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GEOTHERMAL SYSTEM AND MANIFESTATION IN THE WEST JAVA REGION: A REVIEW

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ABSTRACT

Electricity at this time still uses resources from fossils which are decreasing and can run out. There are alternative power plants that do not require fossil resources and there will always be geothermal energy. West Java has several areas which are areas with good geothermal potential. Therefore, this research was conducted to determine the potential for geothermal energy in the West Java area as well as the manifestations of geothermal in West Java, especially in Kamojang, Awibengkok, Wayang Windu and Patuha. In addition, the calculation of the power density of each Geothermal Power Plant is also carried out to see if the value is in accordance with the recommended value. The results show that Awibengkok Geothermal Power Plant has the highest power density, which is 20.94 MW/km^2

KEYWORDS: Geothermal System, Geothermal Manifestation, Power Density, West Java, Power Plant.

1. INTRODUCTION

In this 21st century, electricity is an important thing in human life. From industry to households, everything depends on the availability of electricity. However, electricity at this time still uses resources from fossil which are decreasing and can run out. The increasing need for electricity in the community, making more and more fossil resources used. Thus, this fossil resource will be decreasing time over time and even depleted. The availability of electricity in Indonesia is still low when compared to other ASEAN countries. Table 1 shows that Indonesia has an electrification ratio of 88.30 % in 2017 (Mary, 2017).

However, there are alternatives to electricity generation that do not require fossil resources and there will always be geothermal energy. Indonesia is located at three tectonic plate junctions, which causes Indonesia to have quite a large geothermal energy potential, reaching almost 40% of its geothermal potential (Smith, 2012).

The geothermal that has currently been developed is only 7.6% of the total geothermal potential that can be developed (Asokawaty, 2020). This can be seen from Figure 1 below. Areas that have geothermal potential are usually located in volcanic mountains and are surrounded by protected forests, conservation forests, and nature reserves (Sukendar, 2016). West Java has several areas which are areas with good geothermal potential, namely, Mount Salak, Garut, and Bandung.

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Table 1. Indonesia's Electrification Ratio (Mary, 2017)

No	Province	Electrification Ratio (%)	
		2014	2015
1	Aceh	91.31	94.25
2	North Sumatera	91.03	93.15
3	West Sumatera	80.14	83.82
4	Riau	84.54	87.59
5	Riau Island	74.06	78.60
6	Bengkulu	83.47	86.67
7	Jambi	80.70	84.30
8	South Sumatera	76.38	80.59
9	Bangka Belitung Island	95.53	97.00
10	Lampung	81.27	84.79
11	Banten	92.93	94.78
12	DKI Jakarta	99.61	99.66
13	West Java	86.04	88.87
14	Central Java	82.26	90.59
15	D.I Yogyakarta	83.55	85.64
16	East Java	85.17	86.74
17	Bali	79.77	88.13
18	West Borneo	67.23	83.50
19	Central Borneo	83.57	72.75
20	South Borneo	91.71	86.91
21	North and East Borneo	69.64	76.43
22	North Sulawesi	74.11	88.42
23	Gorontalo	85.53	79.11
24	Central Sulawesi	66.78	79.90
25	West Sulawesi	75.58	78.65
26	South Sulawesi	85.05	88.01
27	Southeast Sulawesi	68.05	72.36
28	West Nusa Tenggara	58.91	73.45
29	East Nusa Tenggara	74.65	65.60
30	Maluku	82.28	85.64

31	North Maluku	77.81	92.70
32	Papua	90.52	52.30
33	West Papua	84.35	81.81
Indonesia's Electrification Ratio		**84.35**	**88.30**

