective areas for Geothermal District where direct use geothermal resource is applicable. The final aim of this project is to optimize the geothermal potential both indirectly and directly in West Java Province – Indonesia.

In the first year, data inventory to identify geothermal potential were conducted. The information comprises of geosciences data (geological, geochemistry and geophysical data, developed and undeveloped geothermal prospects, and existing geothermal power plants) and non-geosciences data (spatial use and government regulation). The results show that the Province has a total potential Geothermal Energy about 5311 MWe. From this number, 705 MWe is generated by four geothermal power plants (Kamojang-140 MW, Gunung Salak-330 MW, Darajat 125 MW and Wayang Windu-110 MW), 185 MW are proven reserve from three prospects that are waiting to be developed up to the year 2008.

In the second year, works were focused on the delineation of geothermal district and economic valuation of direct use geothermal project in this district. The data from first year works are then use to delineate Geothermal District, that consist of (1) Conservation (2) Cultivation and (3) Production area. Four geothermal power plants above were selected and furthermore ranked based on (1) existing industry as market, (2) type of reservoir that produce water for direct geothermal use and (3) preserve forest that limits the district development. This assessment results Wayang Windu as the most prospective area for Geothermal District Pilot Project. In agreement with government business investment strategy, which stated that agribusiness is one of core business in this district, Malabar tea factory (MTF), near by Wayang Windu, is evaluated for application of direct use to replace Industrial Diesel Oil (IDO) used for tea leaves withering and drying.

Economic evaluations are conducted using Net Present Value (NPV) cash flow to compare energy usage between geothermal energy and IDO. Three scenarios are modeled, and the NPV for every scenario has been proved to reduce the cost as follow (1) Scenario if all the capital cost paid by the MTF can reduce up to US$ 409,448, (2) Scenario if Pipelines Investment Paid by Energy Seller, can reduce the cost up to US$ 513,131 and (3) Scenario if Geothermal Fluid Considered as Waste can reduce up to US$ 1,622,862 for 20 years project life.

In summary, this paper describes the preparedness of local government in implementing the direct use geothermal energy and the expectation of contribution from foreign and domestic investor to develop a sustainable energy industry in one solid geothermal conservation area. Finally, one of the above scenarios could be realized with reasonable agreement between the investor, local government, National Electricity Company (PLN) and geothermal company operator.

1. INTRODUCTION

In the year 2002-2003, The Local Government of West Java Province with the assistance of Institute Technology of Bandung conducted a research for valuating the potential resource and reserve of geothermal in this province. The study area is shown in figure 1. The purposes of the study are to optimize the potential use of this energy and to delineate the prospective areas for geothermal development in an integrated geothermal district framework. The results of this study not only summarize the potential geothermal resource in this province but also describe how the geothermal district might be realized as an effort to improve geothermal energy development. The results will be used by local government in constituting regulations for the development of this resource.

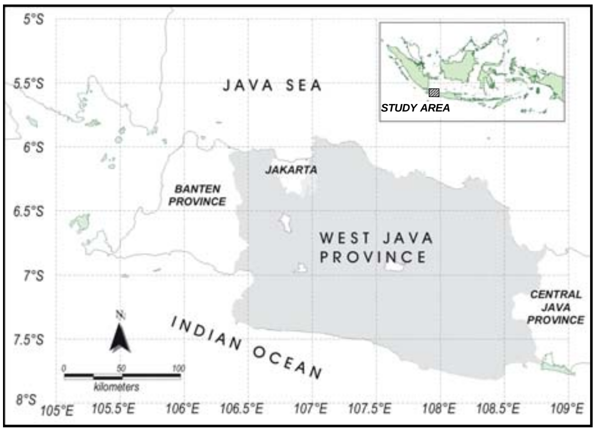

Figure 1: Location of Study area

This paper focuses on the formation of geothermal district where direct use geothermal energy is one of the main support of this district. It is also our intention to promote this sector as the potential investment for domestic and foreign investors. The paper describe the preparedness of West Java Government to welcome the private sector in building their own business related geothermal energy by selecting their own prospective area based on geosciences data or by choosing one of the direct use scenarios available in this paper.

Starting with introduction to the concept of geothermal district, the paper continues with methodology of the research at section three. The geosciences data inventory and their assessment and study of other supporting data such as spatial use data that carried out to delineate prospective area for geothermal district in which direct utilization of geothermal energy as the energy source is described in fourth section. In section five the paper discusses the economic evaluation and the scenarios constructed for direct use. The paper is ended with discussion and conclusions.

2. GEOTHERMAL DISTRICT

By definition, the district means the area chosen for economic activities where geothermal is used as the energy resource both for indirect or direct use. Nevertheless in the further development, economic activities undertaken in this area have to be in agreement with natural resources potential, human resources and man made resources. This distric is proposed as the implementation of Indonesian Act No. 24, 1992 about Spatial Use, that mention 'district' as an area with primary function as conservation or cultivation area. Within this framework, the conservation and cultivation area is applied for geothermal resource area.

Within Geothermal District, there are three main areas with its specific functions namely (1) Conservation Area (2) Cultivation Area, and (3) Production Area (Figure 2). The first, principaly is forestry area where meteoric water is expected to infiltrate and recharge the reservoir water during geothermal production. This area is important because most of geothermal system in West Java is hydrothermal system where fluid especially water is crucial to produce steam. The area is subjected to protect and maintain sustainable geothermal area. The second area acts as consumen (or market) of geothermal energy and where the economic activities take place such as plantation, farming and other industies. The third is the area where geothermal resource is being exploited to generate electricity and is distributed to market or to be used directly.

