Geothermal Capacity Building Program Indonesia - Netherlands

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Market Survey

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1 RESOURCE ASSESSMENT SUMMARY

1.1 VOLCANIC MANIFESTATIONS

Volcanic manifestations data in West Java were obtained from the study of Resource Assessment conducted by a team assigned for work package 3.1 of GEOCAP. The distribution of volcanic manifestations is highlighted on a West Java map shown in Figure 1. An extensive data in Figure 1 is provided in Table A.1 (Appendix A).

Volcanic manifestations in West Java are present as hot springs and fumaroles. A hot spring stands for a thermal spring with warm/hot water which is heated by geothermal activity beneath the Earth's surface. A fumarole is vent on the Earth's surface where steam and hot gases emerge. Considering fluid of fumaroles is technically difficult to be utilized for direct use, so it is excluded from the present study. Volcanic manifestations in West Java, especially hot springs as shown in Figure 2 is based on average surface temperature level and heat load. The heat loads were calculated based on heat content (enthalpy) exerted by certain amounts of geothermal fluid as follows

$$Q = m \times \Delta H \quad (1)$$

where Q is the heat duty in Watt, m is the mass flow in kg/s and ΔH is the enthalpy change in J/kg.

According to Figure 2, the surface temperatures of hot springs in West Java are within the range of 31°-99 °C. Extensive data in Figure 2 is provided in Table A.2. Different levels of surface temperatures and fluid flows result in versatile heat loads at various hot springs. Among those resources, nine spots are considered to be potential in delivering heat required for geothermal direct use since those have medium-to-high temperature levels and adequate heat loads. These spots are Kawah Domas (88°C, 0.41 MW), Cibuni Crater (88°C, 1.06 MW), Ciwidey (80°C, 1.3 MW), Kawah Kamojang (92°C, 0.74 MW), Kawah Hujan (94°C, 0.76 MW), Tanggeung-Cibungur-Cibuni (71°C, 0.58 MW), Talaga Bodas (68°C, 1.95 MW), Cisolok (95°C, 0.76 MW), and Kawah Karaha (91°C, 0.59 MW).

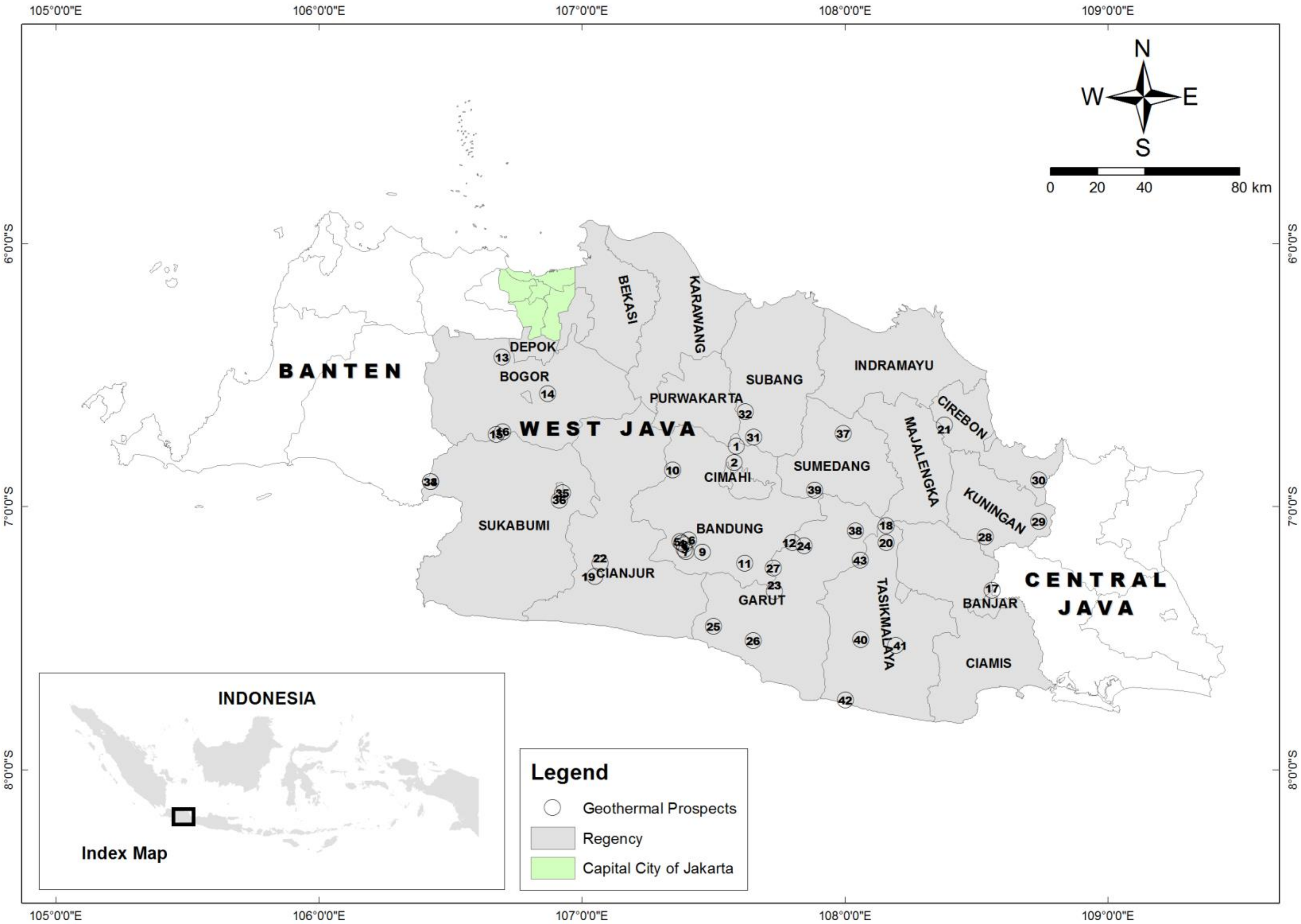


Figure 1. Distribution of Volcanic Manifestations in West Java

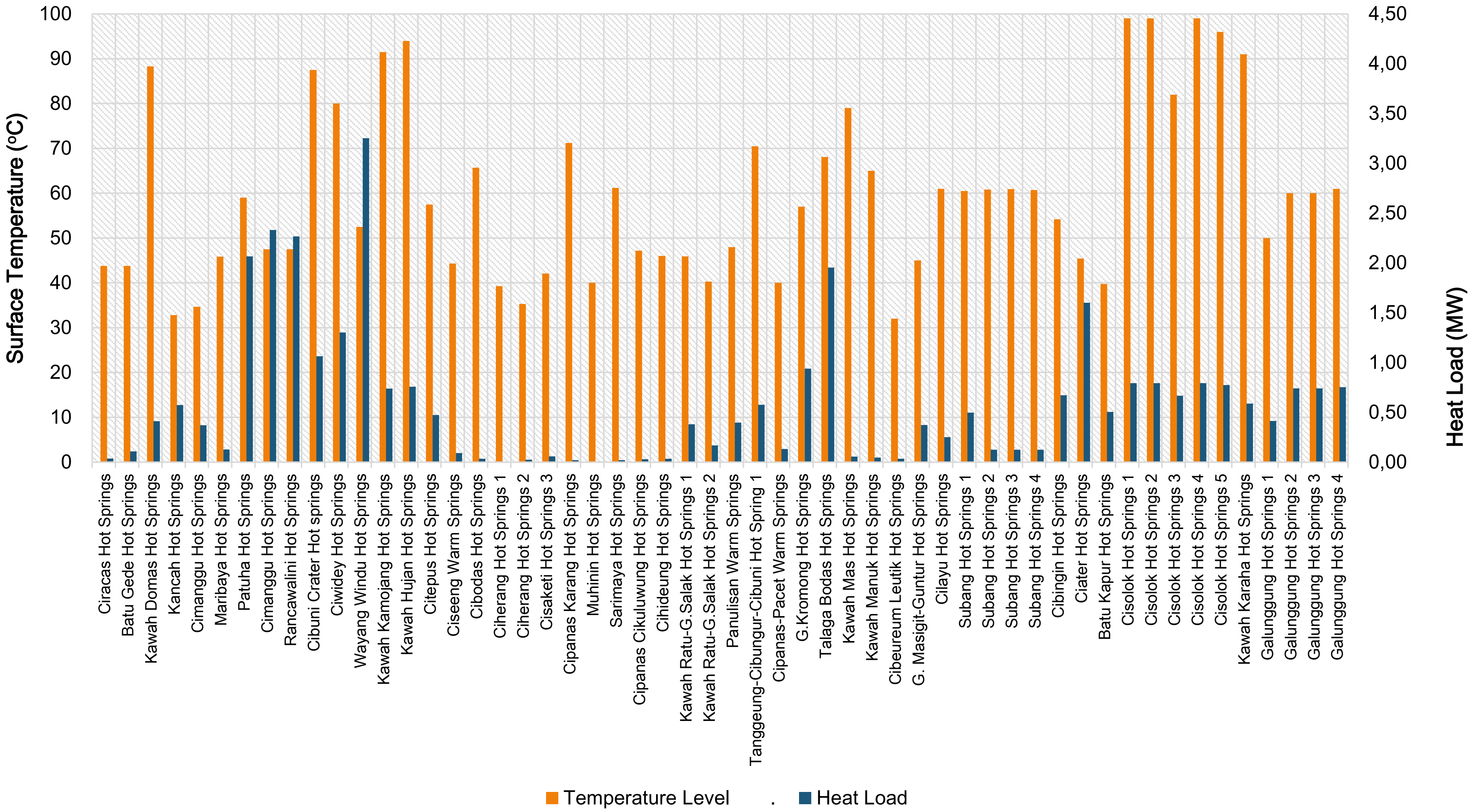


Figure 2. Volcanic manifestations in West Java

1.2 Volcanic Low/Medium Enthalpy

This part will follow as soon as ITB finishes the resource assessment.

1.3 Non Volcanic Hot Aquifer

This part will follow as soon as ITB finishes the resource assessment.

1.4 Geothermal Waste Heat

Existing geothermal power plants in West Java are located in Kamojang, Wayang Windu, Patuha, Gunung Salak, and Darajat. Details of power plants are summarized in Table 1.

Table 1 Existing geothermal power plants in West Java

No	Geothermal Power Plant	Operator	Type of Power Generation Cycle	Installed Capacity (MW)
1	Kamojang	PT. Pertamina Geothermal Energy	Direct Dry Steam – Single Flash	200
2	Wayang Windu	Star Energy	Separated Steam – Single Flash	227
3	Patuha	PT. Geo Dipa Energy	Separated Steam – Single Flash	55
4	Gunung Salak	Chevron Geothermal Indonesia, Ltd	Separated Steam – Single Flash	377
5	Darajat	Chevron Geothermal Indonesia, Ltd	Direct Dry Steam – Single Flash	271

Table A.2 (Appendix A) lists heat load carried by geothermal waste (brine and condensate) in each power plant calculated based on Equation 1. To obtain enthalpy values, fluids of condensate and brine were assumed as saturated water. There are no brine wells in Kamojang and Darajat fields since the plants operate using vapour-dominated liquid. In Patuha field, condensate is associated with brine and therefore reinjected into brine wells.

Figure 3 points out temperature levels and heat loads of geothermal waste in the existing power plants in West Java. According to Figure 3, Wayang Windu Brine (156^{o}C, 32.94 MW), Patuha Brine (165^{o}C, 19.36 MW), and Gunung Salak Brine (173^{o}C, 184.97 MW) show the most prospective characteristics for the direct use of geothermal waste heat since those provide both high temperature levels and high heat loads.

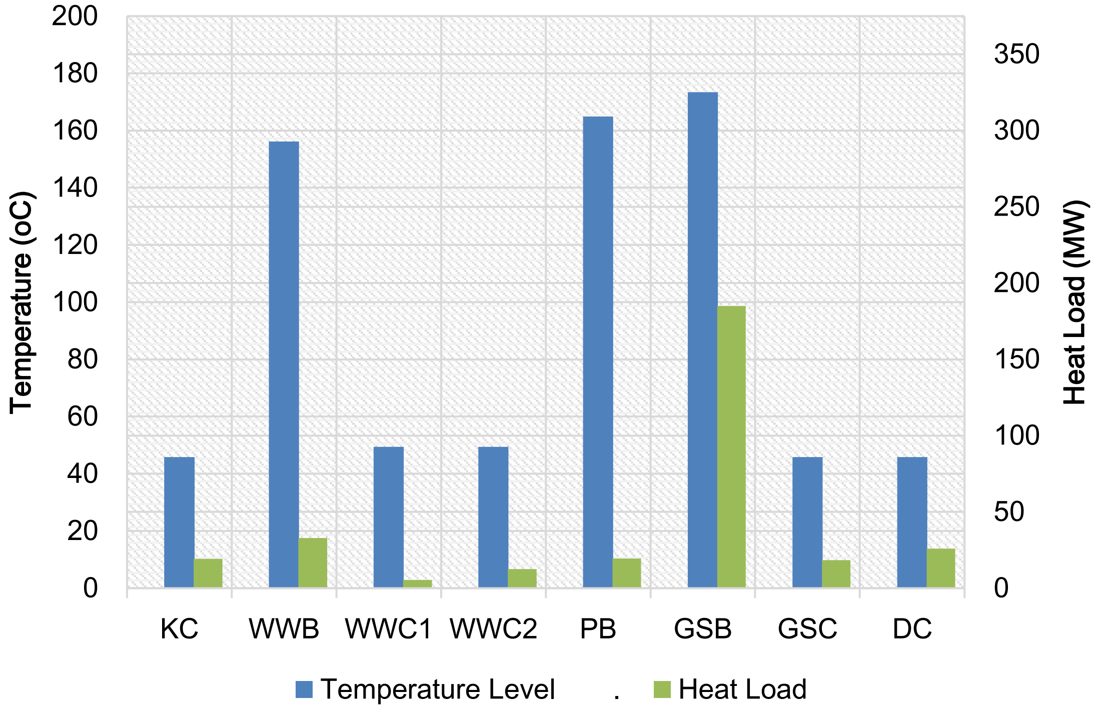


Figure 3. The potential geothermal waste heat in existing gothermal power plant in West Java
KC = Kamojang Condensate, WWB = Wayang Windu Brine, WWC1= Wayang Windu Condensate 1, WWC2 = Wayang Windu Condensate 2, PB = Patuha Brine, GSB = Gunung Salak Brine, GSC = Gunung Salak Condensate, DC = Darajat Condensate

2 Market Identification

A direct use of geothermal heat involves supplying heat of a flow of geothermal fluid to a wide range of utilizations, such as greenhouses, space heating, industrial and agricultural processes. Geothermal direct use requires conformity between versatile needs of users and characteristics of the resource in order to develop a successful project (Lund 2011). In this chapter, general market identification worldwide and in national scale is long listed based on temperature level and heat duty. The existing utilizations and potential uses of low-medium enthalpy geothermal resource in West Java are plotted, to be further matched with the characteristics of geothermal resources.

2.1 Use of Low/Medium Temperature Geothermal Heat in the World

2.1.1 Overview

Geothermal resources have been commercially used for more than a century (Goldstein, Hiriart et al. 2011). Direct utilization of geothermal energy is currently applied in a total of 82 countries, with the estimated capacity of 70,329 MW_t or the annual use of

587,786.43 TJ/year (Lund and Boyd 2015). Geothermal heat is used in various applications such as geothermal heat pumps, space heating, greenhouses heating, aquaculture pond heating, agricultural drying, industrial uses, bathing and swimming, snow melting, and other applications.

Geothermal direct-use in the last 20 years shows an increasing trend. The amount of direct use in 2015 has achieved five times higher than that in 1995. The utilization of geothermal heat all over the world in 1995, 2000, 2005, 2010, and 2015 are 112,441, 190,699, 273,372, 423,820, and 587,786 TJ/year, respectively. Figure 4 shows the geothermal direct-use worldwide in the last 20 years in different applications. Among all applications shown in Figure 4, geothermal heat pumps contribute the most significant utilization of geothermal direct-use in 2015.

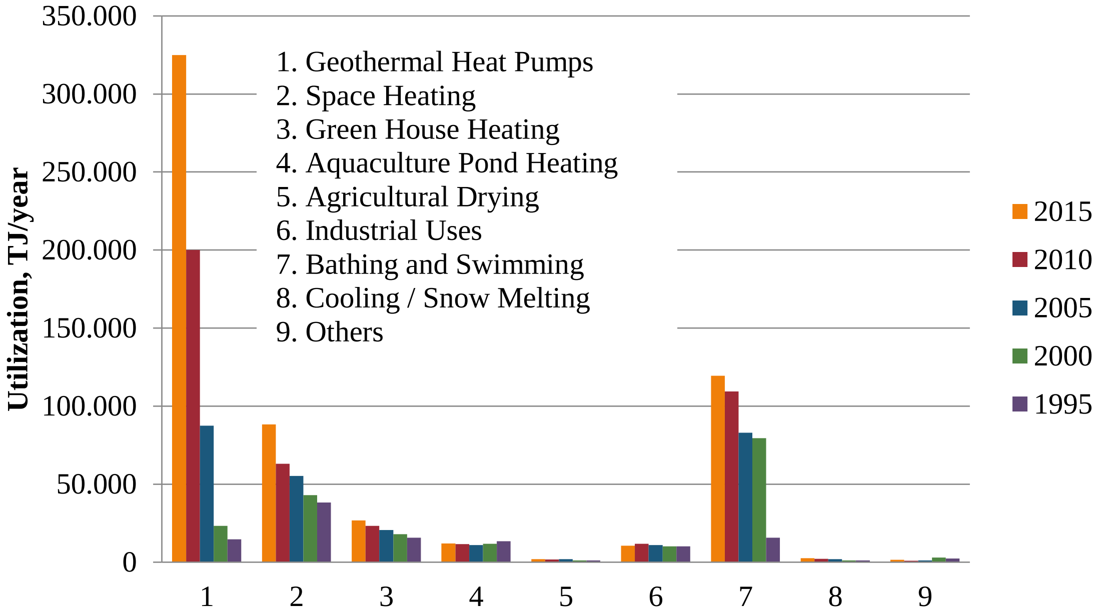


Figure 4. Geothermal direct-use in worldwide within the latest 20 years (Lund and Boyd 2015)

In 2015, geothermal heat pumps account for the largest existing utilization as much as 55.3% of the annual energy use. Most of the utilization are in North America, Sweden, Germany, France, and China. Space heating occupies the second largest utilization worldwide at 15.01% of the annual energy use. The major users in district heating are China, Iceland, Turkey, France, and Germany. The top rankers of the use for individual space heating are Turkey, USA, Italy, Slovakia, and Russia. Other forms of geothermal direct-use are distributed in many different applications in other countries. Besides for vegetable and flower planting, geothermal heat is also used for banana cultivation in greenhouses in Iceland. The heat is consumed by agricultural drying for different types of crops, such as onions in USA, wheat and other cereals in Serbia, coconut meat in Philippines, timber in

Mexico, New Zealand, and Romania. Geothermal heat is also applied in leather industry in Serbia and Slovenia, chemical extraction in Bulgaria, Poland, and Russia, CO_2 extraction in Iceland and Turkey, iodine and salt extraction in Vietnam, and borate and boric acid production in Italy.

2.1.2 Types of Geothermal Direct-Use Based on Temperature Level

Geothermal direct use worldwide characterized by temperature level is shown in Figure 5. Low-temperature fluid (<50 ^{o}C) is used for heat pump, soil warming, aquaculture, and bathing. Lower mild-temperature fluid (50-100 ^{o}C) is useful for applications in snow melting, food and beverage processing, fruit and vegetable drying, greenhouses. Upper mild-temperature fluid (100-150 ^{o}C) is in general used in pharmaceutical, petrochemical, and other industrial sectors. High-temperature fluid (>150 ^{o}C) is lead for ice making, ethanol, biofuel and hydrogenation production, and also for geothermal power plant.