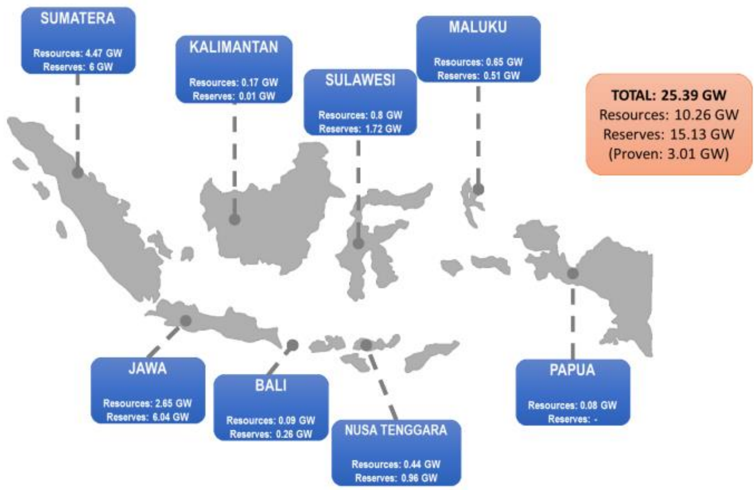

Figure 1. Geothermal Mapping in Indonesia (Asokawaty, 2020)

2. DISCUSSION

2.1 Geothermal System

The earth consists of three main layers, namely: the crust, the mantle, and the core. At the core of the earth, the pressure and temperature are very high (6000 0F). The thickness of the earth's crust varies, generally the earth's crust on land has a thickness of about 35 kilometers and the thickness of the earth's crust under the oceans has a thickness of 5 kilometers. The crust of the earth and the top of the earth's envelope is called the lithosphere (80-200 km). In this area, there are thin and stiff plates. Under the lithosphere, there is a collection of soft and hot rocks called the asthenosphere (200 - 300 km).

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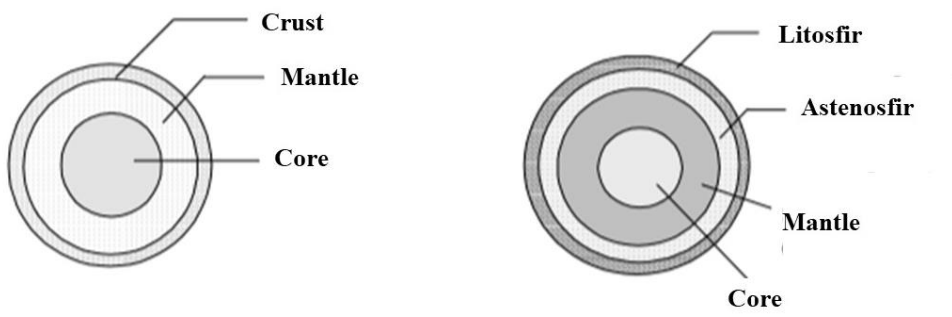

Figure 2. Layers on Earth (Saptadji, 2001)

The magmation process is characterized by plates in the lithosphere that begin to move. Then, because of the heat in the asthenosphere and heat due to friction, the tip of the crushed plate melts and has a high temperature (Saptadji, 2001).

The geothermal system occurs as a result of heat transfer from a heat source to its surroundings which occurs by conduction and convection as in Figure 3. Conduction of geothermal transfer occurs through rocks, then convection geothermal transfer occurs due to contact between the heat source and water. Convection displacement occurs due to buoyancy. In general, water flows downward due to the force of gravity, but if the water is in contact with a heat source there will be heat transfer which causes the temperature of the water to increase and become lighter. This causes water with a higher temperature to move upwards while water with a lower temperature will move downwards and there is water circulation or what can be called a convection current.