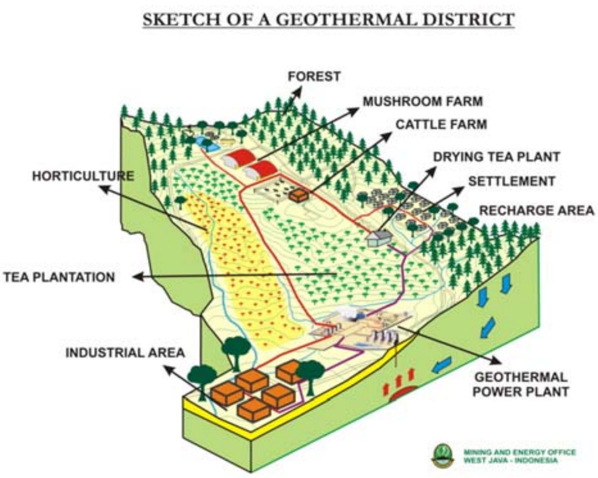

Figure 2: Geothermal District

The geothermal district is expected to be able to give insurance for the investors to run their bussiness especially for direct use geothermal project. It is also to attract the private investor based on the assurance of existing regulations, infrastructure, effortless environmental impact assessment, and optimizing socio-economic development at the surrounding area. Apart from that the development of the system will help in realising the effort to reduce the usage of fossil fuel by optimizing geothermal energy with cascade use.

3. METHODOLOGY

Summary of methodology of the research is shown in flow chart in figure 3 below.

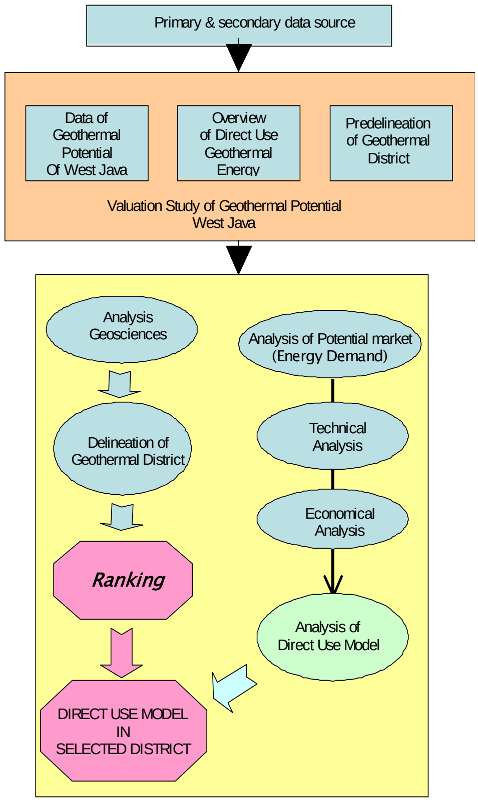

Figure 3: Flow Chart Methodology

Firstly, the literatur study was conducted and all geoscience data were collected as secondary data. Secondly, the field observation is undertaken to collect prymary data which are comprised of geoscience and non geoscience data. The geoscience data includes geological observation, rechecking and inventory of springs and other surface manifestation mentioned in the previous literatures. Whereas non geoscience data compiled during field observation consist of inventarisation of existing land use, agribussiness and tourism area, and forest and recharge conservation around the predeveloping geothermal district

The secondary data for literature study were also acquired from the institutions related with spatial planing of Geothermal District such as PTP Nusantara VIII (Tea Plantation), Cultivation and Plantation Office, Forestry Office, BAPEDA (Office of District Planning and Development), Tourism Office, Low Level Local governmment(Lurah and Camat). During this stage, we also study various potential direct use that maybe applicable to the selected area and the data were also collected as secondary data.

The data were collected and stored as digital and hard copy and can be obtain from Mining and Energy Office of West Java. More Geoscience data can also be acquired from Directorat of Mineral Inventory who also supplied some data for this research.

Data were used to predelineate potential area for geothermal district. Furthermore geoscience assessment conducted to review and delineate the district again and to rank the most prospective area to be selected as pilot project for geothermal district, where direct use geothermal energy will be appllied. After the district was chosen, the economic evaluation was undertaken by constructing scenarios that could be applied to realize the direct use project. The scenarios were constructed based on the technical and economical aspects. The most attractive scenario can be choosen and implemented to direct use project in selected geothermal district. The similar process can be adopted by investor interested in farm in this project.

4. GEOSCIENCE DATA, ASSESSMENT AND RESULTS

In the first year (2002) geothermal prospects inventory was carried out. Geothermal prospects include Production geothermal plants, Geothermal fields which is in feasibility study (have been drilled and awaiting for production), in advance exploration study (exploration drilling have been conducted or geophysical survey have been applied) and in preliminary study (geology mapping and geochemical sampling and assessment). The information about stage of the study above implies the level of confidence during the resource and reserve evaluation as it is shown in Table 1.