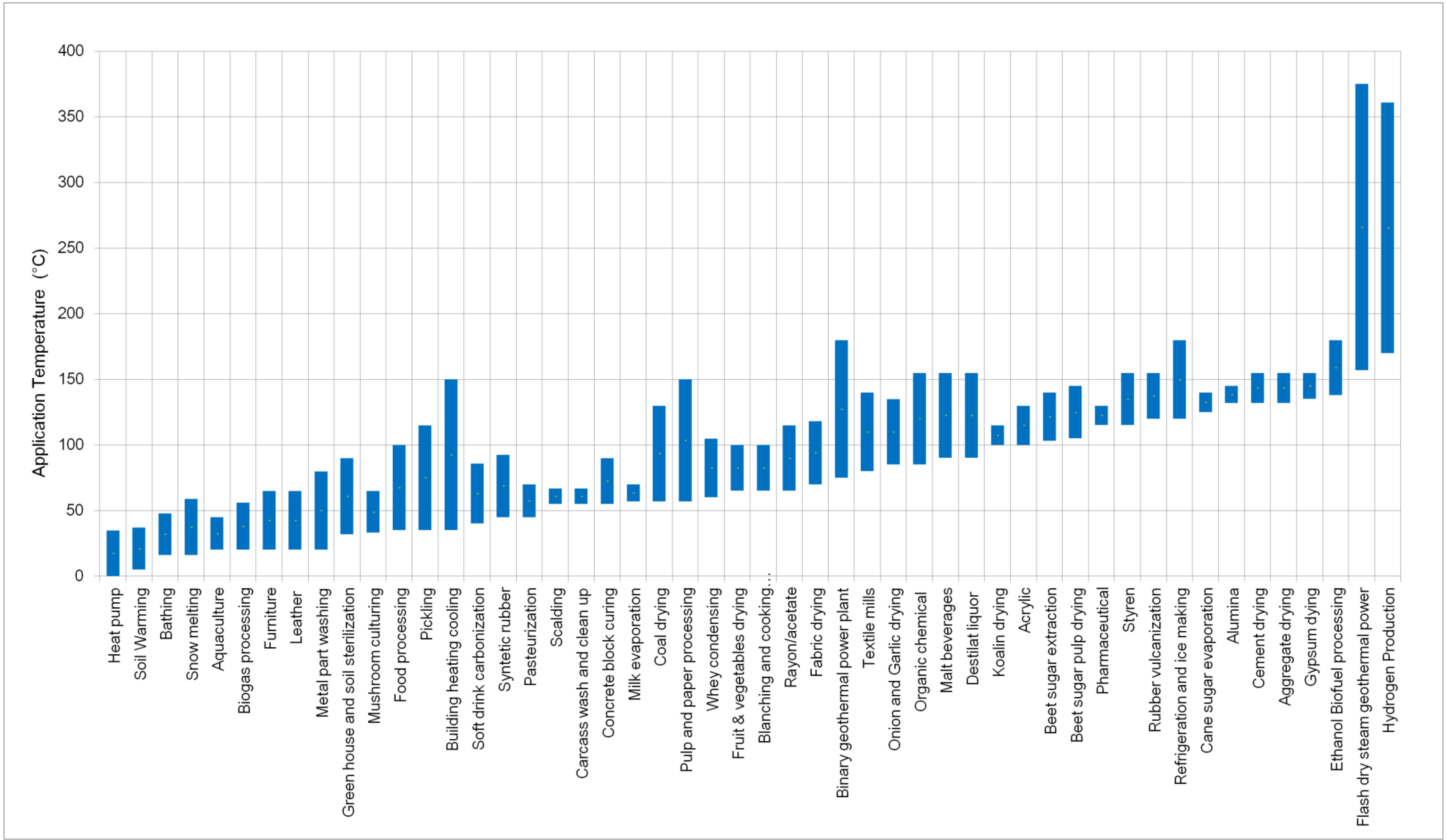


Figure 5. Type of geothermal direct use in worldwide based on temperature level (2014)

2.2 Use of Low/Medium Temperature Geothermal Heat in Indonesia and West Java

Almost 60% of processing industries are located in West Java province. Nearly all of them need heat for product processing. The majority of industrial energy demand is for heat. Heat is integral to many industrial processes including melting, drying, frying, pasteurising, and distilling. Each of these processes uses heat at a temperature specific to the materials involved and the product being manufactured. Current situation in West Java province, almost all heat demand is supplied by coal combustion, oil, solar, gas, and electricity. Very few of of them use geothermal as heat supply for their industrial processes.

Figure 6 Cities and Regencies of West Java. The province of West Java is subdivided into 9 cities and 18 regencies. Those cities and regencies are divided into ± 620 districts which comprise ± 1,576 urban villages. (Reference https://en.wikipedia.org/wiki/West_Java)

The northern area of West Java has become a major industrial area. Areas such as Bekasi, Cikarang, and Karawang are sprawling with factories and industries, such as textiles, processed food, wood carvings and furniture, paper, chemicals, etc. The area in and around Bandung also developed as industrial area. While, in some other parts of the provice, agriculture dominates the economy, especially the mountainous region of West Java which has been known as a major producer of vegetables and other agricultural products, such as rice, sugarcane, corn (maize), cassava, peanuts, tea, coffee, rubber, etc. Near the coastline, there are some fishery owned by small medium enterprises in the north and south part.

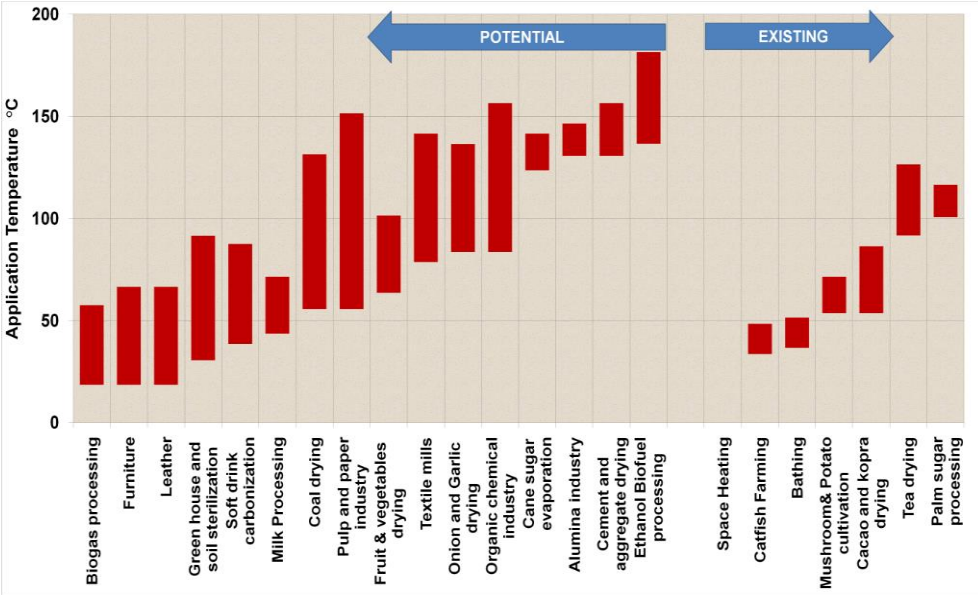


Figure 7 The existing utilizations and other potential applications characterized by temperature level

Figure 65 showing potential and existing geothermal applications in Indonesia in which the details are shown in **Table 10** and **11**.

Table 2 Existing application of geothermal heat in Indonesia

MARKET	Temperature Range (°C)	Status	Location
Catfish Farming	±40	Commercial*	Lampung
Warm Bathing	43-45	Commercial	West Java (Ciater, Gunung Pancar, Cipanas, Cisolok), Central Java (Baturaden), East Java (Cangar), Bengkulu (Suban)
Mushroom & Potato cultivation	60-65	Pilot project**	West Java (Pangalengan)
Mushroom	60-65	Pilot project	West Java (Kamojang)
Cacao and coconut drying	60-80	Pilot project	Lampung (Way Ratai)
Tea drying	98-120	Pilot project**	West Java (Pangalengan)
Palm sugar processing	107-110	Commercial***	North Sulawesi (Lahendong)

***Traditional freshwater fishery in Lampung Province combining natural geothermal hot water with freshwater from a river to grow large catfishes. The farmer reported that the fishes grow better in the geothermal fluid and freshwater mixture.

**Need more confirmation.

*** In 2014, it produced total over 100 tons of sugar, corresponding with almost 1 million liters of sugar juice produced by the farmers. Looking at the income from their sugar palms only, those farmers already earn about 4 times the minimum wage.

Table 3 Potential applications of geothermal heat in Indonesia

MARKET	Temp. (°C)	Potential Location
Fish drying		West Java (Cisolok)
Brick drying		West Java (Cisolok)
Wood drying		West Java (Cisolok, Cisukarame)
Clove drying		West Java (Cisolok)
Coconut drying		West Java (Cisolok, Cisukarame)
Fish farming, cultivation		West Java (Cisukarame)
Tea processing		West Java (Awibengkok, Wayang Windu)
Biogas processing	25-51	Husbandry areas: West Java (Subang, Majalengka, Bogor, Tapos), Central Java (Boyolali)
Furniture (Wood Drying)	25-60	Central Java (Jepara)
Leather industry (Bleaching, Neutralizing and Fat liquoring Process)	25-60	West Java (Garut, Bogor)
Green house and soil sterilization	37-85	West Java (Lembang)
Soft drink carbonization	45-81	West Java (Bogor, Sukabumi), East Java (Malang), North Sumatera (Medan)
Milk Processing (Pasteurization, Evaporation)	50-65	West Java (Subang, Majalengka, Bogor, Tapos, Pangalengan), Central Java (Boyolali), East Java (Malang)
Coal drying	62-125	Sumatera, Kalimantan
Pulp and paper industry (Cooking-Digesting, Bleaching, Drying)	62-145	Riau (Kampar, Pelelawan), North Sumatra (Toba), Lampung, Kalimantan
Fruit & vegetables drying	70-95	East Java (Malang for apple drying), West Java (Cirebon, Indramayu), South Sumatera and Lampung (for coffee processing), East Nusa Tenggara (for maize, cassava, onion drying)
Textile mills (coloring)	85-135	West Java (Bandung Majalaya)

MARKET	Temp. (°C)	Potential Location
Onion and Garlic drying	90-130	Central Java (Dieng, Brebes)
Organic chemical industry (extraction/distillation)	90-150	Nanggroe Aceh Darussalam, North Sumatra, Lampung, West Java, Maluku
Cane sugar evaporation	130-135	West Java (Subang, Majalengka), East Java (Malang), Lampung
Alumina industry	137-140	Kalimantan, Bangka Belitung
Cement and aggregate drying	137-150	Gresik, Cibinong, Cilegon, Padang, Tonasa
Ethanol Biofuel processing	143-175	West Java (Subang, Majalengka), East Java (Malang), Lampung (Way Kana, Tulang Bawang)

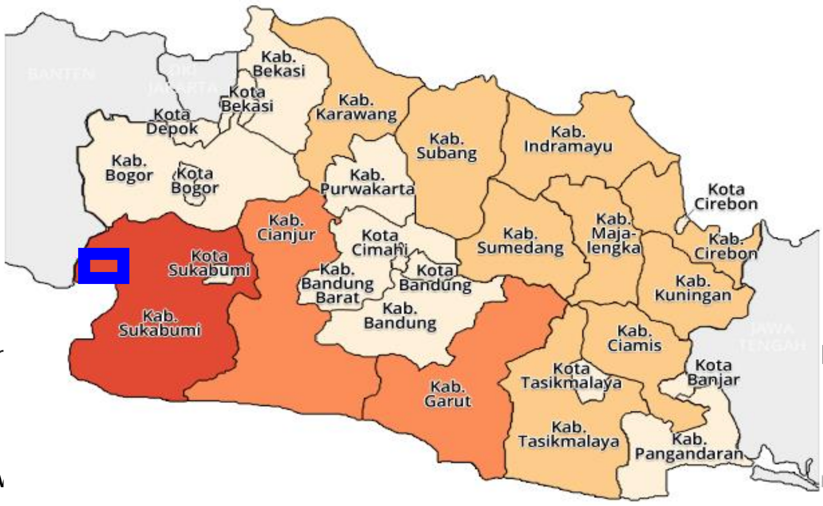


Figure 8 Map sh by the coastline

Especially in W s in hotels and recreational area in Ciater, Cisolok, Gunung Pancar and Cipanas are already commercial. Besides, mushroom and potato cultivation and tea drying in West Java are processed with the direct use of geothermal fluid at pilot plant scale. Economic activities possibly to utilize geothermal waste heat in West Java are biogas processing, leather industry (bleaching, neutralizing and fat liquoring process), soft drink carbonization, milk processing (pasteurization, evaporation), fruit and vegetable drying, textile mills (coloring), organic chemical industry (extraction/distillation), cane sugar evaporation, and ethanol biofuel processing. Its possibility is determined by matching up resource and demand based on consideration of distance constraint, temperature levels and heat loads provided by resources, and temperature levels and heat duty required in demand side.

Figure 9 Palm sugar processing using geothermal heat in Lahendong, North Sulawesi province

Figure 10 Catfish farming using geothermal heat in Lampung province

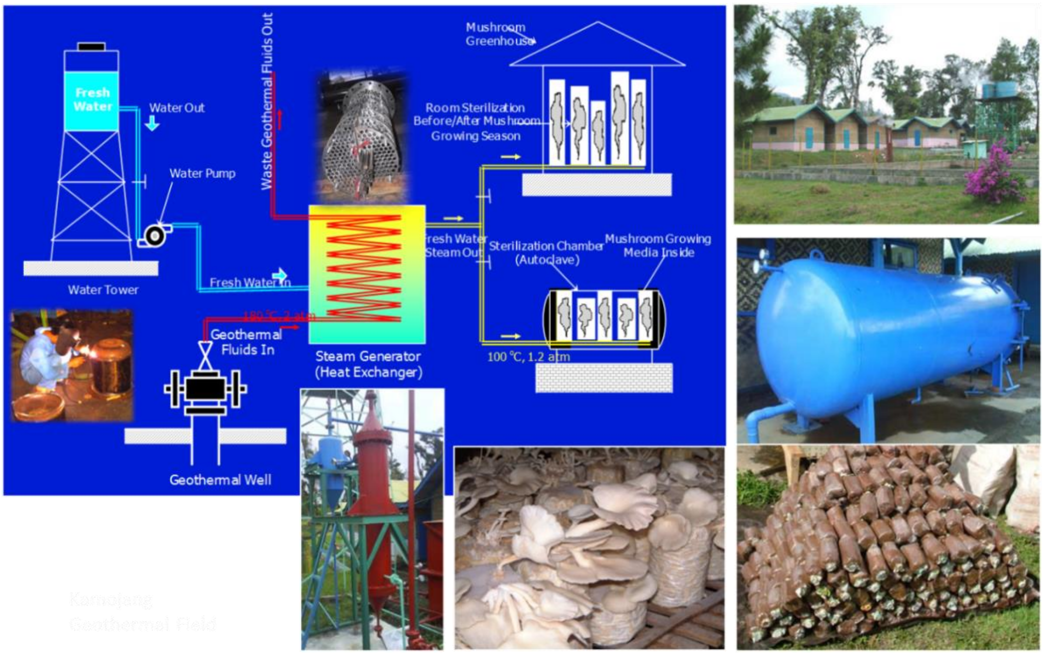


Figure 11 Mushroom cultivation using geothermal heat in Kamojang, West Java province

The scale of development (business scale) of a direct-use project in a particular geothermal field in Indonesia will always be limited to a level where the volume of used energy (geothermal mass intake) will not have an adverse impact to the production activity and capacity. Therefore, direct-use projects are limited to micro-small medium scale enterprises, which require less use of geothermal energy, or only to be part of a field developer's Corporate Social Responsibility (CSR) program. The use of brine from a power generation activity or heat directly harnessed from an available surface manifestation will be sufficient for this scale of development. For these reasons, the presence of direct use projects, in most of these cases, highly depends on the field developer's initiatives, in which they have more critical focus on their power generation activities rather than promoting geothermal to support direct use for business (Taqwim, 2014).

3 MATCHING UP RESOURCE AND DEMAND

Matching up resource and demand is suggested to be carried out through two stage screening. The first screening is identification of distance constraint between geothermal resources and business units. Only business units which have distance less than 20 km to geothermal resources have been taken into account for further screening. This distance limit is taken after considering some data from different countries which have been considered economical as shown in Table 4.

Table 4 Distance from hot springs to consumers in some countries

Hot spring temperature (°C)	Location	Distance from hot spring to consumer (km)	Reference
70°C to 80°C	Canada	27 km, 26.7 km, 21.8 km	Ghomshei (2007)
43°C to 63°C	South Africa	30.3 km, 86 km (not efficient)	Tshibalo and Tekere (2015)
85°C, 100°C	Iceland	18 km, 20 km	Hjartarson *et al* (2005)
50°C	Turkey	27 km,18 km	Horasanli (2010)

This distance limit of 20 km is determined with consideration that insulation was fitted on the pipeline. According to Lund (2010), at flowing conditions, the temperature loss in insulated pipelines is in the range of 0.1 to 1.0 °C/km, and in uninsulated lines, the loss is 2 to 5 °C/km (in the approximate range of 5 to 15 L/s flow for 15-cm diameter pipe) [5]. It is less for larger diameter pipes. The distance will affect capital investment mostly of the provision of pipelines and its insulation (Lund and Boyd 2015). Shorter distance is certainly preferable because of lower capital investment for heating infrastructures. In the second screening, temperature levels and heat loads provided by geothermal resources were compared to those required in the business units.

A large database (comprising 7,000 business units) of small and medium enterprises in West Java for screening candidates has been obtained from the Ministry of Industry in Indonesia. Database of potential large enterprises in West Java has been collected from different sources as in internet, which may not be entirely correct. Only business units listed in Tables 2 and 3 are considered for the application of geothermal direct use in Indonesia.

Process block diagram for each business unit was assessed to obtain which parts of the business unit require heating (see Appendix B). Then, heat duty was calculated by energy balance by processes considered which is proportional to the production capacity. A 'matched resource and demand' is achieved when the location of a business unit is at a distance less than 20 km from a resource or resources, has highest temperature level less than temperature of resources and required heat duty less than heat load provided by resources.

Evaluating the feasibility of heat requires characterizing the heat source. Important parameters that must be determined include:

- Heat quantity,
- Heat temperature/quality,
- Composition,
- Minimum allowed temperature, and
- Availability

3.1 MATCHING UP RESOURCE AND DEMAND

3.1.1 Volcanic Manifestations

In this part, a matrix to match up temperature levels and heat loads supplied by volcanic manifestations of hot springs in West Java and those required by business units are provided (Table 5). Some hot springs in Table A.1 have been selected for matching up in Table 5 based on their high heat loads and temperature levels (see Section 2.1). The first screening by distance constraint has eliminated most of resource and demand combinations. The distance was assessed between the hot springs and markets according to a straight line on the map. The first screening produces 28 potential 'matched resource and demand' items (marked with brown and green boxes in Table 5) to proceed to the second screening. There are only 14 combinations of resource and demand (marked with green boxes in Table 5) which satisfy the requirements of distance, temperatures, and heat loads. The rest of the combinations which fail to satisfy those three requirements mostly are due to unsatisfied temperature level differences.