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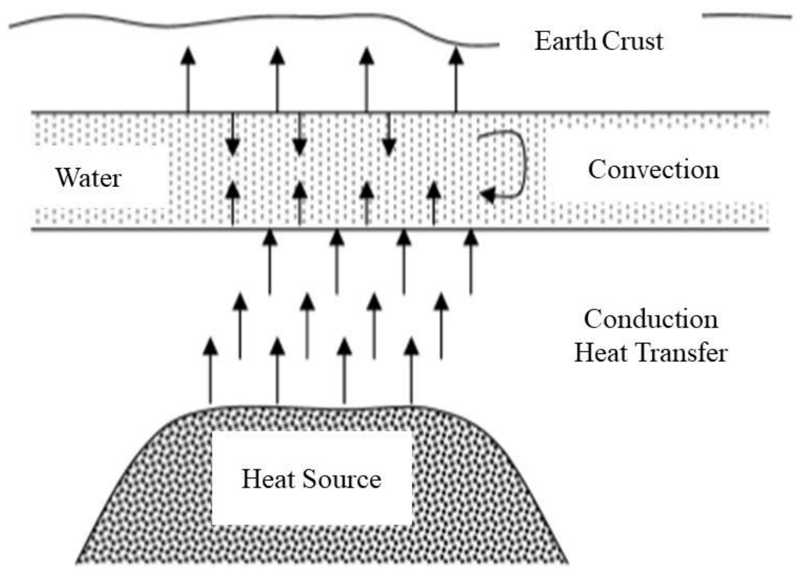

Figure 3. Geothermal Transfer (Saptadji, 2001)

Geothermal energy is divided into 5 types, namely magma energy, earth energy, hot rock energy, hydrothermal energy, and geopressured energy. The energy most commonly used is hydrothermal energy. The system of hydrothermal energy itself is divided into 2, namely a single-phase system and a two-phase system. A single phase system is water that has a temperature of 90-180 °C. Two-phase hydrothermal system is a system consisting of a mixture of fluids. This system itself is divided into 2, namely, a steam domination system and a water domination system.

2.2 Geothermal Manifestation

Geothermal manifestation in some area:

a. Warm Ground. Geothermal resources can be indicated by the presence of land whose temperature is higher than the surrounding land. This is due to conduction from subsurface rocks to upper surface rocks. The presence of warm soil can be determined by measuring the temperature gradient to a depth of 1-2 meters. Temperature measurement is generally carried out by making holes to a depth of 1-2 meters. The temperature on the surface and at a depth of 1 meter is usually measured using a thermometer or thermocouple.

b. Steaming Ground. In some areas, there is often steam coming out of the ground surface. It is thought that the vapor originates from a thin layer near the surface containing hot water whose temperature is equal to or greater than its boiling point. How to map the steaming ground can be done using infra-red. However, this method is quite expensive so it is rarely used.

c. Hot/Warm Spring. Hot/warm springs are also an indication of subsurface geothermal resources. These hot / warm springs are formed due to the flow of hot / warm water from below the surface through rock fractures. The term warm is used when the water temperature is lower than 50 °C and the term hot is used when the water temperature is greater than 50 °C.

d. Hot Pools. The existence of hot springs in nature is also an indication of the existence of geothermal resources below the surface. This hot water pool is formed due to the flow of hot water from below the surface through rock fractures. At the surface of the water, evaporation occurs due to the transfer of heat from the surface to the atmosphere.

e. Hot lakes. Basically, a hot spring lake is also a hot pool, but it is more accurately said to be a lake because of the large area of the water surface. Generally, the term lake is used when the surface area is more than 100m^2. Hot springs are very rare in nature because hot water lakes occur due to massive hydrothermal eruptions.

f. Fumarole. Fumarole is a small hole that emits dry steam (dry steam) or hot steam containing water droplets (wet steam).

g. Geyser. Geysers are defined as hot springs that gush into the air intermittently (at indefinite intervals) with a wide variety of water levels, from less than one meter to hundreds of meters.

h. Mud Pools. The hot mud puddle generally contains non-condensible gas (CO_2) with a small amount of hot steam. The mud is present in a liquid state due to hot nap condensation. Meanwhile, the explosions that occur are due to CO_2 emission.

i. Sintered Silica. Sintered silica is silica deposits on the surface that are silvery in color. Generally found around hot springs and geyser holes that spout water that is neutral. If the flow rate of hot water is not too large, generally around the hot springs, silica terraces are formed (silica sinter teraces or sinter platforms). Sintered silica is the surface manifestation of a water-dominated geothermal system.

j. Alterated Rocks. Hydrothermal alteration is a process that occurs as a result of a reaction between the original rock and the geothermal fluid. Rocks resulting from hydrothermal alteration depend on several factors, but the main ones are temperature, pressure, original rock type, fluid composition (especially pH) and reaction time.