Table 1 : Classification of Geothermal Resource (modified from Dwipa, 2004)

	Energy Potential Status	Required Condition	Formula for Energy Potential Calculation	
RESOURCES (Unidentified resources)	Speculative Resource	• Presence of surface thermal features • Associated with volcanic activity	Assumed that each resource is considered to have an extent of 20 km^2 and the recoverable resource has a power density at 12.5 MWe per km^2	Increasing degree of confidence ↓
	Hypothetical Resource	• Regional studies has been established and used to determine resource size • Fluid geochemistry (geothermometry) anomaly	Heat Stored Calculation (the parameters for energy potential calculation are mostly using geological thinking)	
RESERVES (Identified resources)	Possible Reserve	• Geological and geophysical data indicated the presence of a hydrothermal systems This includes remote sensing, surface sampling and shallow temperature gradient • A surface manifestation (hot spring, steaming ground, etc.) or commercial production must be located within a reasonable distance	Heat Stored Calculation (the parameters for energy potential calculation are based on scientific model estimated from integrated	
	Probable Reserve	• Deep drilling has established producible fluids • Market conditions forecast atypical power plant that is likely to be needed • Current economics do not justify capital investment at present	Heat Stored Calculation (the data for calculation are taken from integrated scientific survey works and boreholes)	
	Proven Reserve	• Engineering and scientific evaluation has confirmed a resource • Commercial wells have been developed • A reservoir model has been developed	• Gomma Formula • Lump parameters	
TOTAL ENERGY POTENTIAL				

The result shows that most of geothermal prospects are located within the quarternary-recent volcanic complex. This is coincident with the tectonic setting of Java Island where at the subduction of India-Australian plate occurs at the south of this island resulting in the formation of volcanic mountain range at the southern part of Java Island. Map showing distribution of geothermal prospect, tectonic setting and vulcanism is shown in figure.4.

Total of 43 prospects were identified, which are distributed in 11 regency. Most of the geothermal system occur in this province are hydrothermal system, indicated by hotsprings as surface manifestation that occur intensively, nevertheless two production field (Kamojang and Darajat) are vapour dominated. Water dominated system is suitable for direct use geothermal, consequently most geothermal area or prospect is potential for direct use. Ten prospects are potentially able to be developed as high entalphy or high temperature geothermal energy. Summary of geoscience data is shown in Enclosure 1.

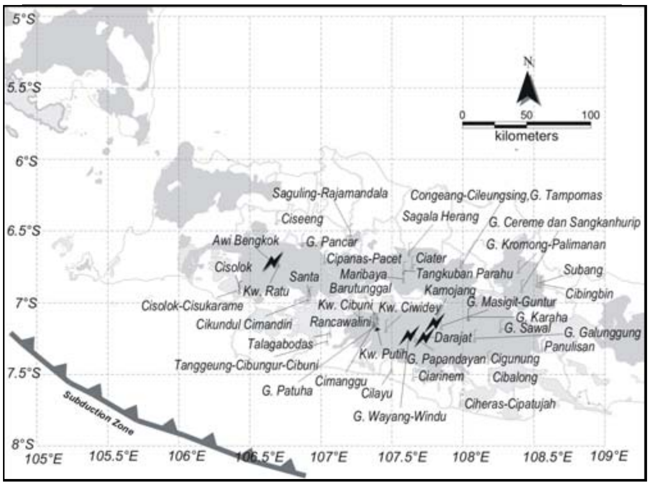

Figure 4: Distribution of Geothermal Prospect in relation with subduction zone, tertiary vulcanism (light grey), quarternary vulcanism (dark grey), and slash symbol is geothermal power plants

The total potential is 5311 MWe. In contrast only 705 MWe is being used as electricity generating energy and more than 1000 MWe will be developed to generate electricity, whereas the other is remain unexplored or is being used for direct use, that is tourism and bathing. Enclosure 2 shows total geothermal potential in West Java. Table 2 shows geothermal power plant being operated and will be developed.

Table 2. Geothermal Power Plants and Development Planning West Java Province (Modify from Dwipa, 2004)

No.	Geothermal Field	Developer	Production (2004)	Development Planning Up to 2008	Development Planning Up to 2012
1	GUNUNG SALAK Cibeureum-Parabakti	Unocal	330	0	110
2	PATUHA COMPLEX Pangalengan				
	- Kawah Cibuni	Yala Teknosa		10	0
	- Gunung Patuha	Geodipa	110	120	60
	- Wayang Windu	MNL		110	110
3	Kamojang-Darajat				
	- Kamojang	Pertamina	140	60	60
	- Darajat	Amoseas	125	190	110
4	Karaha-Talaga Bodas, Cakrabuana	KBC		55	55
	TOTAL (Mwe)		**705**	**545**	**505**

Delineation and Rank of Geothermal District Pilot Project

A Geothermal District consists of (1) Conservation area, (2) Cultivation Area, and (3) Production area. Based on this criteria, a Geothermal District must have a production area, therefore from 43 geothermal prospects idententified, only four prospects which already generate electricity are chosen to be delineated further for geothermal district. They are

1. Kamojang Geothermal Field
2. Kawah Darajat Geohtermal field
3. Awibengkok Gunung Salak Geothermal field
4. Wayang Windu Geothermal field

The four areas are then evaluated and ranked based on the (1) presence of existing industry, (2) type of reservoir and (3) the presence of preserved forest. In more detailed evaluation, we also consider the spatial use plan and goverment regulation of the district and the width of recharge area.

The first criteria act as consumer of geothermal energy both indirectly and directly. The area is usually Cultivation Area. Based on our observation, only Wayang Windu is located near by cultivation area, that is Malabar tea factory.

The direct use geothermal energy within a Geothermal District is planned to use hot residual fluid as energy resource, before it is injected back to the ground. Based on this criteria, water dominated or two-phase geothermal reservoir is preferably selected because it can produce sufficient hot residual water for direct use than vapour dominated. From the four selected field above, only Awibengkok Gunung Salak and Wayang Windu Geothermal field are suitable for this purpose. The other two are eliminated.