Table 5 Matrix of matching up resource and demand for geothermal manifestations in West Java

Orange box: distance is acceptable (< 20 km), temperature level and heat load-duty are not matched. Green box: all parameters are acceptable

No	Business Unit	Type of Product	Production Capacity	Kawah Domas	Cibuni Crater	Ciwidey	Kawah Kamojang	Kawah Hujan	Tanggeung-Cibungur-Cibuni	Talaga Bodas	Cisolok	Kawah Karaha
				88.3 °C, 0.41 MW	87.5 °C, 1.06 MW	80 °C, 1.3 MW	91.5 °C, 0.74 MW	94 °C, 0.76 MW	70.5 °C, 0.58 MW	68.1 °C, 1.95 MW	95 °C, 0.76 MW	91 °C, 0.59 MW
1	CV Mekar Wangi	Green Tea	90 ton/year	72 km	53 km	51 km	27 km	27 km	78 km	34 km	158 km	41 km
2	PO Gunt	Soya Powder	324 kg/year	91 km	93 km	94 km	126 km	126 km	84 km	156 km	52 km	177 km
3	Bijaksana	Chili Sauce	432 ton/year	59 km	59 km	56 km	14 km, 100 °C, 31.65 kW	14 km, 100 °C, 31.65 kW	88 km	19 km, 100 °C, 31.65 kW	162 km	39 km
4	PO Sawargi	Choco Powder	120 ton/year	53 km	49 km	46 km	8 km, 70 °C, 4.19 kW	8 km, 70 °C, 4.19 kW	78 km	29 km	152 km	47 km

Table 5. Matrix of matching up resource and demand for geothermal manifestations in West Java (Cont'd)

No	Business Unit	Type of Product	Production Capacity	Kawah Domas	Cibuni Crater	Ciwidey	Kawah Kamojang	Kawah Hujan	Tanggeung-Cibungur-Cibuni	Talaga Bodas	Cisolok	Kawah Karaha
5	PO Karya Mulya	Jams	144 ton/year	49 km	59 km	56 km	12 km, 82 °C, 1.57 kW	12 km, 82 °C, 1.57 kW	89 km	22 km	160 km	47 km
6	CV Tepung Hoenkwe Cap Boenga	Flour	60.87 ton/year	93 km	79 km	81 km	119 km	119 km	63 km	150 km	35 km	169 km
7	PO Wali Songo	Dried Mango	1,200 can/year	92 km	93 km	94 km	127 km	127 km	84 km	157 km	51 km	178 km
8	PO Mandala Putra	Tomato and Chili Sauce	2,520 ton/year	59 km	59 km	56 km	15 km, 100 °C, 184.6 kW	15 km, 100 °C, 184.6 kW	88 km	18 km, 100 °C, 184.6 kW	163 km	38 km
9	CV Glisindo	Soya Powder	5 ton/year	49 km	60 km	57 km	13 km, 70 °C, 0.23 kW	13 km, 70 °C, 0.23 kW	90 km	23 km	160 km	47 km

Table 5. Matrix of matching up resource and demand for geothermal manifestations in West Java (Cont'd)

No	Business Unit	Type of Product	Production Capacity	Kawah Domas	Cibuni Crater	Ciwidey	Kawah Kamojang	Kawah Hujan	Tanggeung-Cibungur-Cibuni	Talaga Bodas	Cisolok	Kawah Karaha
10	PT Tirta Fresindo	Carbonated drink	7,400 kL/year	87 km	80 km	82 km	118 km	118 km	69 km	148 km	43 km	168 km
11	PT Satya Sumba Cemerlang	Textile	480 ton/year	36 km	44 km	41 km	11 km, 80 °C, 11.63 kW	11 km, 80 °C, 11.63 kW	74 km	39 km	143 km	62 km
12	PT Bintang Indospin Industri	Textile	8,550 bale/year	35 km	55 km	52 km	17 km, 80 °C, 37.58 kW	17 km, 80 °C, 37.58 kW	84 km	37 km	150 km	61 km
13	PT Sejahtera Bintang Abadi Textile	Textile	20,000 bale/year	36 km	51 km	48 km	13 km, 80 °C, 87.91 kW	13 km, 80 °C, 87.91 kW	81 km	37 km	148 km	60 km
14	PT Tribintang Lokawarna, Laswi, Bandung	Textile	269 ton/year	35 km	43 km	40 km	12 km, 80 °C, 6.52 kW	12 km, 80 °C, 6.52 kW	73 km	41 km	141 km	63 km

Table 5. Matrix of matching up resource and demand for geothermal manifestations in West Java (Cont'd)

No	Business Unit	Type of Product	Production Capacity	Kawah Domas	Cibuni Crater	Ciwidey	Kawah Kamojang	Kawah Hujan	Tanggeung-Cibungur-Cibuni	Talaga Bodas	Cisolok	Kawah Karaha
15	PT Pavettia Atsiri Indonesia	Vetiver oil	1,500 kg/year	94 km	92 km	94 km	128 km	128 km	82 km	158 km	45 km	179 km
16	PT ISAM Bandung	Milk	100 ton/day	17 km, 130 - 150 °C, 948.38 kW	39 km	36 km	31 km	31 km	66 km	60 km	127 km	57 km
17	Amerta Indah Otsuka (Pocari Sweat)	Isotonic Drink	45.8 kL/day	91 km	79 km	81 km	118 km	118 km	65 km	149 km	38 km	148 km
18	Indolakto	Milk	217,100 ton/year	91 km	79 km	80 km	118 km	118 km	65 km	149 km	38 km	147 km
19	Asia Sejahtera Perdana Pharmaceutical (Kratingdaeng)	Energy Drink	100 kL/day	91 km	79 km	80 km	118 km	118 km	64 km	149 km	38 km	147 km
20	PT Djojonegoro C-1000	Vitamin Healthy Drink	46.7 kL/day	92 km	79 km	80 km	119 km	119 km	64 km	149 km	37 km	148 km

Table 5. Matrix of matching up resource and demand for geothermal manifestations in West Java (Cont'd)

No	Business Unit	Type of Product	Production Capacity	Kawah Domas	Cibuni Crater	Ciwidey	Kawah Kamojang	Kawah Hujan	Tanggeung-Cibungur-Cibuni	Talaga Bodas	Cisolok	Kawah Karaha
21	Yakult Indonesia Persada	Fermented Milk	195 kL/day	91 km	80 km	82 km	119 km	119 km	66 km	150 km	38 km	148 km
22	The Dayeuh Manggung (under PTPN)	Black Tea	30,000 ton/year	68 km	59 km	57 km	22 km	22 km	87 km	21 km - 120 °C, 2124.97 kW	165 km	28 km
23	Talun Santosa	Black Tea	2,385 ton/year	13 km, 98 - 120 °C, 168.94 kW	41 km	38 km	36 km	36 km	68 km	64 km	125 km	60 km
24	Kertanamah	Black Tea	2,470 ton/year	44 km	70 km	69 km	86 km	86 km	80 km	114 km	96 km	109 km
25	Indorub Sumber Wadung	Black Tea	2,400 ton/year	24 km	48 km	32 km	22 km	22 km	77 km	47 km	141 km	43 km

Table 5. Matrix of matching up resource and demand for geothermal manifestations in West Java (Cont'd)

No	Business Unit	Type of Product	Production Capacity	Kawah Domas	Cibuni Crater	Ciwidey	Kawah Kamojang	Kawah Hujan	Tanggeung-Cibungur-Cibuni	Talaga Bodas	Cisolok	Kawah Karaha
26	Sinumbra	Black Tea	2,434 ton/year	53 km	6 km, 98 - 120 °C, 172.41 kW	8 km, 98 - 120 °C, 172.41 kW	51 km	51 km	27 km	81 km	101 km	82 km
27	Parakan Salak	Black Tea	3,000 ton/year	100 km	85 km	87 km	125 km	125 km	67 km	156 km	28 km	155 km
28	Purasari	Black Tea	1,300 ton/year	112 km	100 km	102 km	140 km	140 km	84 km	171 km	24 km	170 km
29	Tri Keeson Utara	Choco Powder	6,000 ton/year	16 km, 98 - 120 °C, 251.52 kW	41 km	57 km	31 km	31 km	68 km	60 km	128 km	56 km
30	PT Vonex Indonesia	Textile	17,662 ton/year	31 km	53 km	50 km	19 km - 120 °C, 427.85	19 km - 120 °C, 427.85	82 km	40 km	148 km	35 km

3.1.2 Geothermal Waste Heat

In this part, a matrix to match up temperature levels and heat loads supplied by geothermal waste heat and those required by business units are provided (Table 6). The geothermal plants in West Java exhibited in Table A.2 have been included for matching up in Table 6. The first screening by distance constraint has eliminated most of resource and demand combinations. The distance was assessed between geothermal power plants and markets according to a straight line on the map. A large distance is a barrier to make geothermal waste heat use feasible since this contributes to high capital investment of heating infrastructure (costs for pipe insulation and equipment installation). There are 57 potential 'matched resource and demand' items as a result of the first screening (marked with brown and green boxes in Table 6) to proceed to the second screening. There are 16 combinations of resource and business unit which satisfy the requirements of distance, temperatures, and heat loads in the second screening (marked with green boxes in Table 6). The rest of the combinations which fail to satisfy those three requirements mostly because condensate temperatures are smaller than temperatures required in the business units.

Table 6 Matrix of matching up resource and demand for geothermal waste heat resources

KC = Kamojang Condensate, WWB = Wayang Windu Brine, WWC1= Wayang Windu Condensate 1, WWC2 = Wayang Windu Condensate 2, PB = Patuha Brine, GSB = Gunung Salak Brine, GSC = Gunung Salak Condensate, DC = Darajat Condensate.

Orange box: distance is acceptable (< 20 km), but temperature level and heat load-duty are not matched. Green box: all parameters are acceptable

No	Business Unit	Type of Product	Production Capacity	KC	WWB	WWC1	WWC2	PB	GSB	GSC	DC
				46 °C, 19.2 MW	156 °C, 32. 9 MW	50 °C, 5.4 MW	50 °C, 12.4 MW	165 °C, 19.4 MW	173 °C, 185 MW	46 °C, 18.4 MW	46 °C, 26 MW
1	CV Mekar Wangi	Green Tea	90 ton/year	26 km	27 km	27 km	27 km	51 km	144 km	144 km	19 km, 98-120 °C, 6.37 kW
2	PO Gunt	Soya Powder	324 kg/year	140 km	129 km	129 km	129 km	101 km	20 km, 70 °C, 0.01 kW	20 km, 70 °C, 0.01 kW	131 km
3	PO Bijaksana	Chili Sauce	432 ton/year	13 km, 100 °C, 31.65 kW	30.15 km	31 km	31 km	56 km	30 km	30 km	19 km, 100 °C, 31.65 kW
4	PO Sawargi	Choco Powder	120 ton/year	7 km, 70 °C, 4.19 kW	21 km	21 km	21 km	45 km	145 km	145 km	10 km, 70 °C, 4.19 kW

Table 6. Matrix of matching up resource and demand for geothermal waste heat resources (Cont'd)

No	Business Unit	Type of Product	Production Capacity	KC	WWB	WWC1	WWC2	PB	GSB	GSC	DC
				46 °C, 19.2 MW	156 °C, 32. 9 MW	50 °C, 5.4 MW	50 °C, 12.4 MW	165 °C, 19.4 MW	173 °C, 185 MW	46 °C, 18.4 MW	46 °C, 26 MW
5	PO Karya Mulya	Jams	144 ton/year	14 km, 82 °C, 1.57 kW	32 km	32 km	32 km	56 km	142 km	142 km	22 km
6	CV Tepung Hoenkwe Cap Boenga	Flour	60.87 ton/year	119 km	101 km	101 km	101 km	81 km	13 km, 55 °C, 1.93 kW	13 km, 55 °C, 1.93 kW	117 km
7	PO Wali Songo	Dried Mango	1,200 can/year	126 km	105 km	105 km	105 km	91 km	18 km, 70 °C, 0.03 kW	18 km, 70 °C, 0.03 kW	125 km
8	PO Mandala Putra	Tomato and Chili Sauce	2,520 ton/year	15 km, 100 °C, 184.6 kW	31 km	31 km	31 km	56 km	146 km	146 km	20 km, 100 °C, 184.6 kW
9	CV Glisindo	Soya Powder	5 ton/year	14 km, 70 °C, 0.23 kW	33 km	33 km	33 km	57 km	142 km	142 km	25 km

Table 6. Matrix of matching up resource and demand for geothermal waste heat resources (Cont'd)

No	Business Unit	Type of Product	Production Capacity	KC	WWB	WWC1	WWC2	PB	GSB	GSC	DC
				46 °C, 19.2 MW	156 °C, 32. 9 MW	50 °C, 5.4 MW	50 °C, 12.4 MW	165 °C, 19.4 MW	173 °C, 185 MW	46 °C, 18.4 MW	46 °C, 26 MW
10	PT Tirta Fresindo	Carbonated drink	7,400 kL/year	117 km	99 km	99 km	99 km	80 km	15 km, 57.2 °C, 59.47 kW	15 km, 57.2 °C, 59.47 kW	115 km
11	PT Satya Sumba Cemerlang	Textile	480 ton/year	10 km, 80 °C, 11.63 kW	19 km, 80 °C, 11.63 kW	19 km, 80 °C, 11.63 kW	19 km, 80 °C, 11.63 kW	40 km	124 km	124 km	15 km, 80 °C, 11.63 kW
12	PT Bintang Indospin Industri	Textile	8,550 bale/year	13 km, 80 °C, 37.58 kW	26 km	26 km	26 km	44 km	121 km	121 km	21 km
13	PT Sejahtera Bintang Abadi Textile	Textile	20,000 bale/year	16 km, 80 °C, 87.91 kW	18 km, 80 °C, 87.91 kW	18 km, 80 °C, 87.91 kW	18 km, 80 °C, 87.91 kW	49 km	129 km	129 km	23 km
14	PT Tribintang Lokawarna, Laswi, Bandung	Textile	269 ton/year	12 km, 80 °C, 6.52 kW	21 km	21 km	21 km	40 km	123 km	123 km	17 km, 80 °C, 6.52 kW

Table 6. Matrix of matching up resource and demand for geothermal waste heat resources (Cont'd)

No	Business Unit	Type of Product	Production Capacity	KC	WWB	WWC1	WWC2	PB	GSB	GSC	DC
				46 °C, 19.2 MW	156 °C, 32. 9 MW	50 °C, 5.4 MW	50 °C, 12.4 MW	165 °C, 19.4 MW	173 °C, 185 MW	46 °C, 18.4 MW	46 °C, 26 MW
15	PT Pavettia Atsiri Indonesia	Vetiver oil	1,500 kg/year	127 km	105 km	105 km	105 km	94 km	20 km, 140 - 150 °C, 0.23 kW	20 km, 140 - 150 °C, 0.23 kW	125 km
16	PT ISAM Bandung	Milk	100 ton/day	33 km	9 km, 130 - 150 °C, 948.38 kW	9 km, 130 - 150 °C, 948.38 kW	9 km, 130 - 150 °C, 948.38 kW	52 km	239 km	239 km	52 km
17	PT Amerta Indah Otsuka (Pocari Sweat)	Isotonic Drink	45.8 kL/day	118 km	101 km	101 km	101 km	80 km	13 km, 70 - 80 ° C, 188.61 kW	13 km, 70 - 80 ° C, 188.61 kW	115 km

Table 6. Matrix of matching up resource and demand for geothermal waste heat resources (Cont'd)

No	Business Unit	Type of Product	Production Capacity	KC	WWB	WWC1	WWC2	PB	GSB	GSC	DC
				46 °C, 19.2 MW	156 °C, 32. 9 MW	50 °C, 5.4 MW	50 °C, 12.4 MW	165 °C, 19.4 MW	173 °C, 185 MW	46 °C, 18.4 MW	46 °C, 26 MW
18	PT Indolakto	Milk	217,100 ton/year	118 km	101 km	101 km	101 km	80 km	13 km, 70 - 93 ° C, 2940.82 kW	13 km, 70 -93 ° C, 2940.82 kW	115 km
19	PT Asia Sejahtera Perdana Pharmaceutical (Kratingdaeng)	Energy Drink	100 kL/day	41 km	20 km, 70 - 80 °C, 411.82 kW	20 km, 70 - 80 °C, 411.82 kW	20 km, 70 - 80 ° C, 411.82 kW	31 km	95 km	95 km	42 km
20	PT Djojonegoro C-1000	Vitamin Healthy Drink	46.7 kL/day	118 km	101 km	101 km	101 km	80 km	13 km, 70 - 80 ° C, 192.32 kW	13 km, 70 - 80 ° C, 192.32 kW	115 km

Table 6. Matrix of matching up resource and demand for geothermal waste heat resources (Cont'd)

No	Business Unit	Type of Product	Production Capacity	KC	WWB	WWC1	WWC2	PB	GSB	GSC	DC
				46 °C, 19.2 MW	156 °C, 32. 9 MW	50 °C, 5.4 MW	50 °C, 12.4 MW	165 °C, 19.4 MW	173 °C, 185 MW	46 °C, 18.4 MW	46 °C, 26 MW
21	PT Yakult Indonesia Persada	Fermented Milk	195 kL/day	118 km	101 km	101 km	101 km	80 km	13 km, 120 C, 1,783 kW	13 km, 120 C, 1,783 kW	115 km
22	Teh Dayeuh Manggung	Black Tea	30,000 ton/year	22 km, 98 - 120 °C, 2124.97 kW	50 km	50 km	50 km	58 km	150 km	150 km	21 km, 98 - 120 °C, 2124.97 kW
23	Teh Talun Santosa	Black Tea	2,385 ton/year	19 km, 98 - 120 °C, 168.94 kW	41 km	41 km	41 km	35 km	128 km	128 km	11 km, 98 - 120 °C, 168.94 kW

Table 6. Matrix of matching up resource and demand for geothermal waste heat resources (Cont'd)

No	Business Unit	Type of Product	Production Capacity	KC 46 °C, 19.2 MW	WWB 156 °C, 32. 9 MW	WWC1 50 °C, 5.4 MW	WWC2 50 °C, 12.4 MW	PB 165 °C, 19.4 MW	GSB 173 °C, 185 MW	GSC 46 °C, 18.4 MW	DC 46 °C, 26 MW
24	Teh Kertamanah	Black Tea	2,470 ton/year	23 km	37 km	37 km	37 km	24 km	118 km	118 km	16 km, 98 - 120 °C, 174.96 kW
25	Teh Patuahwatte, PT Indorub Sumber Wadung	Black Tea	2,400 ton/year	46 km	44 km	44 km	44 km	3 km, 98 - 120 °C, 170 kW	91 km	91 km	42 km
26	Teh Sinumbra	Black Tea	2,434 ton/year	40 km	37 km	37 km	37 km	5 km, 98 - 120 °C, 172.41 kW	95 km	95 km	36 km
27	Teh Parakan Salak	Black Tea	3,000 ton/year	126 km	108 km	108 km	108 km	88 km	6 km, 98 - 120 °C, 212.5 kW	6 km, 98 - 120 ° C, 212.5 kW	124 km

Table 6. Matrix of matching up resource and demand for geothermal waste heat resources (Cont'd)

No	Business Unit	Type of Product	Production Capacity	KC 46 °C, 19.2 MW	WWB 156 °C, 32. 9 MW	WWC1 50 °C, 5.4 MW	WWC2 50 °C, 12.4 MW	PB 165 °C, 19.4 MW	GSB 173 °C, 185 MW	GSC 46 °C, 18.4 MW	DC 46 °C, 26 MW
28	Teh Purasari	Black Tea	1,300 ton/year	23 km	37 km	37 km	37 km	24 km	118 km	118 km	16 km, 98 - 120 °C, 92.08 kW
29	PT Tri Keeson Utara	Choco Powder	6,000 ton/year	15 km, 98 - 120 °C, 251.52 kW	31 km	31 km	31 km	57 km	147 km	147 km	21 km
30	PT Vonex Indonesia	Textile	17,662 ton/year	20 km, 98 - 120 °C, 427.85	34 km	34 km	34 km	52 km	129 km	129 km	30 km

3.2 POTENTIAL MARKETS

In this part, potential markets of the utilization of hot springs and geothermal waste heat in West Java listed in Tables 5 and 6 are to be summarized. After 'matching up resource and demand' involving 6 spots of hot springs and 8 brine wells, among 30 markets, there are 7 markets which potentially match up with 2 spots of hot spring and 16 markets with 3 brine wells in the geothermal power plants (corresponding with green boxes in Tables 5 and 6).