2.3 Geothermal Potential in Indonesia

According to Budihardi (1998), Indonesia has high potential in areas with young volcanic activity and is located in volcanoes such as on the islands of Sumatra, Java, Bali, Nusa Tenggara, Maluku, and the northern tip of the island of Sulawesi (Saptadji, 2001).

Many regions of Indonesia are surrounded by volcanoes so that the geothermal prospects that are implemented can be divided into 2 types, namely, the active volcanic geothermal prospect and the quaternary or inactive volcanic geothermal prospect. From a survey conducted by Pertamina, it shows that geothermal systems with volcanoes that are under 400,000 years old generally have enough heat to be used as a source of high temperature power generation.

In the central, southeast, southern, and Irian Jaya areas of Sulawesi, heat manifestations are obtained from meteoric water which can become hot due to old volcanic systems (Saptadji, 2001).

2.4 Geothermal System and Geothermal Manifestation in Kamojang

In the Kamojang geothermal power plant, the geothermal system used is the Direct Dry Steam Cycle. This cycle requires a fluid in the form of a vapor phase to be flowed directly into the turbine. After that, the moving turbine will produce energy for motion so that the generator can rotate and then produce electrical energy. This can be seen in Figure 4 below regarding the dry steam cycle scheme for the geothermal system at the Geothermal Power Plant in the Kamojang area.

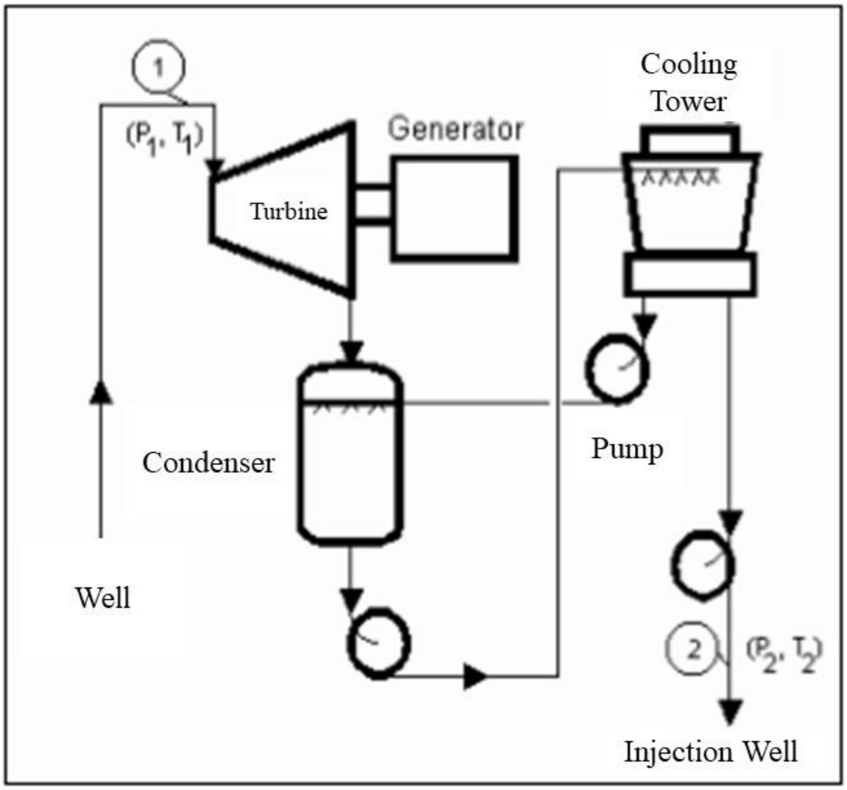

Figure 4. Schematic of Dry Steam Cycle (Saptadji, 2001)