The existence of preserve forest will constrain the development of geothermal district. Based on the Law no 41, 1999, once the area is stated as preserve forest, no other construction activity can be conducted in this area. Therefore it will be difficult to develop direct use project because all building, piping construction, etc is forbiden. Consequently the geothermal field where have no preserved forest is the most preferred, hence Wayang Windu and G. Salak

The recharge area acts as conservation area and preferably is the large area. The land use and the spatial use plan and regulation must support the development of geothermal district both in exploitation of the resource and in conserving the area.

Table 4 summaries the result of evaluation and rank of four Geothermal Field based on the criteria discussed above. It shows that Wayang Windu is the most favourable area for geothermal district pilot project where direct use geothermal energy will be developed.

Table 4.a. Condition of Geothermal District

Number	Criterion	Geothermal District			
		Darajat	Kamojang	Wayang Windu	Awibengkok G. Salak
1	Existing industry	None	None	Present	None
2	Reservoir type	Steam	Steam	2 phase	Water
3	Preserved forest	0.92 km2	8.49 km2	None	None

Table 4.b. Evaluation of Geothermal District

Number	Criterion	Geothermal District			
		Darajat	Kamojang	Wayang Windu	Awibengkok G. Salak
1	Existing industry	N	N	Y	N
2	Reservoir type	N	N	Y	Y
3	Preserved forest	N	N	Y	Y

N = No Y = Yes

The result of predelineation geothermal district also shows that Patuha prospect is one of a good opportunities to be developed because the area is coincident with the location of primary agrobusiness district chosen by government,that is CIPAMATUH (Cikuray, Papandayan, Malabar and Patuha). Unfortunately the geothermal power plant has not been produced yet because of the uncertainty in regulation. Based on Table 3.b, Patuha Geothermal Power Plant will generate electricity in 2008. By this year this area may become another good option to be developed as geothermal district where geothermal direct use can be applied for energy source in tea factory.

5. ASSESSMENT OF DIRECT USE GEOTHERMAL AT MALABAR TEA FACTORY

Previous assessment involving geoscience study and spatial land planning identified Wayang Windu as the most prospective area for geothermal district pilot project. Further work carried out is assesment regarding the cultivation district to be developed with support of geothermal energy. We propose to utilize direct use geothermal energy within this District that is to use hot residual fluid, as energy resource, before it is injected back to the ground. This hot water is planned to be use as heat source for whithering and drying tea leafs in Malabar tea plantation. Currently this factory use Industrial Diesel Oil (IDO) for this process. We offer an alternative to change IDO with geothermal direct use. It is the objective of this economic assessment to evaluate whether the use of geothermal energy is more advantageous compared to the existing system now, that is using IDO.

For this assessment, firstly we studied the amount of energy consumed by this factory. There are six processes performed after fresh tea leaves picked from the plantation and before keeping them in storage or distributing them. The processes are withering, grinding, oxidizing, drying, sorting and packing. From these processes, withering and drying consume high energy, hence IDO. The withering process is done by allowing the fresh air from surrounding to pass through the stacks of leaves to eliminate water content until about 50%. While the drying process is meant to remove water content of tea powder until less then 2% by weight. During the dry season, the withering process needs lower additional energy from IDO compared to rainy season because the dryness of tea leaves is low and the surrounding temperature is quite hot and sufficient for withering process. The average dry tea production is about 3,300 metric tons per year while the average IDO consumption for withering and drying process is 0.38 liter per kilo gram dry tea which is equal to 1.25 millions liter per year. This amount of IDO is equivalent to 0.609 MW.

The component of energy expense to the tea price is very significant. If the price of IDO per liter is Rp. 1650,- (this assumption will not be valid in the near future as the government will gradually reduce and finally wipe out IDO subsidy), the IDO expense will become Rp. 2.069 billions (≈ US$ 230,000,- if US$ 1 is equal to Rp. 9000,-). If the price of tea is US$ 1 per kg, total earning from tea product is US$ 3300,- It is clearly seen that the component of IDO expense is about 7% from tea selling price. When government takes out subsidy for IDO, the IDO price will float to the international crude oil price. At this stage, the price of IDO most likely will reach above Rp. 2500,- (≈ 28 US cents). The ratio of IDO expense to tea selling price will become 10.5%.

Referring to previous study on application of geothermal direct use for tea drying plant in Malabar (Soelaiman et al, 2004) the energy consumption for tea factory is a tenth of available energy from re-injected hot fluid from the existing Wayang Windu geothermal project. To switch the use of IDO to the geothermal heat for withering and drying processes in Malabar tea factory, new investment is needed. Total investment for pipelines, heat exchangers, fans/blowers and pumps is about US$ 75,555,-.

Economic Analysis

Based on available energy point of view, the utilization of geothermal energy for tea withering and drying processes is possible to be developed but economic analysis should be conducted to determine whether the development is feasible and profitable. The very first case which should be analyzed is the NPV (Net Present Value) of existing condition that is withering and drying processes using IDO as energy supply. The case will be compared to 3 scenarios if geothermal heat is used to replace IDO. Those are:

Scenario 1 Base Case

Basically, the steam is paid after becoming electricity. For this case, some geothermal projects in Indonesia sell their steam to PLN (State Electricity Company) at price of about US$ 30 per MWh . If Malabar tea factory requires 0.609 MW, energy cost each year which has to be paid is US$ 160,045,- .

Scenario 2 Pipelines Investment Paid by Energy Seller

If the piping cost would be paid by the energy seller (in this case Wayang Windu) as in the cases where a geothermal field is selling steam to the PLN and PLN accepts steam in power plant (steam header), the expense of pipe is taken care by the company operating the geothermal field. The amount of pipelines investment is US$ 75,556,-.