3.2.1 Site Visit

We have carried out 3 times site visit on western Java. First we visited to PT. Amerta Otsukat and PT. Yakult (soft drinks), PTPN VIII: Parakan Salak Unit and Cianten Unit (tea drying), and Hajj Ede cooperative (vetiver oil refinery). On second visit, we visited Indonesia Atsiri Council at the Ministry of Agriculture (vetiver oil), head office PTPN VIII, Rancabali Unit and Sinumbra Unit (tea drying) and PT. Indolakto and PT Indofood Asahi (soft drinks). Third, we visited Rancabolang unit (tea drying) near Patuha heat source and PT Geodipa Energy. Based on the information obtained, primarily related to production capacity and process-related, it is used to update the potential market.

The complete updated potential markets are shown in Table 7.

Table 7 Matrix of matched potential markets and geothermal resources in West Java

No	Company	Type of Product	Production Capacity	Volcanic Manifestation		Geothermal Waste Heat		
				Kawah Kamojang	Kawah Hujan	WWB	PB	GSB
				91.5 °C, 0.74 MW	94 °C, 0.76 MW	156 °C, 32. 9 MW	165 °C, 19.4 MW	173 °C, 185 MW
1	PO Gunt	Soya Powder	324 kg/ year					20 km, 70 ° C, 0.01 kW
2	PO Sawargi	Choco Powder	120 ton /year	7.32 km, 70 ° C, 4.19 kW	7.32 km, 70 ° C, 4.19 kW			
3	PO Karya Mulya	Jams	144 ton/ year	12.01 km, 82 °C, 1.57 kW	12.01 km, 82 ° C, 1.57 kW			
4	CV Tepung Hoenkwe Cap Boenga	Flour	60.87 ton/ year					13 km, 55 ° C, 1.93 kW
5	PO Wali Songo	Dried Mango	1,200 can/ year					18 km, 70 ° C, 0.03 kW

Table 7. Matrix of matched potential markets and geothermal resources in West Java (cont'd)

No	Company	Type of Product	Production Capacity	Volcanic Manifestation		Geothermal Waste Heat		
				Kawah Kamojang	Kawah Hujan	WWB	PB	GSB
				91.5 °C, 0.74 MW	94 °C, 0.76 MW	156 °C, 32. 9 MW	165 °C, 19.4 MW	173 °C, 185 MW
6	CV Glisindo	Soya Powder	5 ton/ year	12.93 km, 70 ° C, 0.23 kW	12.93 km, 70 ° C, 0.23 kW			
7	PT Tirta Fresindo	Minuman berkarbonasi	7,400 kL/ year					15 km, 57.2 ° C, 59.47 kW
8	PT Satya Sumba Cemerlang	Textile	480 ton/ year	10.12 km, 80 °C, 11.63 kW	10.12 km, 80 ° C, 11.63 kW	19 km, 80 °C, 11.63 kW		
9	PT Bintang Indospin Industri	Textile	8,550 bale/ year	16.33 km, 80 ° C, 37.58 kW	16.33 km, 80 ° C, 37.58 kW			
10	PT Sejahtera Bintang Abadi Textile	Textile	20,000 bale/ year	12.75 km, 80 ° C, 87.91 kW	12.75 km, 80 ° C, 87.91 kW	18 km, 80 °C, 87.91 kW		
11	PT Tribintang Lokawarna, Laswi, Bandung	Textile	269 ton/ year	11.73 km, 80 °C, 6.52 kW	11.73 km, 80 ° C, 6.52 kW			
12	PT Pavettia Atsiri Indonesia	Vetiver oil	1,500 kg/ year					20 km, 140 - 150 °C, 0.23 kW

Table 7. Matrix of matched potential markets and geothermal resources in West Java (cont'd)

No	Company	Type of Product	Production Capacity	Volcanic Manifestation		Geothermal Waste Heat		
				Kawah Kamojang	Kawah Hujan	WWB	PB	GSB
				91.5 °C, 0.74 MW	94 °C, 0.76 MW	156 °C, 32. 9 MW	165 °C, 19.4 MW	173 °C, 185 MW
13	PT ISAM Bandung	Milk	100 ton/ day			9 km, 130 - 150 °C, 948.38 kW		
14	Amerta Indah Otsuka (Pocari Sweat)	Isotonic Drink	45.8 kL/ day					13 km, 70 - 80 °C, 188.61 kW
15	Indolakto	Milk	217,100 ton/ year					13 km, 70 - 93 °C, 2,940.82 kW
16	Asia Sejahtera Perdana Pharmaceutical (Kratingdaeng)	Energy Drink	100 kL/ day			20 km, 70 - 80 °C, 411.82 kW		
17	PT Djojonegoro C-1000	Vitamin Healthy Drink	46.7 kL/ day					13 km, 70 - 80 °C, 192.32 kW

Table 7. Matrix of matched potential markets and geothermal resources in West Java (cont'd)

No	Company	Type of Product	Production Capacity	Volcanic Manifestation		Geothermal Waste Heat		
				Kawah Kamojang	Kawah Hujan	WWB	PB	GSB
				91.5 °C, 0.74 MW	94 °C, 0.76 MW	156 °C, 32. 9 MW	165 °C, 19.4 MW	173 °C, 185 MW
18	Yakult Indonesia Persada	Fermented Milk	247 kL/ day					13 km, 120 ° C, 1,783 kW
19	Patuahwatte tea PT Indorub Sumber Wadung	Black Tea	2,400 ton/ year				3 km, 98 - 120 °C, 170 kW	
20	PTPN VIII Sinumbra Unit	Black Tea	3000 ton/ year				5 km, 98 - 120 °C, 170.37 kW	
21	PT. Indofood Asahi	Beverage	389.6 kL/ day					13 km, 70 - 80 °C, 641.78 kW
22	PTPN VIII Kertamanah Unit	Black Tea	2470 ton/ year			3.7 km, 98 – 120 °C, 174,96 kW		
23	Samarang Vertiver Oil	Vertiver oil	1,500 kg/ year			(Kamojang Condensate; 46 °C, 19.2 MW) 6 km, 120-140 °C, 281.16 kW		

Table 7. Matrix of matched potential markets and geothermal resources in West Java (cont'd)

No	Company	Type of Product	Production Capacity	Volcanic Manifestation		Geothermal Waste Heat		
				Kawah Kamojang	Kawah Hujan	WWB	PB	GSB
				91.5 °C, 0.74 MW	94 °C, 0.76 MW	156 °C, 32. 9 MW	165 °C, 19.4 MW	173 °C, 185 MW
24	PTPN VIII Malabar Unit	Black Tea	4,290 ton/ year			14 km, 98-120 °C, 113,58 kW		
25	PTPN VIII Rancabolang Unit	Black Tea	1,900 ton/ year				98-120 °C, 256,46 kW	
26	Parakan Salak	Black Tea	3,000 ton/year					6 km, 98 – 120°C, 212,5 kW

Temperature differences between resources fluid and operating temperature in the markets are specified based on those data provided in **Table 15**. The temperature differences between potential markets and hot springs in West Java (12-22 ^{o}C) are relatively lower than those differences between demands and geothermal wastes heat (60-118 ^{o}C in majority). By setting up that the longest distance from hot springs to market is 20 km, it has been found that the distances from hot springs to markets vary from 8 to 17 km. This suggests that applying geothermal direct use from hot springs require long pipes and pipe insulation to prevent heat loss along the pipes during the hot water delivery. Therefore, economic aspect is important issue for this application. Meanwhile, with the same maximum distance of 20 km, for geothermal waste heat application, distances from resources to markets have been found to vary from 3 to 20 km. In order to acquire cost and benefit analysis of the application of both hot springs and geothermal waste heat, short visit to the field spanning from the resources to the markets is mandatory. Some tasks to be undertaken are:

1. Acquiring data of locations and capacities of the matched-up large scale enterprises to validate data previously extracted from internet.
2. Mapping up distances between matched-up resources and markets to validate the straight-line extracted distances between these spots previously extracted from internet.

3.2.2 Potential Candidates for Quick Scan

Based on the Table 7, there are 25 potential market consisting of:

- Tea drying, there are 5 locations. Of the five locations, Rancabolang and Kertamanah are the most potential candidate because of the distance that is closest to the source of waste heat
- Essential oil, there are 2 locations but only one adjacent to geothermal sources. It is vetiver oil refinery. Its location close to Kamojang. But the temperature level of the steam is not enough (condensate), so it is necessary to find another supply coming from abandon well. (**ITB may provide this information**)
- Beverage and soft drinks (Milk fluid included), there are 7 locations. Of the seven locations, there are 4 potential candidates which are located quite close to the source and a fourth in nearby locations (Industry cluster).
- Other candidates such as powder product and textile, heat duty is very small so it does not include potential candidates.

3.3 Quick Scan

3.3.1 Preliminary Technical Assessment of Potential Candidates

Based on our last site visit (updated on Table 7), we conclude that:

1. It needs to consider maximum temperature of geothermal waste heat because survey indicates users need temperature 120 – 130 °C, so the condensate is not needed (for Vetiver oil, softdrink and tea drying)
2. In order to get the correct data of heat consumption in large industry, we already do a site visit in several potential users.
3. It is worth examining how to reconcile between continuous heat supply of waste heat and batch heat consumption.

The potential candidates are soft drinks, tea drying and vetiver oil. Hereby the details of each selected candidate.

3.3.1.1 Vetiver Oil Distillation

a. Overview

Vetiver oil is produced by grass root from species of *Vetiveria zizanoides*. The main components in the root are vetivone alpha dan beta. These components give aroma of the vetiver oil. This property allows the root to be used as feedstock for producing the vetiver oil as main component of perfumes and for aromatherapy. In perfume products, the vetiver oil is used as fixative and main aroma component (Martinez et al., 2004). Therefore, the vetiver oil has high economic value.

Table 8 Data of export-import of vetiver oil.

Year	Export		Import	
	Volume (kg)	Price (US $)	Volume (kg)	Price (US $)
2002	79,714	1,973,451	2,572	46,312
2003	45,821	1,428,682	2,465	18,680
2004	58,444	2,445,744	2,231	51,308
2005	74,210	1,544,618	532	22,890
2006	75,199	2,085,458	12,297	31,397

(Source: http://comtrade.un.org/data/)

Data on exports and imports of vetiver oil last published by BPS in 2006. The data also published in comrate.un.org. After 2006, the BPS does not re-issue an export-import data essential oils from plant species vetiver via online. In world trade, vetiver oil from Indonesia is known as "*Java Vetiver Oil*". Table 8 shows that volume of Indonesia export fluctuates from year to year. This is caused by inconsistency of the vetiver oil quality (Kardinan, 2005). This inconsistency makes the position of Indonesia as he largest vetiver oil producer deminished and replaced by Haiti and Bourbon. The operating conditions in refinering vetiver oil affect the quality of the vetiver oil.

In addition to the volume of export - import that is fluctuating, vetiver harvested crops from arable land also decreased from year to year. The data of production and plantation area of vetiver grass is shown in Table 9.

Table 9 Vetiver grass produced from plantation area

Year	Area (Ha)	Production (Ton)
2008	2,372	111
2009	2,367	115
2010	2,354	377
2011	2,356	107
2012	2,355	80
2013	2,360	71
2014	2,365	75

(Source: Direktorat Jenderal Perkebunan, 2014)

b. User Description & Capacity

In West Java, a vetiver oil refinery factory have been in operation in the district of Samarang, Garut Regency. This factory belongs to H. Ede. In this factory, there are 4 distillation kettles in this factory to produce steam for steam distillation. Three kettles has been used for producing vetiver oil, while the other one is still under construction. These three kettles use fuels of diesel oil, used oil and firewood, respectively. A distillation kettle is capable of processing the grass as much as 2 tons for each batch and produces approximately 6 kg of vetiver oil. Production of vetiver oil is not carried out continuously, because the plantation of the grass requires quite long time (about 8-12 months, this is the time required from planting to vetiver produced for harvest) and also the availability of vetiver root of the grass is decreasing today.

c. Pipeline Route

The nearest source of waste heat of geothermal power plant from the refinery is in Kamojang. The distance between the source and the refinery is illustrated in the Figure 7.

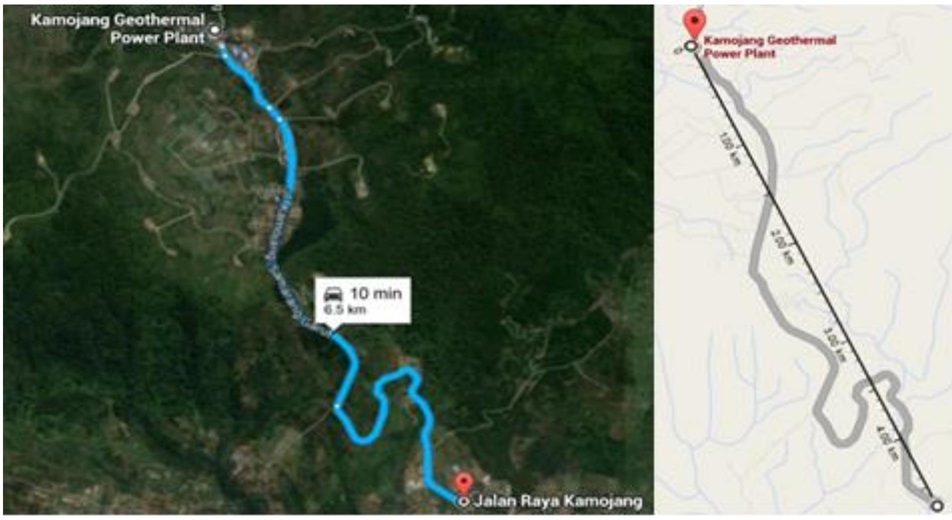


Figure 12 Distance between waste heat source with vetiver oil refinery location

Figure 7 show that the distance is about 6.5 km if it is measured along the main road. However, if the distance is measured in a straight line, it becomes only 4.69 km. However, the geothermal waste heat source only provides condensate whose temperature is about 46°C, much below the temperature required by the distillation units, i.e. 130°C. Identification work of geothermal waste heat originated from from brine should be done if the vetiver oil refinery in the Samarang District is selected as the user. Alternatively, some geothermal wells may be used to provide the heat.

Based on the map of geothermal wells in the area Kamojang that has been done before, there are some wells that can be taken into consideration. The wells are KMJ-16 and KMJ-18. Both wells are at the moment closed but their locations are relatively close to Samarang. However, the data about the temperature and heat load contained in the well are not available. Therefore, further identification of the potential geothermal wells for direct use purpose in Kamojang Geothermal Power Plant areas needs to be done.

d. Process Description & Duty Calculation

Extraction of oil contained in grass can be carried out in different methods. In general, there are 5 methods, i.e. *expression*, water distillation, water and steam distillation, steam distillation and solvent extraction. Among those methods, the steam distillation is generally used to extract vetiver oil. In this method, the steam is contacted directly with grass either in batch or continuous operation because this method is considered to be less costly and easy in operation. The schematics of units of the steam distillation is shown in Figure 8.

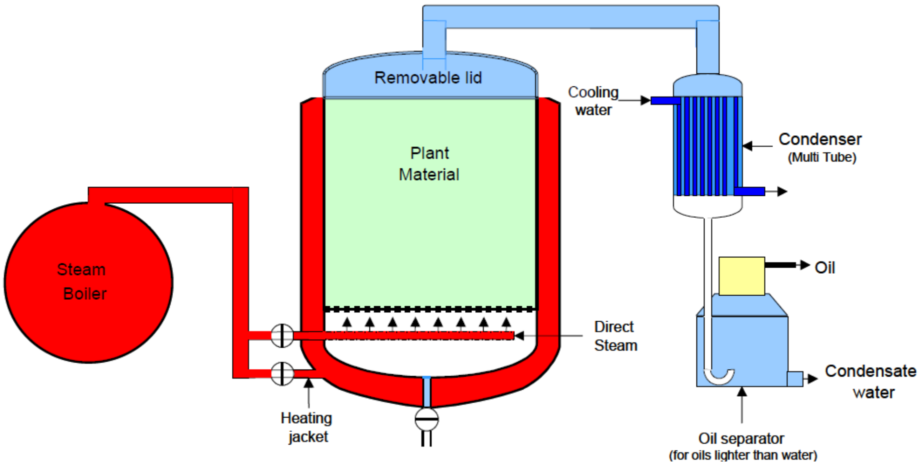


Figure 13 Shematics of equipment used in distillation method
(Source: UNIDO and FAO, 2005)

In the steam distillation method, the grass roots are loaded on a perforated grate below which a kettle to produce steam from water lies. In kettles the combustion of fuels produces saturated and wet steam which rises through the grass roots to vaporise the essential oil within the grass. In kettles, the water temperature slowly increases when the fuel is ignited until it produces steam. The resulting steam will pass through the grate and stack of the grass. Valve located at the top of the refinery unit is closed for 7 hours so that the steam does not flow out of the unit. The steam diffuses into the inside of the grass root material to allow the vetiver oil contained in the plant material to be evaporated. After 7 hours, the valve is opened for 5 hours to allow the vapour containing steam and vetiver oil vapour to flow through a series of condensers before being condensed as a mixture of vetiver oil and water. The total time required for each batch therefore is 12 hours. After passing through the condensers, the mixture of water and vetiver oil is separated in a screen cloth based on their density difference.

In the direct use of geothermal energy, heat supplied by geothermal fluid is used to generate steam in the steam distillation process. The proposed schematics of equipment in vetiver oil refining process utilizing geothermal fluid is as follows :

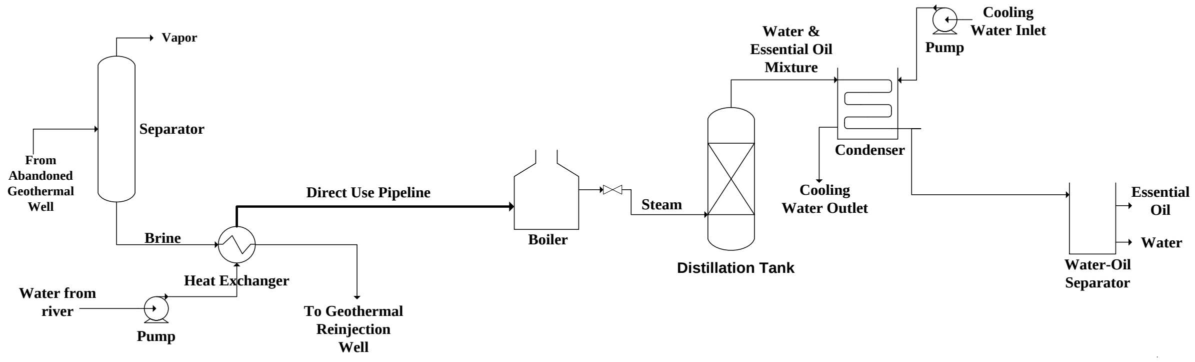


Figure 14 Process flow diagram for geothermal direct use to the vetiver oil refining process

A boiler is proposed to be constructed in the vetiver oil refining system to increase the steam temperature to that required by vetiver oil refinery, i.e. 130°C if this temperature is not achieved by heat exchanger alone to extract heat from the brine. Otherwise, the boiler is not needed.

The energy needed for each batch right is 12,415.6 MJ. Its production capacity is only known production capacity per batch (6 kg of vetiver oil per 2 ton of the grass). Mass flow rate of steam needed during the refining process of vetiver oil is as much as 2 kg/h/kg of dry vetiver roots (Suwarda, 2009). For the capacity of raw materials as much as 2,000 kg of dry vetiver roots, the mass flow rate of water vapor that is required is 4,000 kg/h at 130°C and pressure of about 3 bar. The pipe diameter which is needed to transport steam as much as 4,000 kg / h can be determined as follows:

$$ID = C\sqrt{\frac{F}{v}}$$

where, ID = inner diameter of pipe; C = Constant (13,54 for english unit dan 1133 for SI unit); F = volumetric flow rate of fluid (m^3/s) ; v = velocity of fluid inside the pipe (m/s).