The well in the Kamojang Geothermal Power Plant field is dominated by dry steam with a temperature in the reservoir of 240 C°. The water content in the reservoir rock is about 35% and the rest of the cavity contains steam. The reservoir in the Kamojang field has a depth of between 800 m to 1200 m. The steam is produced from 26 wells that have been managed in the Kamojang field. Geothermal Power Plant Kamojang has 3 units with a total installed power capacity of 140 MW. Unit I has a capacity of 30 MW while Units II and III have a capacity of 55 MW each (Noor, 2012).

In the Kamojang field, geothermal manifestations that can be found are steamy ground surfaces, hot / warm springs, fumaroles, hot mud puddles, sintered silica, and rocks that have undergone alteration.

2.5 Geothermal System and Geothermal Manifestation in Awibengkok

At the Awibengkok geothermal power plant that is located on Mount Salak, the geothermal system used is a single flash steam cycle. This cycle is carried out when the hot fluid coming out of the well is a mixture of the liquid phase and the vapor phase. Therefore, the fluid must first be separated in a separator. After that, the fluid with the vapor phase will flow into the turbine and the liquid fluid will be injected back into the earth (Saptadji, 2001).

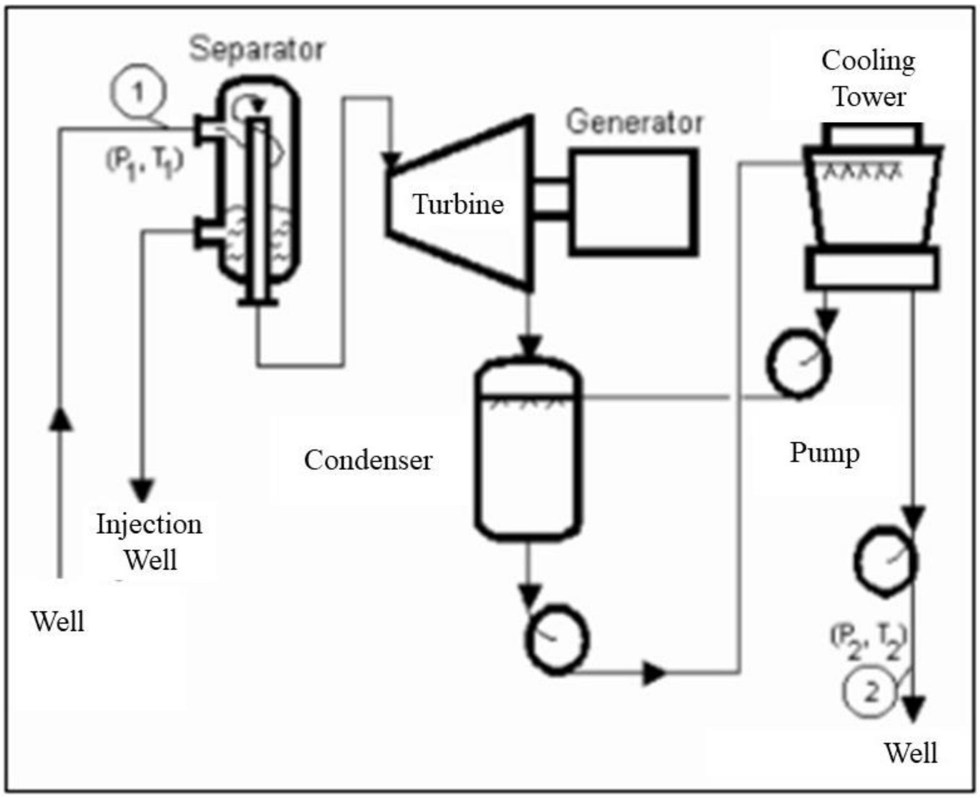

Figure 5. Schematic of the Separation Result Steam Cycle (Saptadji, 2001)

The well in the Awibengkok field, Mount Salak is dominated by the liquid phase fluid and also a little mixture of vapor phase fluids where the temperature of the reservoir ranges from 220-230 C°. Geothermal Power Plant Awibengkok has a total power capacity of 377 MW and has 6 Geothermal Power Plant units (Saptadji, 2001). In the Awibengkok field, geothermal manifestations that can be found are hot/warm springs and also fumaroles.