Scenario 3 Geothermal Fluid Considered as Waste

If geothermal fluid is assumed as waste and does not have selling value for Wayang Windu. The logical impact of this assumption is the total investment including pipelines should be paid by Malabar tea factory.

Other economic parameters which are needed to accomplish for economic analysis are operating and maintenance cost (O&M Cost), discount rate and life time of project. Operation and Maintenance (O&M) cost if geothermal heat is used is estimated to be 5% of total investment per year which will increase 3% gradually every year. Discount rate of 10% is applied for this analysis. Life time of project is assumed to be 20 years.

The result of economic calculation for all scenarios for 20 years are presented in the Figure 5, 6, 7 and 8. The NPV for existing condition (using IDO) is US$ -2,048,861,-. The NPV for Scenario 1, 2 and 3 are US$-1,639,412, -1,535,730 and -425,999 respectively. Running scenario 1, 2 and 3 will reduce the energy cost by US$ 409,448, 513,131 and 1,622,862 respectively. Based on this economic analysis, it’s clearly seen that replacing IDO with geothermal heat is attractive for all scenarios even if all investment costs such as in Base Case is charged by Malabar tea factory.

In summary the economic analysis above suggest that:

(1) The energy supply at Wayang Windu geothermal area that can be used directly is estimated as 6.23 MW, or more than 10 times the energy demand of the tea plant, which is 0.61 MW.

(2) Replacing IDO with geothermal heat is attractive for all scenarios although all the investment costs must be paid by Malabar tea factory

(3) The most attractive scenario is when the geothermal fluid is considered as waste.

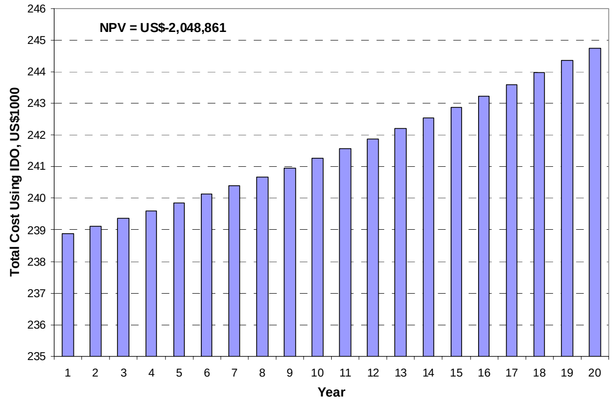

Figure 5. NPV of Existing Condition (Using IDO)

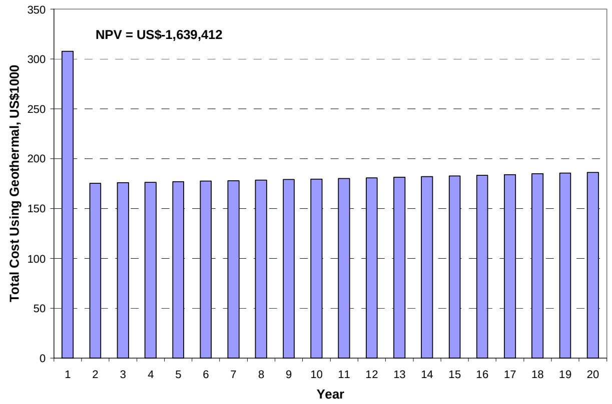

Figure 6. NPV of Base Case

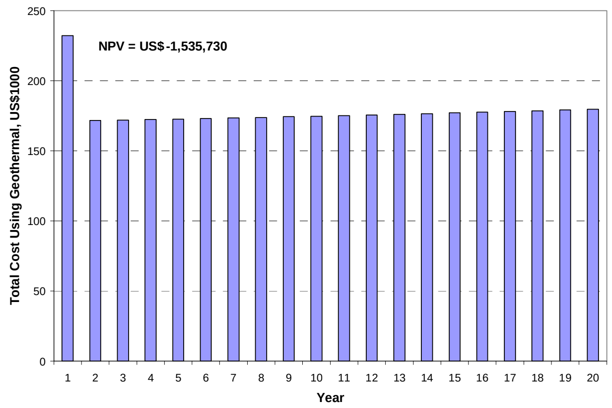

Figure 7. NPV if Pipelines Investment Paid by Energy Seller

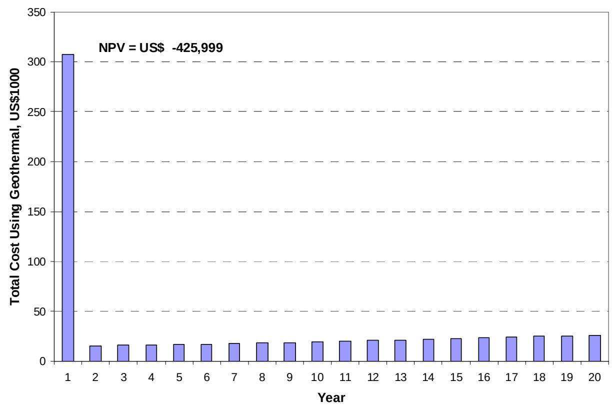

Figure 8. NPV if Geothermal Fluid Considered as Waste

6. DISCUSSION AND CONCLUSIONS

The Government of West Java Province has conducted an intensive study to develop geothermal energy both for direct and indirect use. Considering the direct use geothermal energy, the assessment has come to the economic evaluation for the investment in this sector. Four scenarios in using direct use geothermal energy for tea drying and withering has been offered. However, in order to implement successfully one of the scenario above or other business related geothermal energy, Local Government (Kabupaten and Province) and Office of Mining and Energy needs to collaborate with Geothermal Operator Company, National Electricity Company (PLN), the industry, the owner of plantation, Office of Forestry and the community. They need to create a strategic alliance in optimizing the geothermal energy in the district.