Steam flow rate in the pipes is equal to 4,000 kg/h or 1 m³/s and the velocity of the steam flowing in the steam pipes is typically equal to 80 ft/s or at 26.67 m/s. Thus, the diameter of the pipe required is

$$ID = 1133\sqrt{\frac{1\,m^3/s}{26.67\,m/s}}$$

$$ID = 219.27\,mm = 8.63\,inch$$

e. Existing Utility Cost

The utility cost of the existing vetiver oil refining plant is calculated by determining the amount of fuel used to generate steam in each production batch. The cost of process water supply is not calculated, because the water used in the existing plant is available for free. Based on data obtained from the first site visit, it is known that the main fuel used in the refining process of vetiver oil is trace oil.

Trace oil is used, because of its availability and also its price is cheaper than the prices of other types of fuels. The price of the trace oil is Rp 4,000/liter. Each production batch requires 300 liters of oil trace. Thus, the cost of providing fuel for each batch of production is Rp 1,200,000.

3.3.1.2 Tea Industry

a. Overview Tea Industry in Indonesia

Globally, the tea market growth rate is about 1.7% a year since 2005 (Dallinger & Claasen, 2013). In 2001, Indonesia was the fifth greatest tea producer in the world following India, China, Srilanka and Kenya with production capacity of 166,867 MT. However, the ranking of Indonesia steadily decreases up to 2011 with the capacity of 142,400 MT and it ranked the eighth as shown n Figure 10.

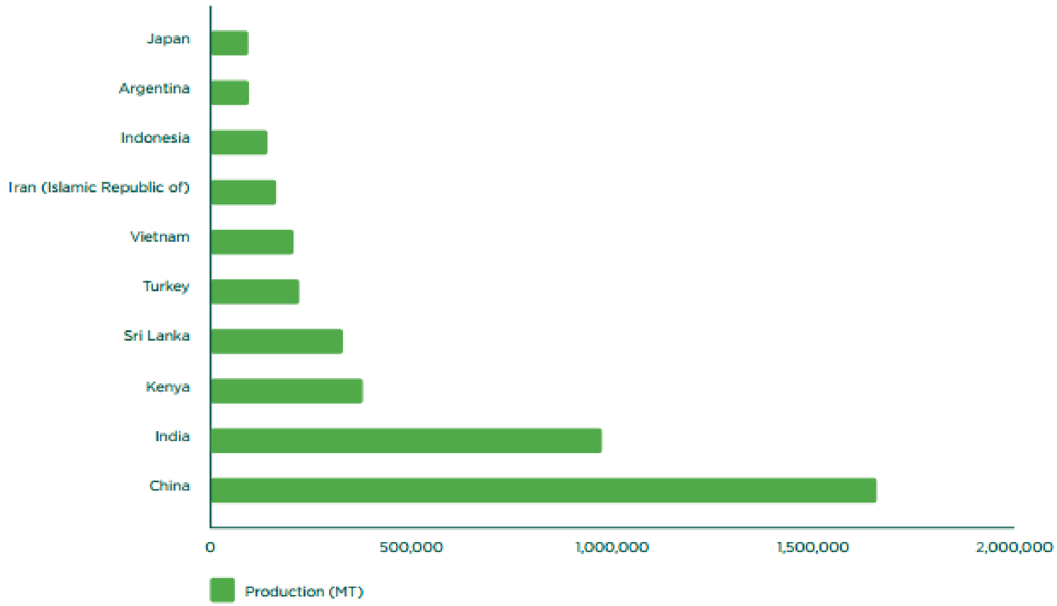


Figure 15 Production capacity of tea in some countries

(*Source:* IDH, 2013)

The drop of Indonesia tea production capacity is due to limited plantation area. In 2010, the area available for tea plantation was 124,400 hectares. Three years later, the area reduced to 123,500 hectares. This affects directly to the tea production capacity from 156,604 to 146,682 tonnes within the same period. Data of tea production is shown in Table 10. The data shows that the largest tea producer in Indonesia is West Java province which contributes to 72% of national production capacity or approximately 108,902 ton in 2012 (Directorate General of Plantation, 2013)

Table 10 Data of tea production of Indonesia from 2010 to 2014

Year	Production capacity (Ton)
2010	156,604
2011	150,776
2012	145,575
2013*	146,682
2014**	147,704
Average growth (%/year)	-1,43

*) Temporary data **) Estimated data

Source : Ministry of Agriculture, 2015

b. Overview of Tea Processing

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

Tea processing using CTC method can be seen in Figure 2. After picking up from tea plantation, tea leaves are withered at atmospheric condition. The purpose of the withering is to reduce the moisture content from 80% to 68%. In this withering stage, air is passed on the surface of tea leaves. The withering process takes 12 hours with leave reversal after 6 hours. This pends on weather condition. At the end of this process, the leaves become weak and ready to be broken down. In addition, during this process, there is a bio-chemical process to attain better aroma and taste.

After withering, the tea leaves undergo rolling. During this process the tea leaves are broken down into still coarse sizes. In CTC method, the withered tea leaves are broken down into more uniform sizes. After that, they are fed to CTC machine to undergo cut, tear and curling processing. Out of the CTC machine, the curled tea is brought to a moving conveyer where it undergoes fermentation in which the enzyme contained in tea in contact with air is oxidised. This fermentation improves taste, colour and strength of tea. This process is controlled by moving speed. The fermentation process may take half to two hours.

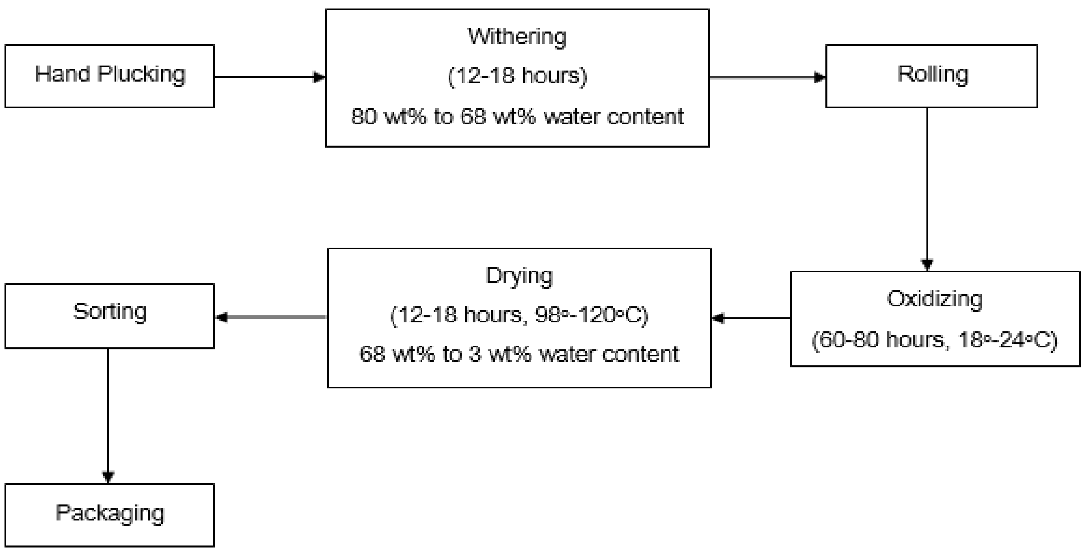


Figure 16 Tea processing diagram

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

c. User Description and Capacity

One tea plantation potential to use heat from geothermal brine is Kertamanah tea plantation. This plantation is passed by a geothermal injection pipe of Wayang Windu geothermal power plant. The plantation was established in 1926 covering 4 villages, i.e. Margamukti, Pangalengan, Margamulya and Tarumajaya. The plantation area locates 60 km south of Bandung at altitude 1400-1600 meters above the sea.
Kertamanah plantation produces high quality tea and has two concurrent methods of producing tea in one factory, i.e. CTC and orthodox methods, which is the only plantation with such concurrent methods under management of PTPN VIII. Its tea processing units produce 2,500 tonnes of dry tea a year and can process up to 50 tonnes wet top picked-tea in a day. In 1999, this plantation was awarded Certificate of Quality Management System ISO 9002 and in 2005 certificate of HACCP to ensure that the processing is hygienous and consumable.

d. Pipeline Route

Figure 12 that tea Kertamanah plantation site locates about 3.6 km from the geothermal power plant of Wayang Windu. Therefore, the plantation is potential candidate to utilise the geothermal brine heat.

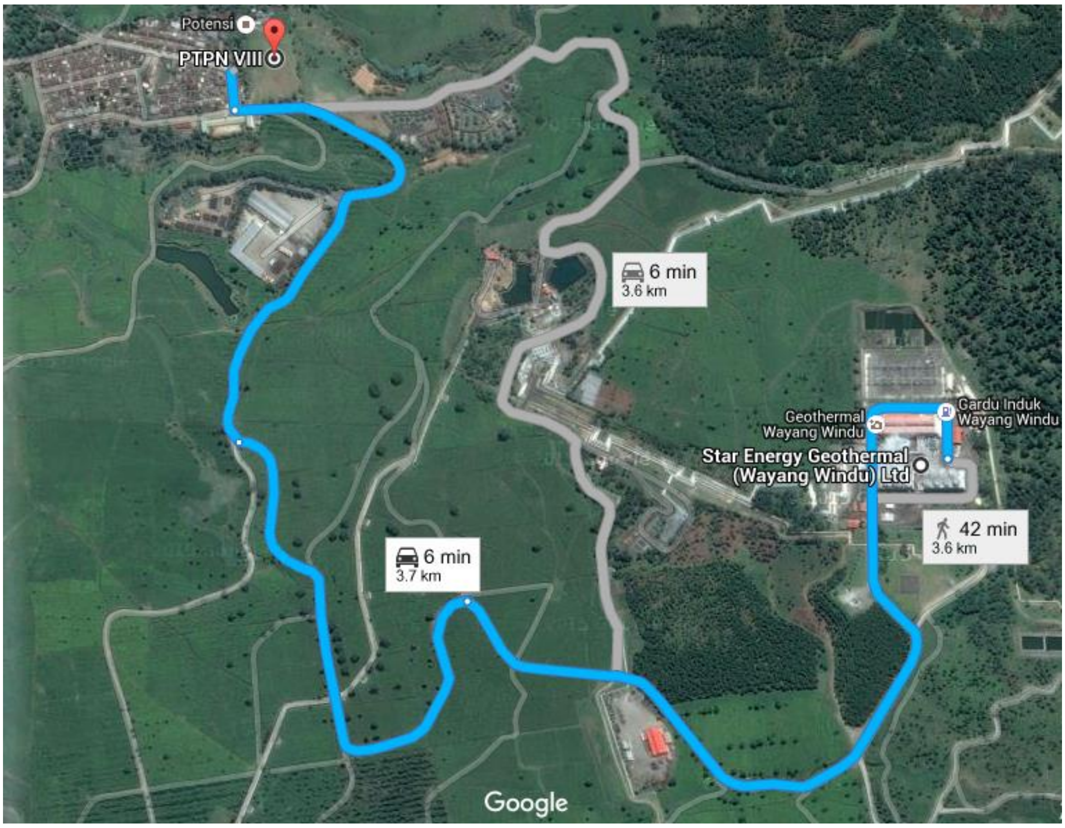


Figure 17 Map showing the distance of Kertamanah tea plantation from Wayang Windu Power Plant.

Table 7 shows that heat load produced by brine of Wyang Windu brine is approximately 32.94 MW at temperature of 156ºC. In addition, the other heat waste from this power plant originates from condensate with estimated heat load of 18 MW at temperature of 50ºC.

e. Technical Aspect

The drying process takes the most of energy in tea processing (Temple and Boxtel, 1999). It takes 15-20 minutes and requires hot air at 125-130ºC to reduce moisture content from 68% to 2%. In general tea drying is carried out using *Fluidized-Bed Dryer* with a belt conveyer to deliver tea to be dried. The thickness of the tea stacking is another parameter which determines the uniformity of the drying. The thickness of 7-8 cm is considered to be optimum to get uniform dryness of the tea. Because the prices of fossil fuels are expensive, some plantations use firewood to fulfil their requirement for drying. In this case, the temperature of hot air becomes unstable depending on the wetness of the wood. Off course, this will affect the drying duration and uniformity of the tea dryness.

Figure 13 shows a process flow diagram of tea drying utilising brine waste heat for tea drying. The brine flow contains minerals which may cause scaling and corrosion.

Moreover, the brine pressure must be maintained when it is is injected. Therefore, a water flow is required to bring heat from the brine into the tea drying unit. Heat from the brine is taken out using a heat exchanger of *shell and tube* type. The brine flow, after being heat exchanged, is reinjected into injection wells. The water may be taken from rivers in plantation area. In the heat exchanger, the water may be converted into steam.

In drying unit, the steam flows in pipes over which dry air is blown by a *blower* to take heat from the steam and subsequently dry the tea stacking. The hot air flows through the stacking from the bottom the stacking tray and flows out of the top of the stacking.

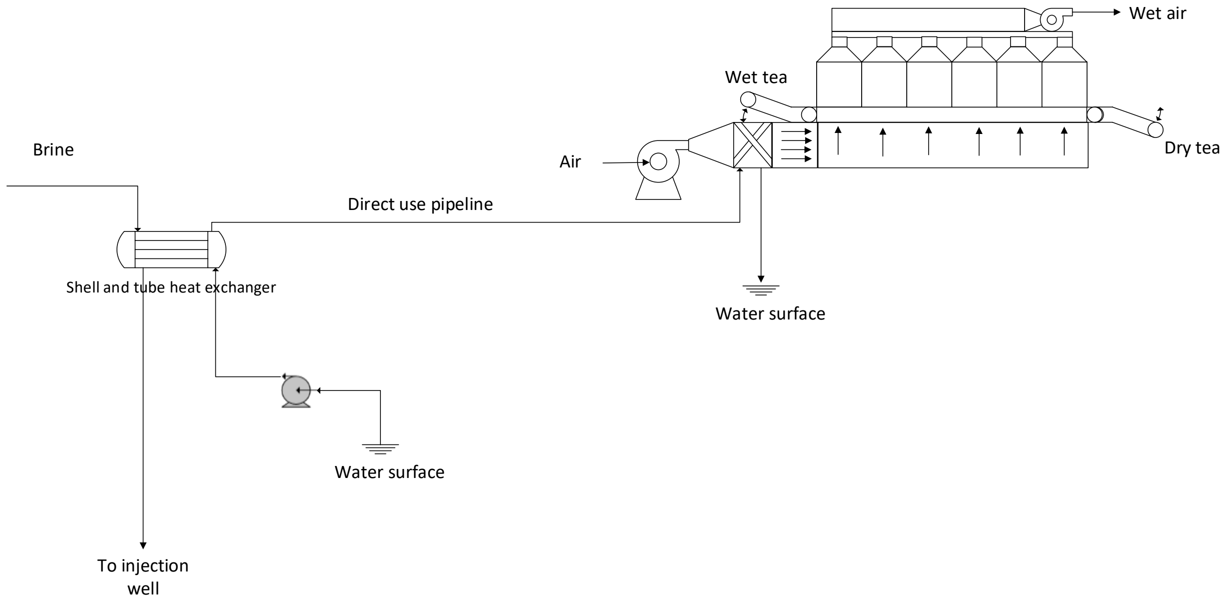


Figure 18 Process flow diagram of geothermal brine waste heat utilisation for tea drying

From market survey, it is known that the duty required to dry tea leaves in Kertamanah tea plantation is approximately 147.66 kW. This heat can be taken from the brine waste heat of Wayang Windu. It is assumed that to bring heat from the brine, water at temperature of 20oC is brought to the heat exchanger *shell and tube* and flows out of the heat exchanger at 145oC as steam. With steam heat capacity of $C_{p,w} = 4.2\ kJ/kg\ °C\ C_{p,v} = 2\ kJ/kg°C$ and latent heat of $= 2{,}256\ kJ/kg$, the flow rate of steam required is

$$m = \frac{Q}{(C_{p,w}\Delta T + L + C_{p,v}\Delta T)} \qquad (1)$$

$$m = \frac{(147.66)}{(4.2)(100-20) + 2{,}256 + (2)(145-100)} = 0.055\frac{kg}{s}$$

By assuming that the steam has density of $\rho = 2.24\frac{kg}{m^3}$ and pressure of approximately$P = 4.158\ bar$, the the volumetric rate of the steam is $= 0.0245\frac{m^3}{s}$. Typically, the velocity of the steam is approximately $= 80\frac{ft}{s} = 27.2\frac{m}{s}$. Therefore, the diameter of the pipe required to transport the steam is as follows

$$D(cm) = 113{,}3\sqrt{\frac{0.0245}{27.2}} = 3.4\ cm \approx 1.35\ inch \quad (2)$$

f. Existing Cost Utility

In tea drying, most of the tea processing in Indonesia use firewood as heat source. In order to produce 1 kg of dry tea, the amount of firewood needed is more or less 1.41 kg. The survey to the tea drying site showed that the cost of purchasing firewood is in average Rp 400 per kg and the cost of the whole tea processing is approximately Rp. 1200/kg of dry tea. Therefore, about 25% of the cost is used for tea drying. If gas had been used as fuel, the cost would have been Rp. 2800/kg of dry tea.

3.3.1.3 Drink industry

a. Introduction

Direct utilization of geothermal energy is now venturing into the food industry. In the food processing industry there is a heating process involved. This process can take the heat from a geothermal source. At Cicurug region, Sukabumi, West Java, there is a food industry complex adjacent to Mount Salak geothermal sources. Some food factories there are PT. Djojonegoro C-1000, PT. Indolakto, PT. Asahi Indofood, and Yakult Indonesia. Next to the complex, there is a drink factory owned by P.T. Amerta Indah Otsuka.

PT. Djojonegoro C-1000 is a company that produces isotonic drinks and PT. Indolakto is a manufacturer of dairy product. PT. Asahi Indofood is a producer of bottled drinks. All these three companies cannot be reviewed for implementation of the geothermal heat in their heating process especially for milk and bottle sterilization since there are obstacles in gain the data and survey the industry. But it is possible to utilize the geothermal energy for the industry. P.T. Amerta Indah Otsuka producing isotonic drinks has been assessed, but it cannot be a candidate in the application of geothermal heat because it has already owned steam-producing unit derived from its gas turbine power plant. PT Yakult Indonesia, a fermented milk beverage company, may be a candidate for the implementation of geothermal utilization because survey on site shows that this company requires the supply of heat to the process of milk and bottle sterilization.

b. Beverage Processing

Yakult and Process Description

Yakult is a fermented milk drink containing Lactobacillus casei Shirota strain that can reach the intestines alive. This beverage may help maintain healthy digestion and suppress the growth of harmful bacteria in the digestive tract.

Yakult production process starts from the stage of mixing raw materials consisting of skimmed milk powder, glucose, sucrose, flavour, and sterilized water (Figure 14). Meanwhile, the bacteria Lactobacillus casei Shirotai stain cultivates in the 'seed tank' in the laboratory. The next step is sterilization. At this stage the raw material mixture is sterilized at high temperatures known as ultra-high-temperature. Then after cooled into a 37 °C, the solution is transferred through a piping system to the culture tank to mix the bacteria with raw materials. At this tank solution is to be fermented by the bacteria for one week until the bacteria reach the ideal concentration is equal to 108 cfu mL-1. Then the concentrate is sent to the mixing and storage tanks. Tank is cooled to a temperature of 2°C. Flavouring, syrups, vitamins, and calcium added to the concentrate. The next stage is the bottling and packaging.