2.6 Geothermal System and Geothermal Manifestation in Patuha

The Patuha geothermal power plant has a well which is dominated by a liquid phase fluid. Thus, the geothermal system used in this Geothermal Power Plant is a separated steam cycle. The Patuha

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Geothermal Power Plant has a total resource capacity of 55 MW, with an area of 36.12 km^2. In the Patuha field, geothermal manifestations that can be found are hot / warm springs and fumaroles.

2.7 Geothermal System and Geothermal Manifestation in Wayang Windu

The Wayang Windu geothermal power plant has a well which is dominated by a liquid phase fluid. Thus, the geothermal system used in the Wayang Windu Geothermal Power Plant is a separated steam cycle. Geothermal Power Plant Wayang Windu has a total resource capacity of 227 MW with an area of 58.6 km^2. At Geothermal Power Plant Wayang Windu, geothermal manifestations that can be found are steamy ground surfaces, hot / warm springs and also fumaroles.

2.8 Exploration Data of Geothermal Manifestations in West Java

Table 2 showed exploration data of geothermal manifestation in West Java.

Table 2. Geothermal Manifestations in West Java (Saptadji, 2001; Hochstein, 2008)

Geothermal Manifestations	Area			
	Kamojang	Awibengkok	Patuha	Wayang Windu
Warm Land	-	-	-	-
Steaming ground	V	-	-	V
Hot/Warm Springs	V	V	V	V
Hot Water Pool	-	-	-	-
Hot Water Lake	-	-	-	-
Fumarole	V	V	V	V
Geyser	-	-	-	-
Hot mud puddle	V	-	-	-

Sintered Silica	V	-	-	-
Alterated Rocks	V	-	-	-

2.9 Calculation of the Power Density of Geothermal Power Plant

Table 3 shows data regarding the four Geothermal Power Plants in West Java. The data taken is in the form of the number of units in the Geothermal Power Plant, the area of the Geothermal Power Plant, the power capacity of the Geothermal Power Plant, and the characteristics of the Geothermal Power Plant. After that, the calculation of the electrical power that can be generated per unit area is carried out to determine the potential of each Geothermal Power Plant. The calculation formula in Equation (1) used in this study.

$$H = A \times Q \qquad (1)$$

where,

H = capacity of resource (MW)

A = area of geothermal area (km^2)

Q = power density (MW/km^2)

Table 3. Power Density Data per Unit Area of Geothermal Power Plant West Java (Pambudi, 2017; Saptadji, 2001)

Geothermal Power Plant Site	Number of units	Area (A) in km^2	Resources (H) in MW	Characteristics	Power Density (Q) in MW/km^2
Kamojang	3	45.38	140	Steam Domination	3.08
Awibengkok	6	18.00	377	Water Domination	20.94
Wayang Windu	2	58.60	227	Water Domination	3.87