The government of West Java needs also to build up the regulation and laws of geothermal utilization that can give assurance to the investor and facilitate all the parties who have interest in this sector. Such as in the case of study above, Law No. 24, 1992 about Spatial Use and the regulation to advance agrobusiness in geothermal district (CIPAMATUH area), can be use to support development of geothermal resource. The result of this study is used by the Government of West Java Province in issuing regulations on geothermal energy in this province.

There are several conclusion can be drawn from this study:

1. West Java Province has geothermal potential 5311 Mwe, where only 705 Mwe is used to generate electricity.
2. The utilization of geothermal energy in this province is still limited both indirectly (as in the point 1 above) and directly (where only use for tourism and bathing)
3. To optimize geothermal energy is possible by applying a concept of geothermal district that consist of Conservation district, Cultivation district and Production district.
4. Based on the criteria of existing industry, type of reservoir and preserve forest, Wayang Windu Geothermal field has been selected as geothermal district pilot project.
5. Economic and technical analysis of using geothermal direct use to change IDO (industrial diesel oil) in the cultivation area of Wayang Windu Geothermal District (that is Malabar tea factory) shows that using energy from geothermal direct use is more advantageous than using IDO.
6. Three scenarios to develop direct use geothermal project at Malabar tea plantation has been offered to give overall impression to government, investors and other parties who have interest in geothermal district in developing this project.
7. In general this study shows the seriousness and the preparedness of West Java Government to optimize geothermal potential in this province
8. It is expected that through this study, investment opportunities in geothermal energy sector especially in direct use will increase in the near future, due to lower investment than in indirect use.

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ENCLOSURE 1. Summary of Geoscience Data

REGENCY/ KABUPATEN	GEOTHERMAL PROSPECT	SURFACE MANIFESTATION	GEOLOGY	STRUCTURE	GEOTHER-MOMETER
BANDUNG	TANGKUBAN PARAHU	volc.crater, solfatara, hot springs, steaming ground, rock alteration, mud pools, active silica sinter	Stratovolcanic Andesitic in Quarter, collaps become caldera as center for recent volcanisme	Caldera (recent crater) Quarter vulcnism occur within grabben complex Plio-pleist but still active now) bounded by Tembakan fault in the N and Lembang fault at the S croosed by NE-SW younger fault.	200 C
	MARIBAYA	Hot springs	Outflow of G.Tangkuban Parahu	Lembang Fault,	120 C
	PATUHA	Volcanic crater, hot springs, fumarol, solfatara,cool mudpool, surface alteration, silica sinter	Tertier volcanic rock related to Patuha volcano activities overlies by quarter vulcanic rock from the same vulcanism.	Stratovolcanic complex. Regional structure is NE and NW	>240C (up to 270 C)
	CIMANGGU	Outflow Patuha to the West, Sulfur, iron oxide and travertine at Cimanggu springs.	Similar to Patuha	Stratovolcanic complex. Regional structure is NE and NW	
	RANCAWALINI	Outflow Patuha to the NW. Ebullian Hotsprings (CO2) with sulfur deposit, iron oxide and carbonate sinter	Related to vulcanism of Patuha	Stratovolcanic complex. Regional structure is NE and NW	
	BARUTUNGGUL	NE of Patuha, Hotsprings with iron oxide and travertine	Related to vulcanism of Patuha	Stratovolcanic complex. Regional structure is NE and NW	270 C
	KAWAH PUTIH	SE of Patuha, acid warm springs, mudpools, solfatara, steaming ground	Related to vulcanism of Patuha	Stratovolcanic complex. Regional structure is NE and NW	
	CIBUNI CRATER	steaming ground, fumarols solfatar, mud pools and hot springs, extensive surface alteration rock. Predicted as upflow differ from Patuha system.	Related to Patuha vulcanism	NE-SW trending normal fault Cibuni controlled the crater and W-E faults.	240 C
	CIWIDEY	interpreted as up flow, fumarols, solfatara, mud pools and hot springs, surface alterationn rock	Related to old Patuha vulcanism. Andesitic lava flow and lava dome overlies tertiary vulcanic rock.	Two NW-SE trending normal fault forming grabben in this system.	240 C
	SAGULING RAJAMANDALA	Hot springs	Thermal manifestation occur within the calcareous sedimentary rock of Rajamandala Fm. The stratigraphy consist of Sedimentary Rock of Citarum and Rajamandala Fm.	Fracture dominantly tending W-E and NE-SW, thrust flt trending W-E, strike slip fault trending N-S.	120-135 C
	WAYANG WINDU	Two volcanic craters (Wayang and Windu craters), hot and nearly boiling springs, steaming ground, fosil hydrothermal system (Burung Crater) with sulfur deposit, silika sinter, surface alteration, fumarols, solfataras and geyser.	Located within old vulkanic complex known as Pangalengan High, stratigraphycally Wayang-Windu is vulcanic cone occupied by volcanic rocks of quarter age.	NW-SE, N-S and NE-SW lineament from aerial photo and landslide	250-270 C
	KAMOJANG	Hot springs, fumarol, mudpools, vulcanic crater, surface alteration.	Stratigraphycally the area occupied by younger augite-hyperstene andesite of Gandapura Unit on the west and older pyroxene andesite of Pangkalan unit on the east	Prominent NW-SE and NE-SW lineament.Lokal normal fault trending NW-SE forming grabben and cross cutting by NE-SW faults.	Steam dominated 245 C
BOGOR	CISEENG	Warm springs with travertine deposit, flow rate 2-5 l/sec occur in alluvial unit.	The system probably caused by thermal water pass through fault and occur as warmsprings	strongly controll the system	
	G.PANCAR-SANGGABUANA	Hot springs, weak ebullient, travertine, low sulfur content	The system is located within Bogor Zone anticlinorium. The heat source probably from cooling intrusion of andesite porphyry	N-S trending faults, NNE-SSW fractures.	Mod-high T
	AWIBENGKOK; G.SALAK	Hotsprings,fumarol, solfatara	Located within stratovolcanic complex of andesite-andesitic basaltic vulcanism in Late Pliocene-recent.	NE-SW trending strikeslip fault, NW-SE normal fault. N-S regional stress causing N-S open fracture in the reservoir.	245-325 C
	KAWAH RATU; G.SALAK	Hot springs, fumarol, solfatara mudpools, vulcanic crater, surface alteration.			225-325 C
CIAMIS	PANULISAN	Warm springs with travertin and iron oxide , flow rate 1-2 l/sec, altered ground, fossill of solfatara	Covered by quarter and recent volcanic and alluvial rock respectively.	Normal and strikeslip fault both trending NW-SE	
	G.SAWAL	Altered ground	Dominated by quarter volcanic rock, product of old vulcanism	Normal fault trending W-E, NE-SW and NW-SE	
CIANJUR	TANGGEUNG-CIBUNGUR-CIBUNI	Hotsprings occurred in several places	Intrusion of andesite porphyry is probably the heat source of geothermal system.It intrudes Miocene sedimentary rock of Jampang and Beser Fm	infered normal faults and strike slip faults trending W-E, NE-SW and NW-SE	103-197 C (low temperature)
	CIPANAS-PACET	Hotsprings	Covered by Tertiary sedimentary rock - Cantayan FM overlies by Quarter volcanic rock	infered normal faults and strike slip faults trending W-E, NE-SW and NW-SE	103-197 C (low temperature)
CIREBON	G.KROMONG	Mudpools,hotpools,hotsprings, travertine, silica sinter, altered ground	Sedimentary rock of tertiary age overlies by volcanic rock of quarter ages. Andesite intrusion of quarter age.	Regional structure is fold and fault. Radial normal faults are part of this structure due to the formation of lava dome. Two normal faults trending SSW-NNE and NNW-SSE are not related to radial faults and controlled the occurrence of surface manifestation	interpreted as low enthalpy