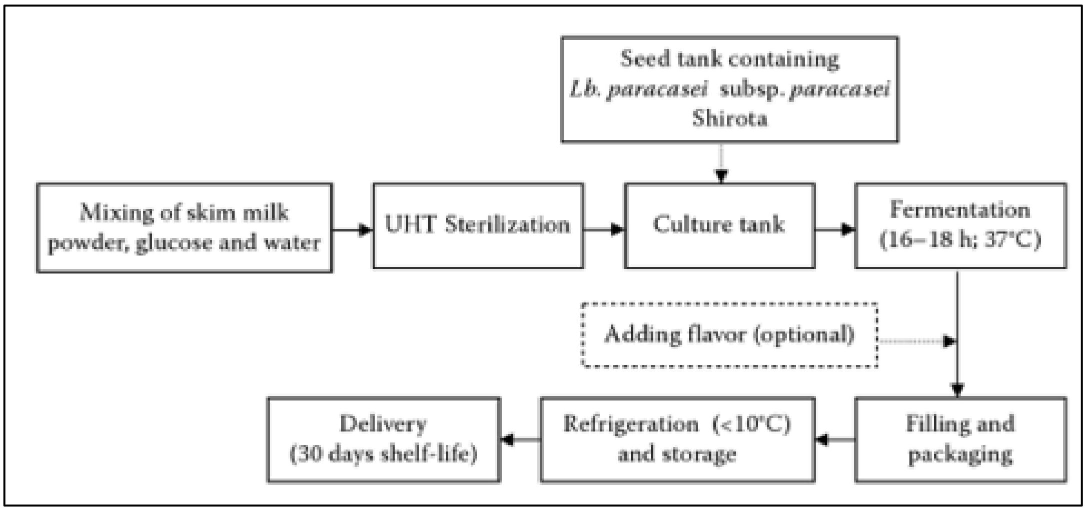


Figure 19 Fermented Milk Processing

PT. Djojonegoro C-1000 and PT. Indofood Asahi

PT Djojonegoro produces C-1000 that is a vitamin drink containing of C vitamin. This beverage may help maintain stamina and healty. PT Indofood Asahi produces flavoured beverages that help in refreshing the body. Their production process approximately can be seen in (Figure 15). All ingredient will be mix in mixing tank, then it will be cooled to make it durable by cooling process on shelf life stability of the product. The next step is filling it to the bottle or carton embed aluminium foil. After the mixing product has been filled, it will be warming 57°C in water to sterilize the bottle with LTLT (low temperature, long time). The next stage is packaging.

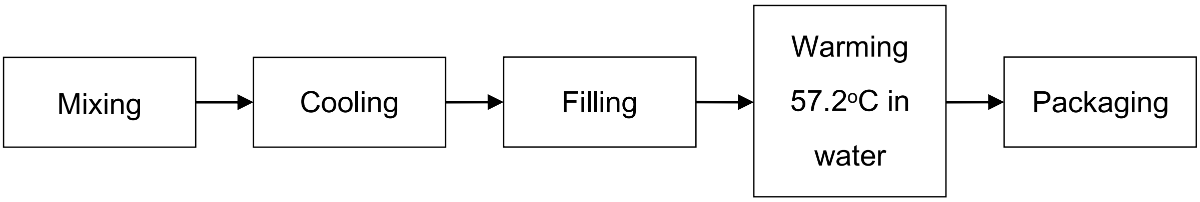


Figure 15. Beverage processing

PT. Indolakto

PT. Indolakto produces milk beverage with various flavour like chocolate, strawberry and mocha. The milk beverage is processed by UHT (ultra-high temperature). The production process approximately can be seen in Figure 16. The main processes are sterilization, homogenization, cooling, and aseptic packaging.

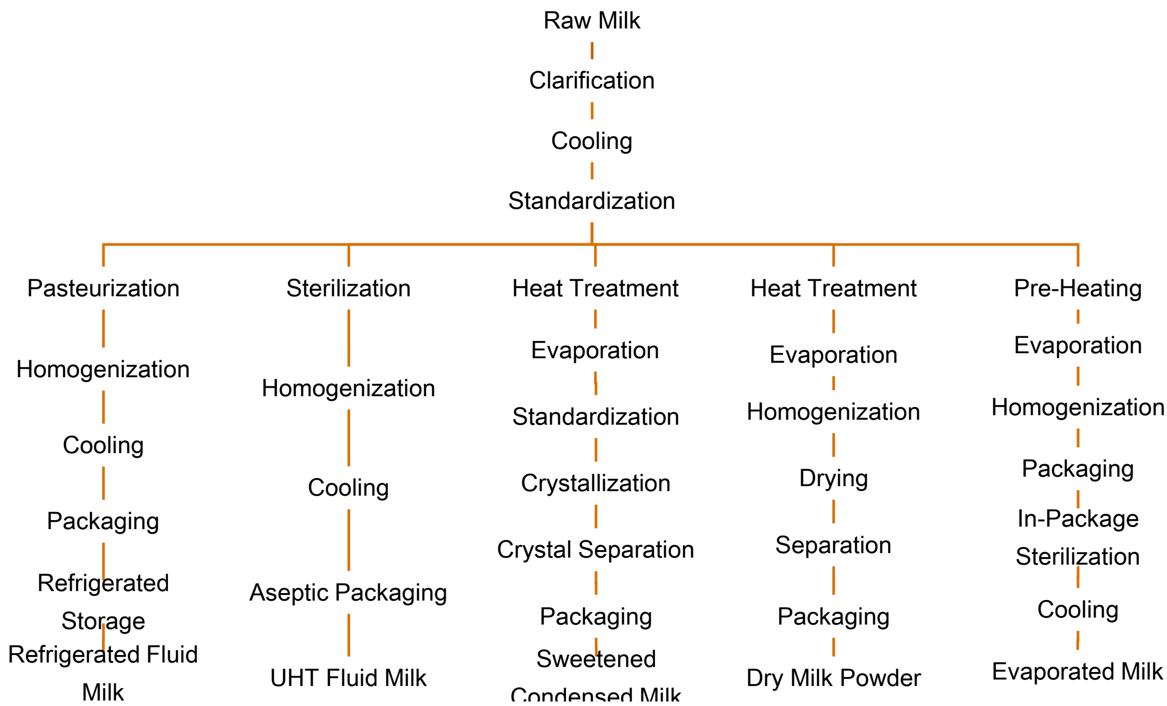


Figure 16. Milk processing

Ultra High Temperature

Ultra high temperature (UHT) milk sterilization is a technology that can extend the shelf life. UHT technology generally operates at a temperature of 140°C for 5 seconds which will then be followed by a cooling process (Gedam, et al., 2007). Method of heating of the UHT technology uses indirect heating such as plate and frame heat exchangers and tubular type heat exchangers such as shell and tube or scraped surface heat exchanger. Another method is by steam infusion of UHT technology. Below is an explanation of the process heat supply of UHT technology:

a. Indirect heating

In this heating method, a product with a heating medium does not contact directly through a heat exchanger. Heat exchanger used is a plate and frame, tubular heat exchangers and scraped surface exchanger.

b. Infusion steamed

The basic concept of this method is to put in the product stream at high pressure through a nozzle into a distribution chamber that has been filled with low pressure steam at culinary quality. This system is characterized by including a number of small volumes of product through the flow steamed chamber. The product is then collected at the bottom of the chamber and is fed forward via a timing pump.

c. Production Capacity

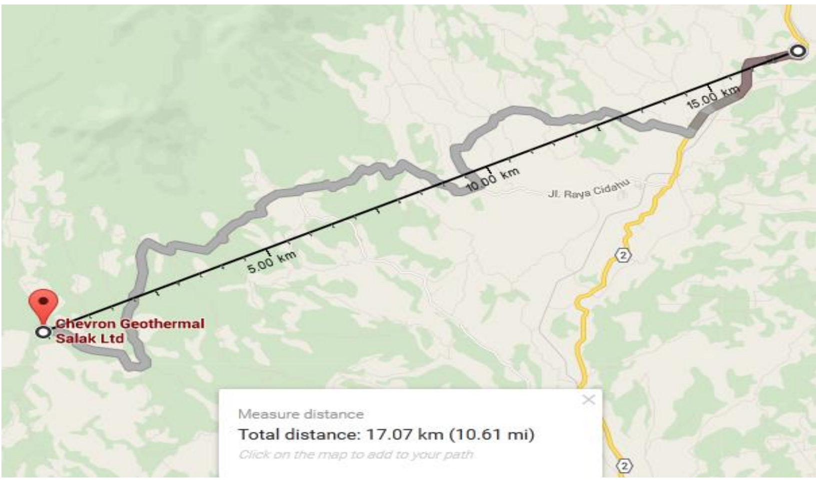
Based on the data obtained, the production capacity of PT. Djojonegoro C-1000 amounted to 46,700 liters per day and the duty is 192.32 kW with bottle sterilization temperature of 70-80°C.

PT. Indolakto has a production capacity of 21,700 tons per year and the duty for bottle sterilization unit is 2,941 kW with temperatures of 70-93°C.

PT. Asahi Indofood has a production capacity of 389.6 tons per day with duty of 641.78 kW for heating the bottle sterilizing with temperature of 70-80°C.

PT Yakult Indonesia production capacity is 3.8 million bottles per day. Temperature steam used for sterilization of milk is at 140°C for 16 minutes with a total duty of 10,874kW every day. While the heat required for the sterilization process of packaging is 698.29kW. Steamed supplied is equal to 210 kg/h

d. Pipeline Route



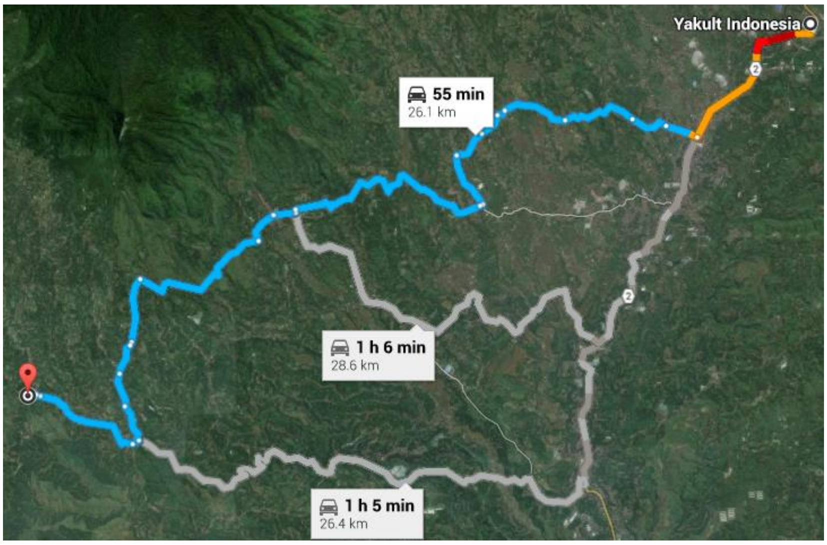
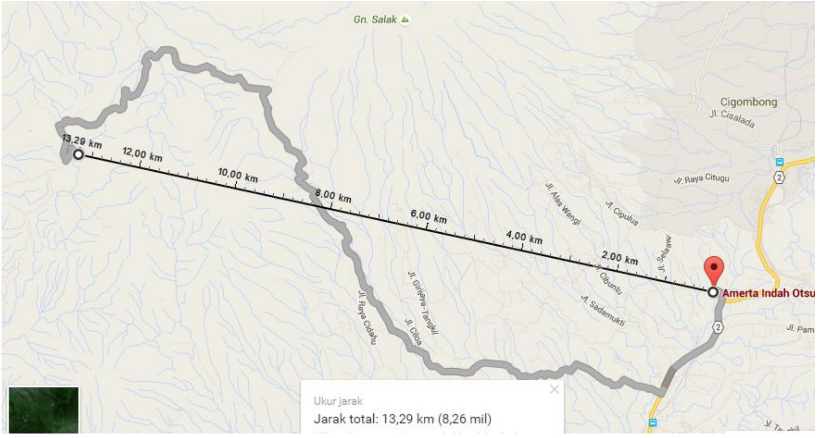


Figure 207 Geothermal Source (Mt. Salak) and Food Processing Industry



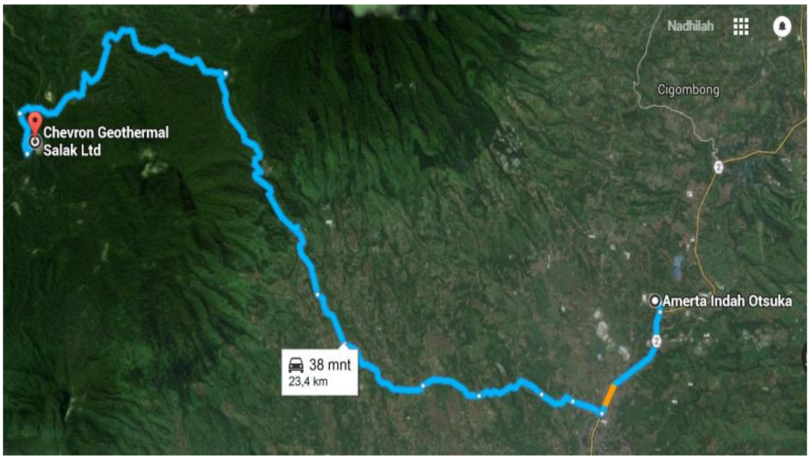


Figure 218 Geothermal Source (Mt. Salak) and PT. Amerta Indah Otsuka Location

The potential geothermal resources for food processing industry originate from geothermal field in Mount Salak. The distance between geothermal field and the food industry region consisting of PT. Djojonegoro C-1000, PT. Indolakto, PT. Asahi Indofood, and Yakult Indonesia is 17.07 km if the distance is assumed to be withdrawn straight away and if it is assumed in accordance with a landline which has been built, the distance between the geothermal field with the target industry amounted to 26.1 km. While the distance between the Mt. Salak Geothermal and PT. Amerta Indah Otsuka located outside the food industry complex is 13.29 km if the distance is assumed to be withdrawn in straight line and if it is assumed in accordance with a landline which has been built, then the distance is of 23.4 km. Distance described above is assumed to be the distance in the piping system to send steam to the location of the food industry.

e. Technical Aspect

Geothermal field that used is Mount Salak which is a liquid dominated field. The application of direct use system is described in Figure 19.

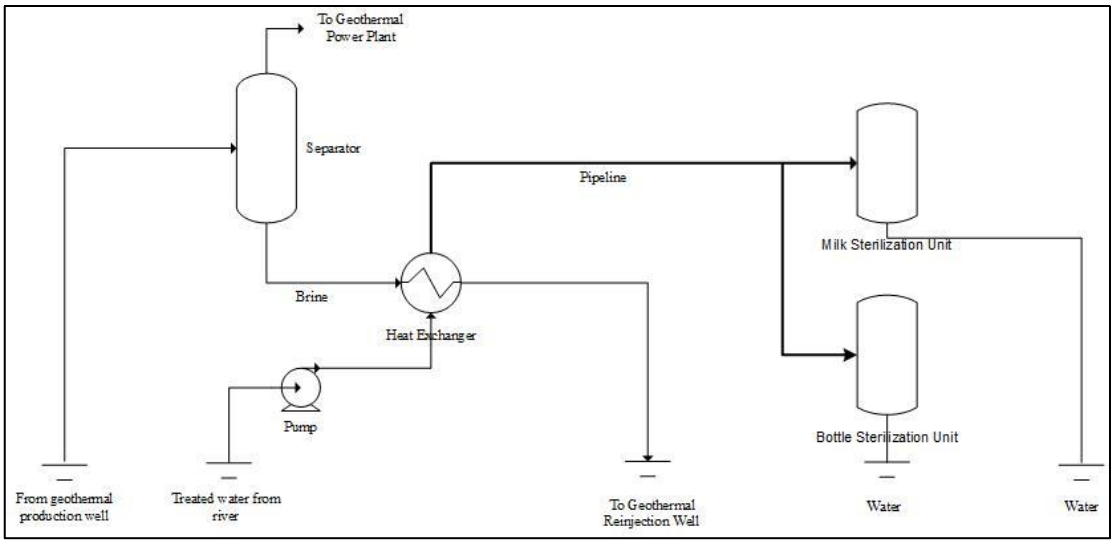


Figure 229 Direct Use Process Description

Geothermal energy produced from geothermal wells is liquid dominated field. Before the steam is sent to the food industry, the geothermal fluid will be separated in the separator to separate steam and brine. The steam will be delivered to the power plant while the brine will be used for heating in the food industry. Brine will then be exchanged with treated water from the river that had been prepared beforehand. Then the steam that has been heated by utilizing the heat from geothermal fluid will be sent directly through a distribution piping system, meanwhile the cold brine will be injected back into the geothermal wells. Steam coming out of the piping system will then enter the unit of milk and packaging sterilization. Vapour mass flow rate of water needed to run the milk sterilization process is of 210 kg per hour with sterilized milk capacity of 10,300 kg per hour. Steam pressure is equal to 4.67 bar. Pipe diameter needed to transport 210 kg per hour steam can be determined as follows:

Erosional velocity of steam in pipeline system

The allowed steam velocity in the pipe can be calculated using the following equation:

$$v = \frac{100}{(\rho)^{0.5}}$$

The density of water vapor on the operating conditions of the distillation (150 °C and 4.67 bar) is 2:55 kg / m^3, then

$$v = \frac{100}{(2.55)^{0,5}}$$

$$v = 62.60\frac{m}{s} = 20.87\ ft/s$$

The value is in conformity with the maximum speed limit allowed steamed to prevent erosion (maximum of 80 ft/ s).

Pipeline diameter calculation

Steam pipe diameter is calculated using the following equation:

$$ID = C\sqrt{\frac{F}{v}}$$

where, ID = inside diameter; C = constant (13.54 in english and 1133 units in SI units); F = fluid flow rate (m3 / s); v = velocity of fluid in the pipe (m / s). Steam flow rate of water flowing in the pipes is equal to 210 kg / h or 0023 m3 / s, then

$$ID = 1133\sqrt{\frac{0.023\ m^3/s}{62.6\ m/s}}$$

$$ID = 21.65\ mm = 0.85\ inch$$

f. Existing Cost

PT. Djojonegoro C-1000

Based on the above data, the heat required for the process of sterilizing bottles in isotonic beverage industry for 192.32kW or equal to 165 365 kcal per hour. If we assumed yield of the process of the formation of steam is 80%, then the calorie needed by the calculation is equal

$$165365 \text{ kcal per hour x} \frac{100}{80} = 206706.25\ kcal\ per\ hour$$

If the Lowest Caloric Value for diesel oil is 10000 kcal / kg, then the amount of fuel consumed is

$$\frac{206706.25\ kcal/hour}{10000\ kcal/kg} = 20.7\ kg/hour$$

If the specific weight of diesel oil amounted to 0.85kg / L, then the amount of fuel consumed is equal

$$\frac{20.7\ kg/hour}{0.85\ kg/L} = 24.35\ Litre\ per \text{ hour}$$

The price of diesel oil per liter in 2015 is Rp6700, so the total cost for utilization is

$$24.35\ Litre\ per \text{ hour x} \frac{24 \text{ hours}}{1\ days}\ x\ \frac{30 \text{ days}}{1 \text{ moths}}\ x\ Rp\ 6700/L\ = Rp117{,}464{,}400\ \ every\ months$$

PT. Indolakto

Based on the above data, the heat required for sterilization of milk and bottle in the industry for 2941kW or equivalent to 2,528,804 kcal per hour. If we assumed yield of the process of the formation of steam is 80%, then the calories needed by the calculation is equal

$$2528804 \text{ kcal per hour x} \frac{100}{80} = \ 3161005 \ kcal \ per \ hour$$

If the Lowest Caloric Value for diesel oil is 10000 kcal / kg, then the amount of fuel consumed is

$$\frac{3161005 \ kcal/hour}{10000 \ kcal/kg} = \ 316.1 \ kg/hour$$

If the specific weight of diesel oil amounted to 0.85kg / L, then the amount of fuel consumed is equal

$$\frac{316.1 \ \ kg/hour}{0.85 \ kg/L} = 371.88 \ Litre \ per \text{ hour}$$

The price of diesel oil per liter in 2015 is Rp. 6700, so the total cost for utilization is

$$371.88 \ Litre \ per \text{ hour x} \frac{24 \text{ hours}}{1 \ days} \ x \ \frac{30 \text{ days}}{1 \text{ moths}} \ x \ Rp \ 6700/L \ \ = Rp1{,}793{,}960{,}470 \ \ every \ months$$