Patuha	1	36.12	55	Water Domination	1.52

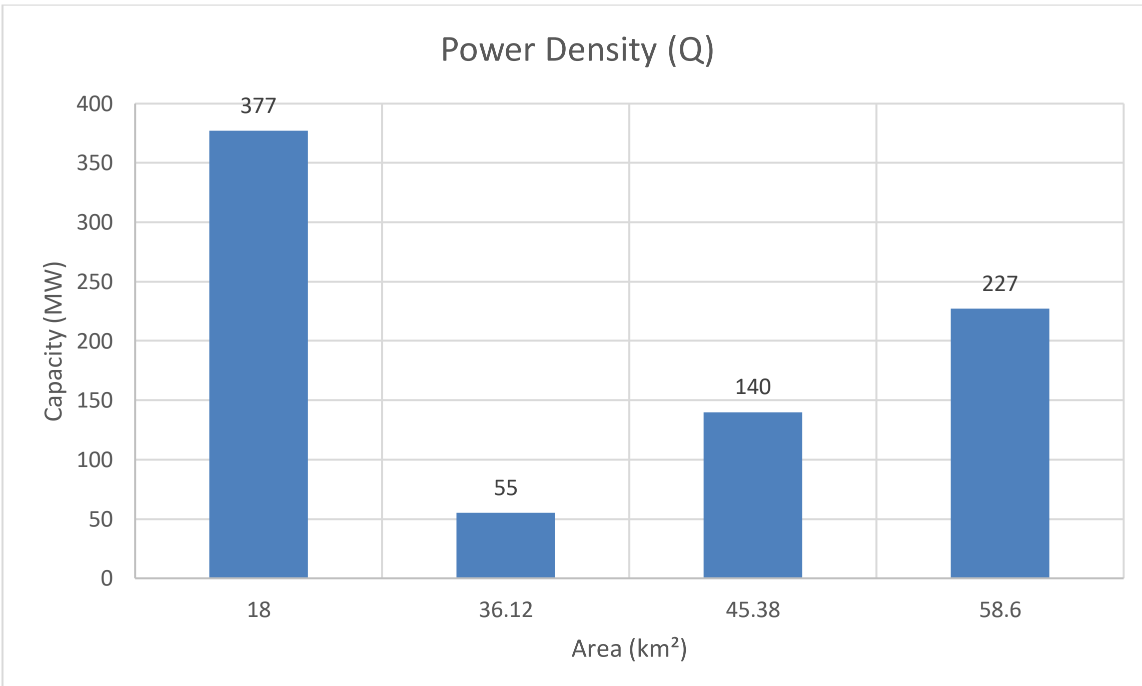

Figure 5. Power Density Data at Geothermal Power Plant West Java (Pambudi, 2017)

From the results obtained, Geothermal Power Plant Wayang Windu is the field with the largest area, namely 58.6 km^2. The data above also shows that the Geothermal Power Plant with the greatest power density is the Awibengkok Geothermal Power Plant with a power of 20.94 MW. Meanwhile, the Patuha, Kamojang, and Wayang Windu Geothermal Power Plants have a power per unit area of 1.52 MW, 3.08 MW, and 3.87 MW, respectively. This shows that the Awibengkok Geothermal Power Plant has the greatest value of geothermal power that can be generated by a wide unity. In addition, the Awibengkok Geothermal Power Plant also has the most Geothermal Power Plant units when compared to other Geothermal Power Plants in West Java. According to Grant (2000), the recommended power density value for Geothermal Power Plant ranges from 10 - 20 MW. Of the four Geothermal Power Plants above, the power density value of the Awibengkok Geothermal Power Plant is the closest to the recommendation from Grant (2000).

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CONCLUSION

In summary, Geothermal Power Plant Kamojang has the most geothermal manifestations, namely in the form of steamy ground surfaces, hot/warm springs, fumaroles, hot mud puddles, sintered silica, and rocks that have undergone alteration. Then, Geothermal Power Plant Awibengkok and Geothermal Power Plant Patuha have the same number of geothermal manifestations, namely hot / warm springs and also fumaroles. Meanwhile, Wayang Windu Geothermal Power Plant has hot / warm springs, fumarole and steamy ground surface. From the four existing Geothermal Power Plants, the Awibengkok Geothermal Power Plant has the greatest total power and also the largest number of units. In addition, the Awibengkok Geothermal Power Plant also has the greatest potential for geothermal development because it has a large enough power value per unit area when compared to the other three Geothermal Power Plants. This Geothermal Power Plant also has a power density value that is closest to the value recommended.

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