ENCLOSURE 1 continued. Summary of Geoscience Data

REGENCY/ KABUPATEN	GEOTHERMAL PROSPECT	SURFACE MANIFESTATION	GEOLOGY	STRUCTURE	GEOTHER-MOMETER
GARUT	TALAGA BODAS	Hotsprings,fumarol, solfatara, sulfur deposit arraound vent, weak ebullient, hydrothermal alteration	Covered by quarter vulcanic rock	NW-SE structures controlling distribution surface manifestations	
	PAPANDAYAN	Volcanic crater, solfatara, hot ground, altered ground, hot springs and mudpools.	Papandayang is recently active volcano.The rock found in this area includes volcanic rock of quarter ages.	Two major strike faults trending NE-SW (Walirang fault and Papandayan Fault paralel to each other) occur in this area. Thedirection coincides with regional trend.	
	CIPANAS-TAROGONG (G.MASIGIT-GUNTUR	Hot springs	Covred by quarter volcanic rock	Normal faults controleed the sysrtem	
	CILAYU	Hotsprings and hydrothermal alteration along fault zone, travertine and iron oxide arround the springs	Diorite-micro diorite intrusion crossing sedimentary rock of Bentang Fm and volcanic rocks.	NE-SW fault controlled the geothermal system and intrusion	168C
	CIARINEM	Hotsprings, hydrothermal alteation,	Miosen sedimentary rock overlain by quarter volcanic rock, and andesite intrusion.	Normal fault trending W-E controlling springs distribution. Strike slip fault trending NNE-SSW and ENE-WSW	Low entalphy 120C
	KAWAH DARAJAT	Volcanic crater, fumarol, hot ground, altered ground, hot springs, boiling pool and mudpools.	Covered by quarter andesitic-basaltic rock.	NE-SW Kendang fault and Gagak fault	245C
KUNINGAN	SUBANG	Hotsprings with sulfur deposits around it.	The area dominated by sedimentary rock of Tertiary age, overlain by quarter volcanic rock product of Ceremai volcano.	Fold with W-E trending axis, Normal fault trending W-E and strikeslip fault trending N-S.	
	CIBINGBIN	Hotsprings	Tertiary sedimentary rocks overlain by quarter volcanic rock	Normal faults controlling springs distribution	
	G.CEREMAI-SANGKAHURIP	Hotsprings	The area covered by quarter volcanic rock produced by Ciremai vulcanism	infered normal fault trending WNW-ESE and N-S.	
SUBANG	CIATER	Hotsprings with silica deposits, iron and aluminium oxide and phosphat deposit.	Occupy by tertiary volcanic rocks of sunda vulcanism and overlain by quarter vulcanic rock from Tangkuban Parahu	infered normal fault trending WNW-ESE and N-S.	
	SAGALA HERANG	Hotsprings, travertine, iron oxide arround the springs and H2S smells.	Occupy by tertiary volcanic rocks of sunda vulcanism and overlain by quarter vulcanic rock from Tangkuban Parahu	Sedimentary rocsk of Tertiary age overlain by quarter vulcanic rocks	
SUKABUMI	CISOLOK	Hotsprings, geysers, solfatara, altered ground	The system probably outflow from mountain range at the north.The reservoir is limestone, and vulcanic material occur in the faults complex	Intersection of structure trending N20E and N110E controlled the occurrence of geyser.Regional structure forming grabben extending N from Pelabuhan Ratu to G.Salak	140 C and 220 C
	CISUKARAME	Hotsprings	The system probably outflow from mountain range at the north.The reservoir is limestone, and vulcanic material occur in the faults complex	Regional structure forming grabben extending N from Pelabuhan Ratu to G.Salak. The sam grabben as it is in Cisolok area	200 C
	SANTA	Hotsprings with iron oxide deposited arround the springs	Oligocene rock of Walat Fm, Batuasih Fm and Rajamandala Fm overlain by Miocene rock of Jampang Fm, Bojong Lopang Fm and Nyalindung and overlain unconformably by quarter volcanic rock	Fold with W-E trending axis, Normal fault trending N-S and NE-SW.	low enthalphy 130C