PT. Indofood Asahi

Based on the above data, the heat required for the process of sterilizing bottles in the beverage packaging industry amounting to 641.78 kW, equivalent to 551 831 kcal per hour. If we assume that yield of the process of the formation of steam is 80%, then the calories needed by the calculation is equal to

$$551831 \text{ kcal per hour x} \frac{100}{80} = \ 689788.75 \ kcal \ per \ hour$$

If the Lowest Caloric Value for diesel oil is 10000 kcal/kg, then the amount of fuel consumed is

$$\frac{689788.75 \ kcal/hour}{10000 \ kcal/kg} = \ 69.0 \ kg/hour$$

If the specific weight of diesel oil amounted to 0.85kg / L, then the amount of fuel consumed is equal

$$\frac{69.0 \ \ kg/hour}{0.85 \ kg/L} = 81.16 \ Litre \ per \text{ hour}$$

The price of diesel oil per liter in 2015 is Rp. 6700, so the total cost for utilization is

$$81.16 \ Litre \ per \text{ hour x} \frac{24 \text{ hours}}{1 \ days} \ x \ \frac{30 \text{ days}}{1 \text{ moths}} \ x \ Rp \ 6700/L \ \ = Rp391{,}475{,}403 \ \ every \ months$$

Yakult

Based on the above data, the heat required for sterilization of milk and bottle in the industry yakult for 10874kW or equivalent to 9,349,957 kcal per hour. If we assumed yield of the process of the formation of steam is 80%, then the calories needed by the calculation is equal

$$9349957 \text{ kcal per hour x} \frac{100}{80} = 11687446.25\ kcal\ per\ hour$$

If the Lowest Caloric Value for diesel oil is 10000 kcal / kg, then the amount of fuel consumed is

$$\frac{11687446.25\ kcal/hour}{10000\ kcal/kg} = 1168.7\ kg/hour$$

If the specific weight of diesel oil amounted to 0.85kg / L, then the amount of fuel consumed is equal

$$\frac{1168.7\ kg/hour}{0.85\ kg/L} = 1374.94\ Litre\ per \text{ hour}$$

The price of diesel oil per liter in 2015 is Rp. 6700, so the total cost for utilization is

$$1374.94\ \ Litre\ per \text{ hour x} \frac{24 \text{ hours}}{1\ days}\ x\ \frac{30 \text{ days}}{1 \text{ moths}}\ x\ Rp\frac{6700}{L} = Rp6{,}632{,}710{,}560\ every\ months$$

3.3.1.4 Onshore Northwest Java Basin (Potential Hot Sedimentary Aquifer?)

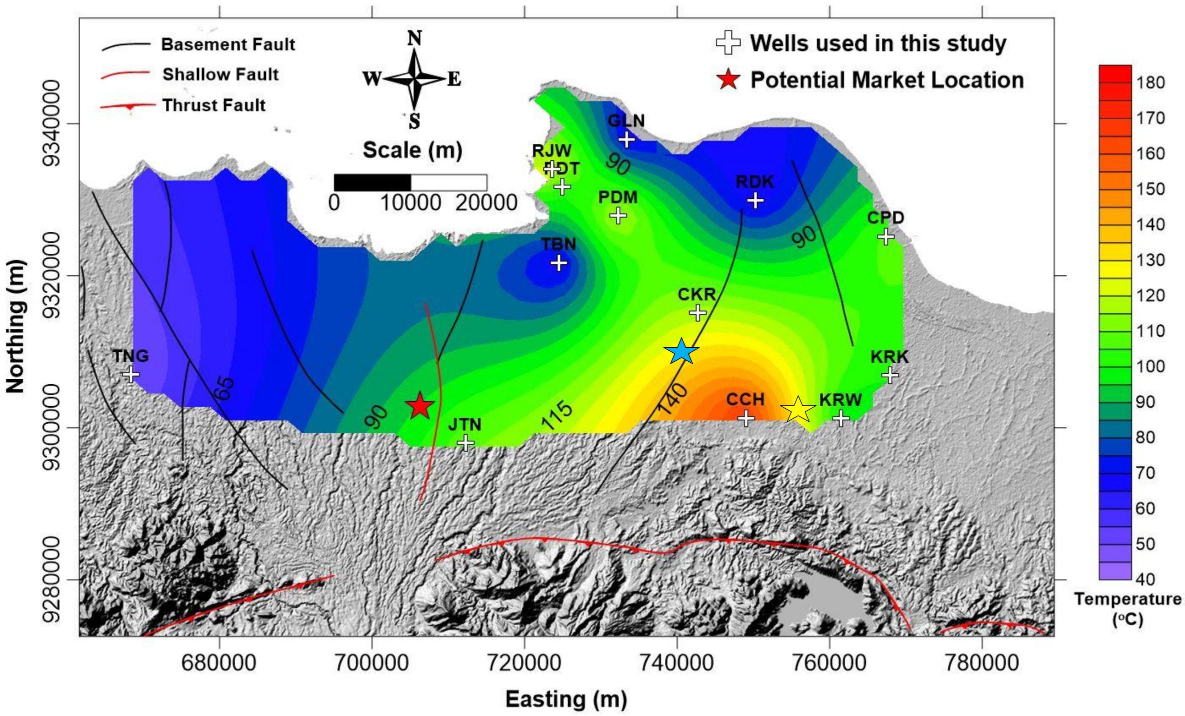


Figure 23 showing locations of potential markets for potential hot sedimetary aquifer

★ = Jababeka Industrial Estate

★ = Milk Factory

★ = Karawang International Industry City

Quite different from Hot Springs and Manifestations, where their temperatures and heat loads are clearly defined. There is no firm indication that in Northwest Java Basin, present hot aquiferat certain depth. Although some old oil and gas data proved that there was an anomaly of temperature gradient at some depths, but since the data is quite sparse and no well has been drilled to prove the availability of hot aquifer, it is still needed further study on this case. However, following information about some potential markets in Northwest Java Basin Area can be highlighted which can be seen as future prospect of applying geothermal direct or indirect use from hot aquifer.

Milk Factory

There is a milk factory in the region south of Jababeka.. It will have a large heat demand and might therefore be a potential customer.

Jababeka Industrial Estate (Cikarang Industrial Estate)

The Jababeka Industrial Estate is the first modern Indonesian eco-industrial estate and jointly developed with ProLH GTZ under a technical cooperation program collaboratively established by Indonesia's Ministry of Environment and the Republic of Germany. Since its establishment in 1989, Jababeka Industrial Estate has been acknowledged as the most successful industrial estate in Indonesia in terms of attracting multinational companies (MNCs), leading local companies and small & medium enterprises.

It spans more than 2,000 hectares and contains more than 1,650 local and multinational corporations from 30 countries, such as USA, Japan, France, UK, The Netherlands, Australia, Korea, Singapore, Taiwan, Malaysia, and numerous others.

In Jababeka there is also a company providing electricity supply for some industries, called PT Cikarang Listrindo.

Company	Short Profile
PT Cikarang Listrindo	PT Cikarang Listrindo is one of an independent Power Generation companies which are given the trust to manage some of the industry in terms of providing electricity supply. PT Cikarang Listrindo founded in 1991 located in Cikarang Bekasi, it is designed as a power plantation using Gas and Steam with "Combine Cycle". operating system and connected to the Java Bali interconnection system.

Other than that, in order to augment power requirements from the industrial estate and surroundings, Jababeka embarked on a 130MW Power Plant, operated and managed by wholly owned subsidiary PT Bekasi Power. Jababeka has looked in the future and realized power demand will keep growing, which is why enough space for a second 130MW power plant is available.

The Power Plant consists of two state-of-the-art frame 6B gas turbines, manufactured by General Electric Energy with an installed capacity of 40 - 42 MW each by ISO rating. Furthermore, there are two heat recovery steam generators (HRSG) from Thermax Babcock and Wilcox Limited. The combined cycle is completed by a steam turbine from Shin Nippon with a capacity of 46 - 50 MW, which is driven by pressurized high temperature steam from both HRSGs that are fired by using the exhaust gasses from the gas turbines. The total installed capacity amounts to 130MW and is planning to double its capacity to 2 x 130MW in the coming years.

A Joint Operation Agreement between PLN and Bekasi Power allows Bekasi Power to not only enhance Kota Jababeka's electricity and energy infrastructure by providing specialized services to industrial customers, but also directly support PLN's mission to strengthen its electricity system, especially in the Bekasi and Karawang industrial areas.
With international standard equipment and redundant gas supply, Bekasi Power ensures an Uninterruptible Power Supply (UPS) at a competitive price that would help support Indonesia's national power grid and industrial growth for years to come.
In Jababeka complex there are various types of industries, e.g. manufacturing, automotive, food, food ingredients, fruit, vegetable, milk, vegetable oil, softdrink, water processing, comestic, pharmaceutical, electronic, spareparts, machinery, chemical, furniture, plactic,

alumunium, rubber, steel product, garment or textile, household equipment, paint, kids toys, pump and compressor, etc.

Karawang International Industry City

KIIC is a green and modern industrial estate located in west Karawang, south of Jakarta. It is a joint venture between Sinar Mas Land and ITOCHU Corporation Japan. It encompasses an area of 1200 hectares and contains a variety of national and multinational corporations. Similar to Jababeka in types of industries. Not many information can be gathered since its website broke.

3.4 FURTHER ANALYSIS

The next step of the Geocap WP3 is to investigate more details of the potential candidates especially on supporting data for technical assessments and economical assessment and detail feasibility analysis of two candidates for UI. Furthermore, the completion the delay target of 2015; smart selection and solving barriers that should done in 2016.

Appendix A

Table A.1 Hot Springs in West Java

No.	Surface Manifestation	Surface Temperature (°C)	Flowrate (L/s)	Heat Load (MW)
1	Ciracas Hot Springs	41.6-46	0.2	0.04
2	Batu Gede Hot Springs	42.1-45.5	0.2-1	0.11
3	Kawah Domas Hot Springs	85.5 -91.1	0.3-2	0.41
4	Kancah Hot Springs	31.1-34.5	3.3-5.1	0.57
5	Cimanggu Hot Springs	34.1-35.2	2.3-2.85	0.37
6	Maribaya Hot Springs	45.1-46.6	0.23-1.1	0.13
7	Patuha Hot Springs	35-83	2-15	2.07
8	Cimanggu Hot Springs	40-55	7.82-15.87	2.33
9	Rancawalini Hot Springs	40-55	7.17-15.87	2.27
10	Cibuni Crater Hot Springs	85-90	>3	1.06
11	Ciwidey Hot Springs	70-90	>4	1.30
12	Wayang Windu Hot Springs	39-66	15	3.25
13	Kawah Kamojang Hot Springs	90-93	2	0.74
14	Kawah Hujan Hot Springs	94	2	0.76
15	Citepus Hot Springs	55-60	2	0.47
16	Ciseeng Warm Springs	44.3	0.5	0.09
17	Cibodas Hot Springs	65.7	0.13	0.04
18	Ciherang Hot Springs 1	39.3	0.03	0.00
19	Ciherang Hot Springs 2	35.3	0.17	0.02
20	Cisaketi Hot Springs 3	42.1	0.33	0.06
21	Cipanas Karang Hot Springs	71.2	0.07	0.02
22	Muhinin Hot Springs	40	0.03	0.00
23	Sarimaya Hot Springs	61.2	0.08	0.02
24	Cipanas Cikuluwung Hot Springs	47.2	0.15	0.03
25	Cihideung Hot Springs	46	0.18	0.03

Table A.1 Hot Springs in West Java (Cont'd)

No.	Surface Manifestation	Surface Temperature (°C)	Flowrate (L/s)	Heat Load (MW)
26	Kawah Ratu-G.Salak Hot Springs 1	45.9	2	0.38
27	Kawah Ratu-G.Salak Hot Springs 2	40.3	1	0.17
28	Panulisan Warm Springs	44-52	2	0.40
29	Tanggeung-Cibungur-Cibuni Hot Spring 1	70.5	2	0.58
30	Cipanas-Pacet Warm Springs	40	0.8	0.13
31	G.Kromong Hot Springs	57	4	0.94
32	Talaga Bodas Hot Springs	68.1	7	1.95
33	Kawah Mas Hot Springs	79	0.17	0.05
34	Kawah Manuk Hot Springs	65	0.17	0.05
35	Cibeureum Leutik Hot Springs	32	0.25	0.03
36	G. Masigit-Guntur Hot Springs	45	2	0.37
37	Cilayu Hot Springs	61	1	0.25
38	Subang Hot Springs 1	60.5	2	0.50
39	Subang Hot Springs 2	60.8	0.5	0.13
40	Subang Hot Springs 3	60.9	0.5	0.13
41	Subang Hot Springs 4	60.7	0.5	0.12
42	Cibingin Hot Springs	54.2	3	0.67
43	Ciater Hot Springs	44-46.9	2 – 15	1.60
44	Batu Kapur Hot Springs	39.4-40.1	2.2 – 3.9	0.50
45	Cisolok Hot Springs 1	99	2	0.79
46	Cisolok Hot Springs 2	99	2	0.79
47	Cisolok Hot Springs 3	82	2	0.67
48	Cisolok Hot Springs 4	99	2	0.79
49	Cisolok Hot Springs 5	96	2	0.77
50	Kawah Karaha Hot Springs	91	1.6	0.59
51	Galunggung Hot Springs 1	50	2	0.41
52	Galunggung Hot Springs 2	60	3	0.74
53	Galunggung Hot Springs 3	60	3	0.74
54	Galunggung Hot Springs 4	61	3	0.75

Table A.2 Existing Geothermal Power Plant in West Java

No.	Geothermal Prospect	Waste Heat	Temperature (°C)	Pressure (bar)	Flow Rate (kg/s)	Heat Load (MW)
1	Kamojang	Condensate	46*	0.1	100	19.18
2	Wayang Windu	Brine	156*	5.6	50	32.94
3		Condensate 1	49*	5.3	26	5.38
4		Condensate 2	49*	0.9	60	12.41
6	Patuha	Brine	165*	7.0	27.78	19.36
8	Gunung Salak	Brine	173	6.6	252	184.97
9		Condensate	46*	0.1	N/A	18.43**
10	Darajat	Condensate	46*	0.1	135	25.89

*Temperature values are calculated based on pressure, with an assumption that the fluid is saturated water

**The data of flow rate is not available. Therefore, heat load was calculated according to common ratio heat load carried by condensate to installed capacity of electricity which is generated from Single Flash power plant.