	CIKUNDUL-CIMANDIRI	Hotsprings with sulfur deposits around it.	Quarter vulcanic rock	Faults are dominant	100-140 C
SUMEDANG	CONGEANG-CILEUNGSING,G.TAMPOMAS	Hotsprings with salt, silica sinter and iron oxide.	The old rock is sedimentary rock. This unit overlain by lava andesitic and the youngest is alluvial deposits.Intrusion occur in several places.	Fault trending NW-SE controlled the distribution of springs.	Low entalphy
TASIKMALAYA	KAWAH KARAHA	Volcanic crater, fumarol, hot ground, altered ground, hot springs	The area is located in the volcanic complex. Quarter volcanic rock overlain by Holocene volcanic rock	NW-SE faults are the regional trend. The NE-SW faults are the younger one that bound the Hg anomali in this area	
	CIPACING	Hotsprings,travertine	The area is located in the volcanic complex. Quarter volcanic rock overlain by Holocene volcanic rock		259-271 C
	CIGUNUNG	Hotspring	Sedimentary rock of tertiary age overlies by volcanic rock of quarter ages product of G.Galunggung eruption. Andesite intrusion of quarter age.	NW-SE strikeslip fault is prominent in this area.Normal faults controll the distribution of springs	
	CIBALONG	Hotsprings	Miocene Sedimentary rock overlain by volcanic rocks	Regional structures comprise of anticline and sincline trending N-S and normal faults.Normal faults control the distribution of springs	
	CIHERAS-CIPATUJAH	Hotsprings	Covered by Tertiary sedimentary rock overlain by recent alluvial deposit	NE-SW lineament interpreted as faults	
	GALUNGGUNG	Hotsprings,fumarol,solfatar,altered ground, volcanic crater	G.Galunggung is recently active volcano. The product of eruption is find since quarter-recent. Depresion in the crater forming caldera	caldera complex	

ENCLOSURE 2. Geothermal potential in West Java

No	Regency (Kabupaten)	Geothermal Prospects	Sub Area	Installed Capacity	Resource		Reserve			Sub total
					Speculative	Hypothetic	Possible	Probable	Proven	
1	BANDUNG	G. TANGKUBAN PARAHU				100				100
		MARIBAYA			25					25
		KOMPLEKS G. PATUH A	G. PATUHA			65	247		170	482
			CIMANGGU		25					25
			RANCA WALINI		25					25
			BARUTUNGGAL		25					25
			KAWAH PUTIH		25					25
			KAWAH CIBUNI				140			140
			KAWAH CIWIDEY			84	140			224
		SAGULING, RAJAMANDALA			25					25
		GUNUNG WAYANG -WINDU		110		75		135	250	460
		KAWAH KAMOJANG		140				73	227	300
2	BOGOR	CISEENG				100				100
		G.PANCAR-SANGGABUANA			50					50
		AWIBENGKOK, G.SALAK		330			115		485	600
		KAWAH RATU, G.SALAK					72	30		102
3	CIAMIS	PANULISAN			25					25
		G.SAWAL			25		70			95
4	CIANJUR	TANGGEUNG-CIBUNGUR DAN CIBUNI			100					100
		CIPANAS-PACET			25					25
5	CIREBON	G. KROMONG			100					100
6	GARUT	TALAGA BODAS					120	80	120	320
		G.PAPANDAYAN				225				225
		CIPANAS-TAROGONG (G. MASIGIT-GUNTUR)			25					25
		CILAYU			100					100
		CIARINEM			25					25
		KAWAH DARAJAT		125				70	280	350
7	KUNINGAN	SUBANG			50					50
		CIBINGBIN			50					50
		G.CIREMAI-SANGKANHURIP			50					50
8	SUBANG	CIATER			outflow Tangkuban Parahu					
		SAGALA HERANG				185				185
9	SUKABUMI	CISOLOK				50	50			100
		CISUKARAME					83			83
		SANTA			25					25
		CIKUNDUL DAN CIMANDIRI			25					25
10	SUMEDANG	CONGEANG-CILEUNGSING					100			100
11	TASIKMALAYA	KAWAH KARAHA			50			100	120	270
		CIPACING (KEC. CIAWI)			25	75				100
		CIGUNUNG, KEC.CIBALONG			25					25
		CIBALONG			25					25
		CIHERAS-CIPATUJAH			25					25
		G. GALUNGUNG			100					100
			TOTAL	705	1075	959	1137	488	1652	**5311**