Appendix B

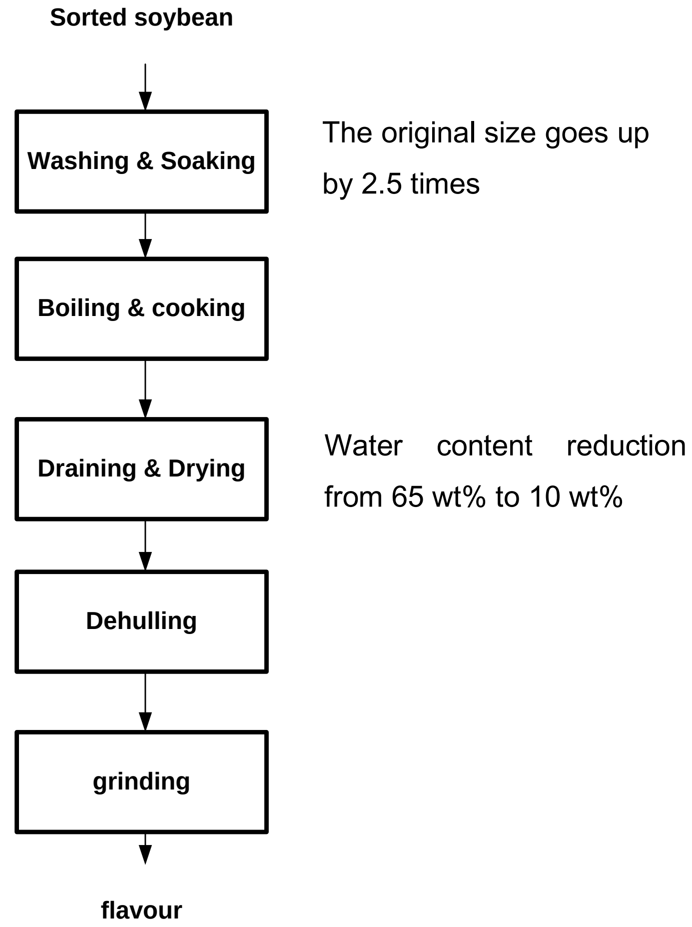


Figure B.1 Soya powder processing

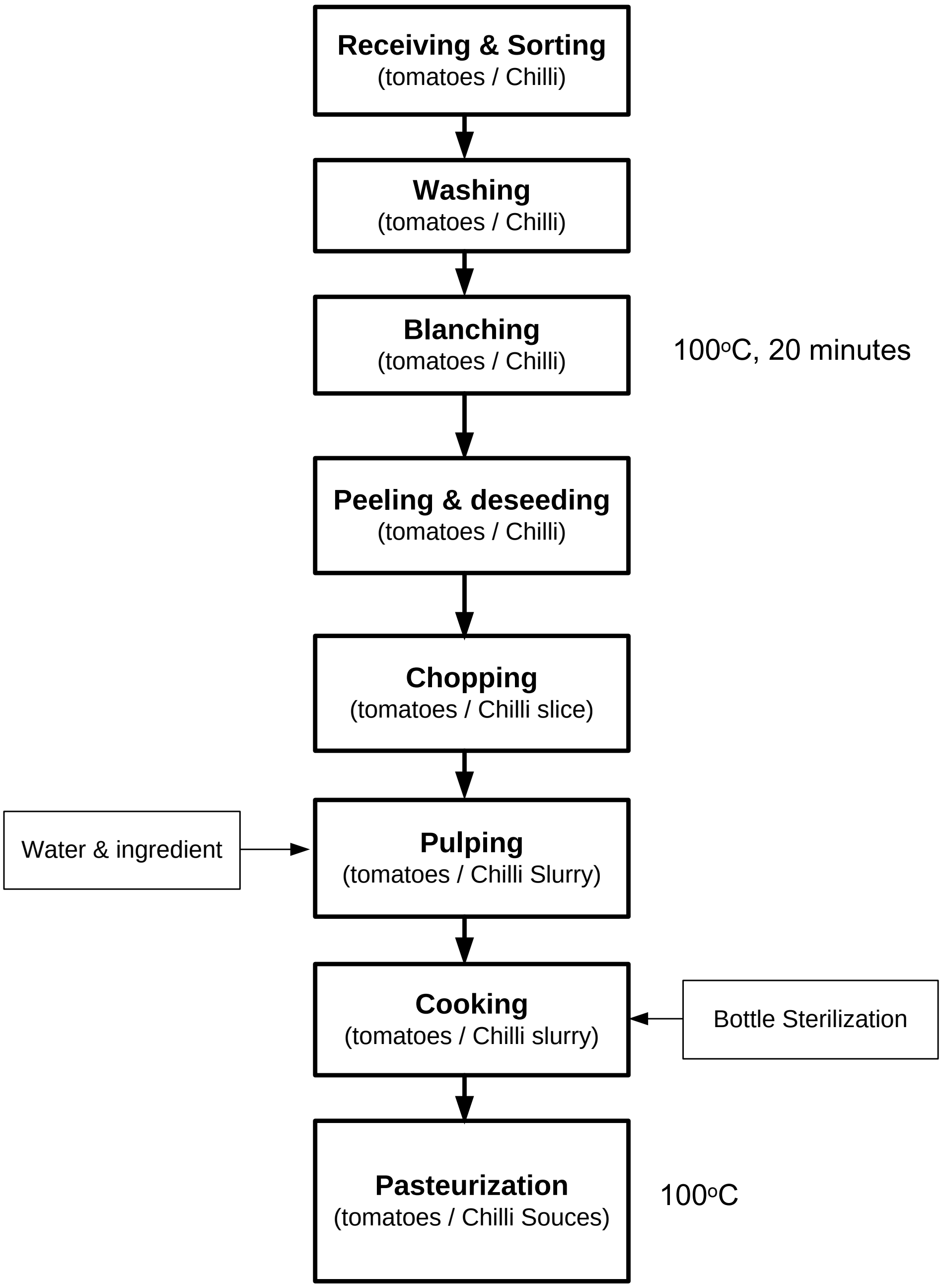


Figure B.2 Chili and tomato sauce processing

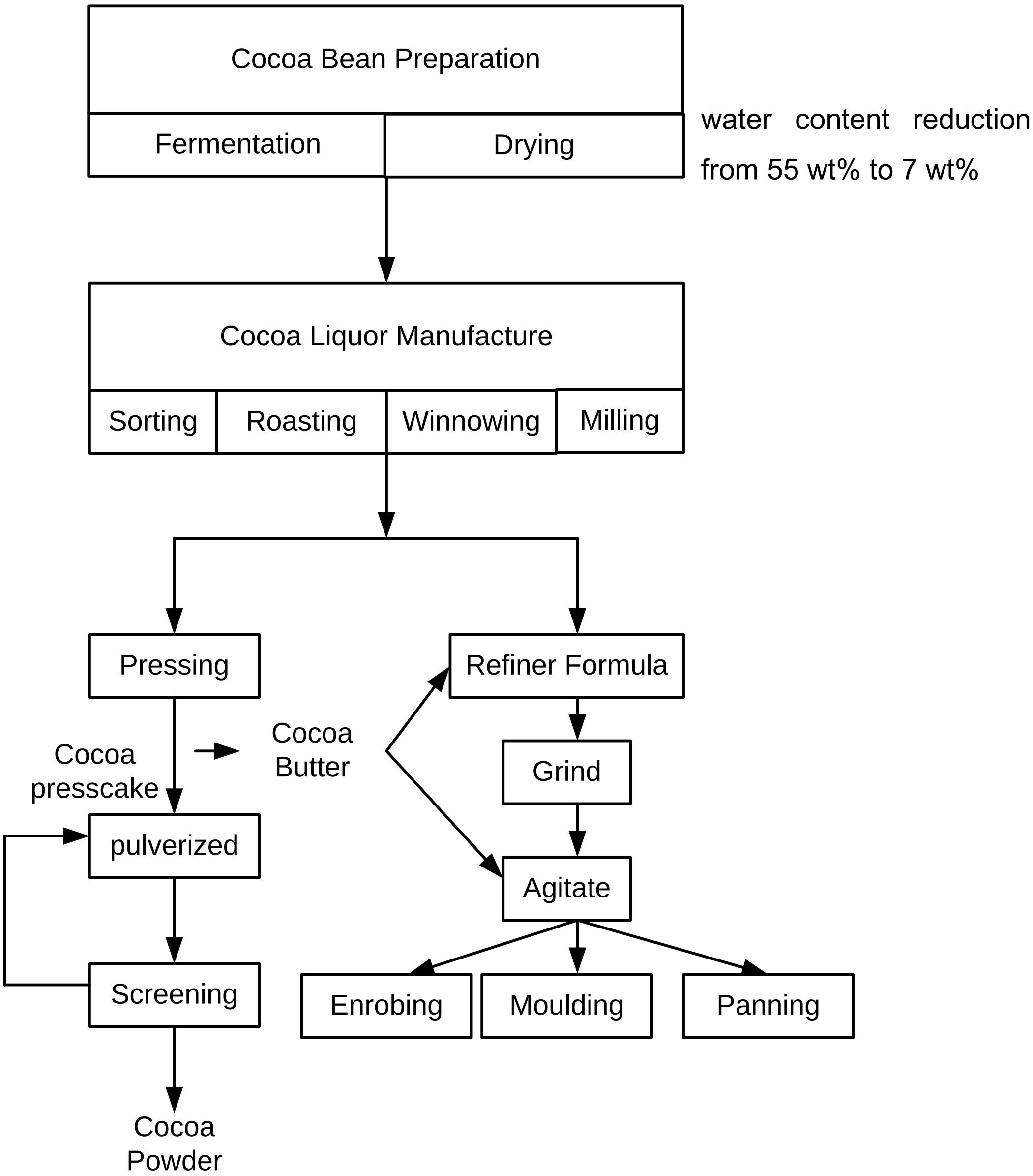


Figure B.3 Choco powder processing

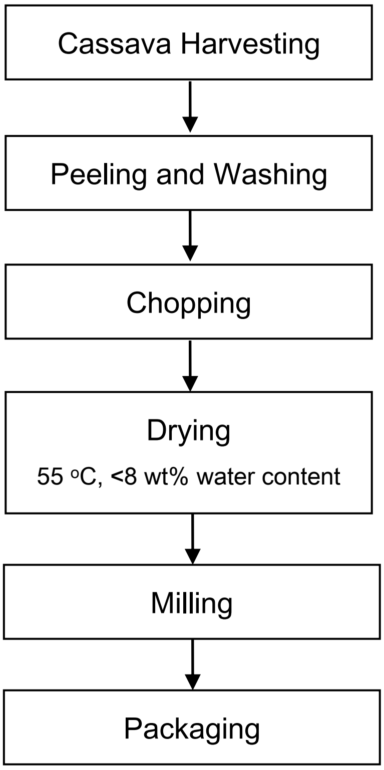


Figure B.4 Flour processing

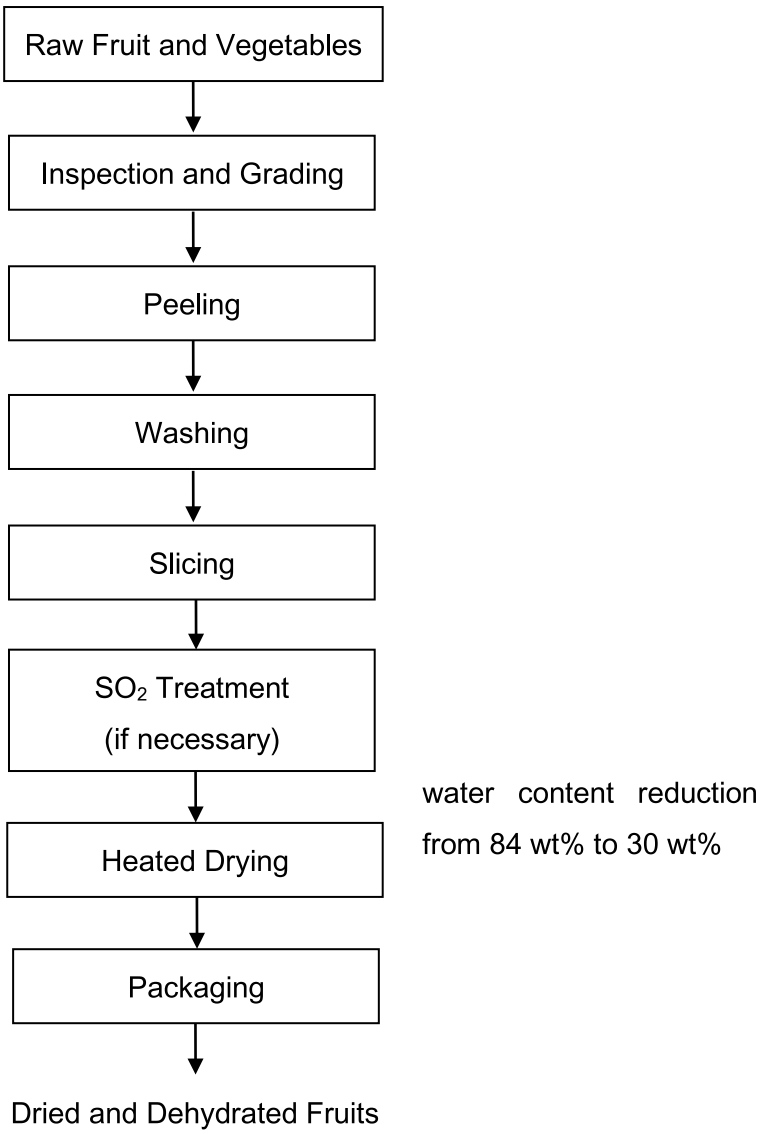


Figure B.5 Carbonated drinks processing

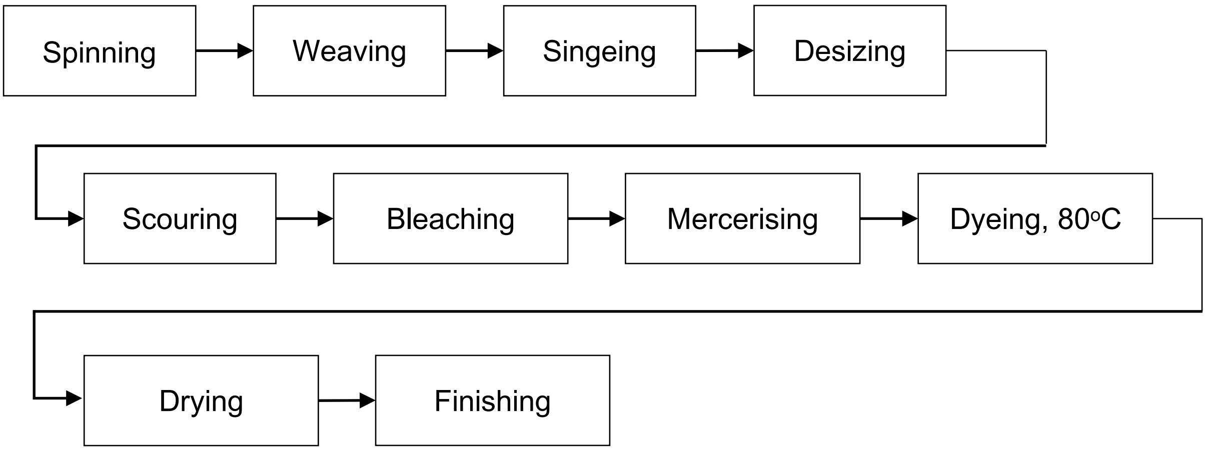


Figure B.6 Textile processing

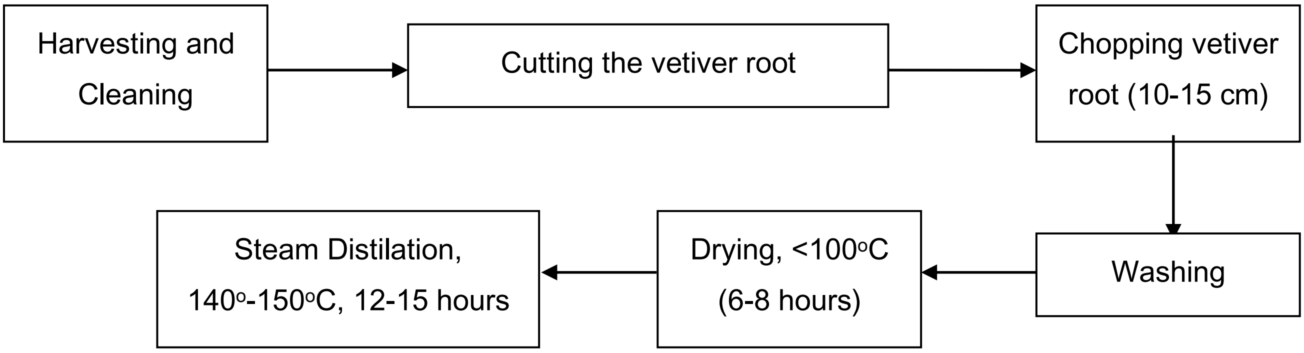


Figure B.7 Vetiver oil processing

Appendix C

Regency	District	Village	Status of Area	Type of business	Production		Distance	Energy Demand (MW)	Energy Supply (MW)	Temp Demand (°C)	Temp Supply (°C)	Potential for Utilization (MW)	Maintenance Cost (Million Rupiah)	Capital Cost (Million Rupiah)	Energy Price/year (Million Rupiah)	Direct Use Price/year for 20 yrs
					Volume	Area										
Bandung	Pangalengan	Pangalengan	KPB/KS from Wayang Windu	Milk Processing Factory KPBS	The products are milk cup and pure milk. Of 105 ton of milk, only 20% is self proceseed, 80% is sold to Ultrajaya		3,2 x 5000 = 16 km	0.146	0.32	80 Pasteurizatio n	151.5	0.146	HIGH	9674.9	504.0	483.7
Bandung	Pangalengan	Pangalengan	KPB/KS from Wayang Windu	Tofu Factory	1 kuintal (area 36 m2). Production = 18 gilingan x 2 cetakan x 15 x 23 x Rp. 70,- = Rp. 869.400,-		3,0 x 5000 = 15 km	0.040	0.64	100-180 Boiling and Frying	153.0	0.040	HIGH	8880.7	64.5	444.0
Bandung	Pangalengan	Margaluyu	KPB/KS from Wayang Windu	Tea Factory Kertamanah	Big scale, Export market		2,9 x 2 km = 5,8 km	1.001	3.91	97-105	168.2	1.001	LOW	5488.0	2069.4	274.4
Bandung	Pangalengan	Margaluyu	KPB/KS from Wayang Windu	Tea Factory Malabar	Big scale, Export market		4,3 x 2 km = 8,6 km	1.001	2.83	97-105	163.2	1.001	LOW	7112.0	2069.4	355.6

Regency	District	Village	Status of Area	Type of business	Production		Distance	Energy Demand (MW)	Energy Supply (MW)	Temp Demand (°C)	Temp Supply (°C)	Potential for Utilization (MW)	Maintenance Cost (Million Rupiah)	Capital Cost (Million Rupiah)	Energy Price/year (Million Rupiah)	Direct Use Price/year for 20 yrs
					Volume	Area										
Bandung	Kertasari	Tarumajaya	KPB/KS from Wayang Windu and Darajat	Tea Factory PT. Lonsum	Big scale, Export market		1,9 x 5000 = 9,5 km dari Wayang Wandu	1.001	2.48	97-105	161.6	1.001	LOW	7634.0	2069.4	381.7
Bandung	Pangalengan	Margaluyu	KPB/KS from Wayang Windu	Tea Factory Purbasari	Big scale, Export market		5 x 2 km = 10 km	1.001	2.31	97-105	160.8	1.001	LOW	7924.0	2069.4	396.2
Bandung	Pangalengan	Margaluyu & Margamukti	KPB/KS from Wayang Windu	Tea Factory Villagers	Small scale Produksinya berupa Tulang & teh hijau, tapi tidak sampai packing		2,4 x 5000 = 12 km	0.004	1.60	97-105	157.5	0.004	HIGH	7068.1	8.3	353.4
Bandung	Kertasari	Tarumajaya	KPB/KS from Wayang Windu and Darajat	Tea Factory Villagers	Small scale Produksinya berupa Tulang & teh hijau, tapi tidak sampai packing --> dikirim kan ke Semarang sebagai bahan baku untuk Teh Sosro		1,7 x 5000 = 8,5 km from Wayang Windu	0.004	2.85	97-105	163.3	0.004	LOW	5038.1	8.3	251.9
Bandung	Pangalengan	Pangalengan	KPB/KS from Wayang Windu	Yogurt Factory	750 liter/day		2,7 x 5000 = 13,5 km	0.021	1.11	100	155.2	0.021	HIGH	7972.1	72.0	398.6

Regency	District	Village	Status of Area	Type of business	Production		Distance	Energy Demand (MW)	Energy Supply (MW)	Temp Demand (°C)	Temp Supply (°C)	Potential for Utilization (MW)	Maintenance Cost (Million Rupiah)	Capital Cost (Million Rupiah)	Energy Price/year (Million Rupiah)	Direct Use Price/year for 20 yrs
					Volume	Area										
Garut	Talegong	Ds. Sukamulya	KS Wayang Windu	Tofu Factory	1 kuintal (luas 36 m2). Produksi = 18 gilingan x 2 cetakan x 15 x 23 x Rp. 70,- = Rp. 869.400,-		3,5 x 5000 = 17,5 km	0.040	0.37	100-180	152.8	0.040	HIGH	10330.7	64.5	516.5
Garut	Leles	Ds. Ando	KPB Darajat	Vetiver hedge processing		200-300 m	1,2 x 5000 = 6 km	0.050	2.86	100-130 Distillation	171.6	0.050	LOW	3680.9	49.3	184.0
Garut	Leles	Ds. Lembang	KS Darajat	Vetiver hedge processing		200-300 m	2,5 x 5000 = 12,5 km	0.050	1.35	100-130 Distillation	160.2	0.050	LOW	7450.9	49.3	372.5
Garut	Leles	Ds. Cipancar		Vetiver hedge processing		200-300 m	3,2 x 5000 = 16 km	0.050	0.64	100-130 Distillation	154.9	0.050	HIGH	9480.9	49.3	474.0
Garut	Samarang	Ds. Sukarasa	KS from Kamojang and Darajat	Vetiver hedge processing	1- 2 ton	200-300 m	9km	0.050	2.13	100-130 Distillation	166.1	0.050	LOW	5420.9	49.3	271.0

Regency	District	Village	Status of Area	Type of business	Production		Distance	Energy Demand (MW)	Energy Supply (MW)	Temp Demand (°C)	Temp Supply (°C)	Potential for Utilization (MW)	Maintenance Cost (Million Rupiah)	Capital Cost (Million Rupiah)	Energy Price/year (Million Rupiah)	Direct Use Price/year for 20 yrs
					Volume	Area										
Bandung	Pacet	Cikawao	KS* Kamoja ng	Poultry farm Broilers	50 ton/season		2,5 x 5000 = 12,5 km	0.044	1.35	20-30	160.2	0.044	LOW	7439.5	43.2	372.0
Bandung	Ibun	Ibun	KS Kamoja ng	Poultry farm: broilers			0,8 x 5000 = 4 km	0.022	3.39	20-30	175.6	0.022	LOW	2464.7	21.6	123.2
Bandung	Ibun	Laksana	Kamoja ng	Poultry farm: broilers			1 km	0.022	4.24	20-31	181.9	0.022	LOW	724.7	21.6	36.2
Bandung	Ibun	Mekarwangi	Kamoja ng	Poultry farm: broilers			5 km	0.022	3.13	20-32	173.6	0.022	LOW	3044.7	21.6	152.2
Bogor	Pasarwangi	Ds Cibunian	KS from Awi bengkok	Poultry farm			1,9 x 5000 = 9,5 km	0.066	1.93	20-30	179.3	0.066	LOW	5744.2	9.3	287.2
Sukabumi	Kabandungan	Kabandungan	KPB/KS	Poultry farm Broilers			9 x 5000 = 45 km	0.066	-0.90	20-30	136.1	0.066	HIGH	26334.2	9.3	1316.7

Regency	District	Village	Status of Area	Type of business	Production		Distance	Energy Demand (MW)	Energy Supply (MW)	Temp Demand (°C)	Temp Supply (°C)	Potential for Utilization (MW)	Maintenance Cost (Million Rupiah)	Capital Cost (Million Rupiah)	Energy Price/year (Million Rupiah)	Direct Use Price/year for 20 yrs
					Volume	Area										
Sukabumi	Parakansalak	Lebaksari (pada dasarnya hampir semua desa ada)	KS	Poultry farm Broilers	5-10% dari pembibitan, tergantung pada cuaca		5 x 5000 = 25 km	0.055	0.35	20-30	155.3	0.055	HIGH	14711.8	9.3	735.6
Garut	Samarang	Ds.Parakan	KS from Kamojang and Darajat	Tradisional Tobacco Drying	676 ton/ district	246 ha /district	2,5 x 5000 = 12,5 km dr kamojang & 2 x 5000 = 10 km from Darajat			40-50 Drying						
Garut	Samarang		KS from Kamojang and Darajat	Tradisional Tobacco Drying	676 ton/ district	246 ha /district	2,1 x 5000 = 10,5 km from Kamojang			100-130 Distillation						
Bandung	Pangalengan	Pangalengan	KPB/KS from Wayang Windu	Caramel Factory /Milk Candy, Dodol Milk, Milk Crackers,			2,7 x 5000 = 13,5 km			Heating 100°-150°C Bathing 40°-50°C						

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