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Revision of Geothermal Resource Classification in Indonesia Based on Type of Potential Power Generation

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ABSTRACT

Nearly 300 potential high-to low-enthalpy geothermal areas have been identified across Indonesia. Recent estimates of the possible power production from these geothermal resources is exceeding 29,000 MWe. This number has been obtained by adding all of the estimated geothermal potential resources and reserves classified as "speculative, hypothetic, possible, probable, and proven" from all sites where such information is available. However, this approach to estimating the geothermal potential is flawed because it includes double counting of some reserve estimates as resource estimates, thus giving an inflated figure for the total national geothermal potential.

A previous paper (Fauzi, 2013) redefined and revised the geothermal resource estimate for Indonesia using a more realistic methodology. The potential geothermal resources and reserves for Indonesia are estimated to be about 24,000 MWe. This estimate can be classified as either (1) potential high-enthalpy resources suitable for conventional steam turbine power plants or (2) low-enthalpy resources better suited for binary power plants or other Understanding the type of potential power plant is important to stakeholders, especially investors who are not familiar with the geothermal industry.

Publically-available data were reviewed to determine whether a site is potentially a high-enthalpy or low-enthalpy resource. The resource classification was based on the estimated subsurface temperatures, location (e.g. volcanic or non-volcanic), and the type of surface thermal features. The results of the review suggest that approximately 14,500 MWe of the total estimated geothermal resources for Indonesia may be considered as high-enthalpy resources (conventional steam turbine power plants) and 9,500 MWe of the total estimated geothermal resources are lower enthalpy resources more appropriate for binary power plant applications or other.

1. INTRODUCTION

Many of the geothermal sites in Indonesia, are situated along the volcanic belt, stretching from Sumatra to Java, Bali and Maluku up to Sangihe Island, resulting in many high-enthalpy geothermal resources in these areas. Low-enthalpy sites are associated with non-volcanic environment (e.g. in Sulawesi and, a few in Kalimantan and Papua) and / or, as the outflow of those high enthalpies.

The most recent estimate of total geothermal resources is exceeding 29,000 MWe (Table 1, Geological Agency, 2012). However, through the new proposed summation methodology (Fauzi, 2013) the total resources number will be revised and briefly described in this paper. This paper will first attempt to describe the potential numbers that are eligible to be classified as high and /or low enthalpy. The revised data will be used as reference in a new classification. The classification will be strongly related / dedicated to the Generation Designation as end user.

Although there are many possible criteria for classification available, most agree that estimated reservoir temperature is the primary criterion. In this paper, the locality, estimated subsurface temperatures, and impression of thermal features were used as main indicators to classify resources..

Table 1: Geothermal Resources and Reserves: 2012 Status

Location	Resources (MWe)		Reserves (MWe)			Installed (MWe)
	Speculative	Hypothetical	Possible	Probable	Proven	
Sumatra	3,547	2,427	6,849	15	380	122
Java	1,710	1,826	3,708	658	1,815	1,134
Bali	70	58	226	-	-	5
Nusa Tenggara	290	359	787	-	15	
Kalimantan	145	-	-	-	-	-
Sulawesi	1,323	119	1,374	150	78	80
Maluku	545	97	429	-	-	-
Papua	75	-	-	-	-	-
TOTAL (297 Locations)	7,705	4,886	13,373	823	2,288	1,341 (2013)
	12,591		16,484			
	29,075					

Geological Agency & EBTKE (2012)

2. BACKGROUND

Geothermal resources in Indonesia are generally hydrothermal systems that can be divided between high temperatures (> 200^{o}C), and low to moderate temperatures (< 200^{o}C).

At present, no distinction between high and low enthalpy prospects, nor its generation designation, have been presented by Government Agencies. Are the resources available for electricity generation through conventional power plants or binary power plants or other?. This classification is important because the data and /or information are often mistakenly interpreted by geothermal developers. The geothermal resource classification should be used as a basis that is satisfactory to investors, and other stakeholders. Local governments also need a resource classification that allows them to properly prepare the appropriate tender.

For investors and local governments, it is equally important (even though of different concern) in terms of financing, while for the central government, this information is critically important for planning the provision of energy, particularly electricity.

It is also expected that this proposed classification will be the starting point or the trigger to government agencies to do further detailed work on the classification.

3. RESOURCES AND RESERVES: A REVISION

Currently, the geothermal potential classification process includes estimating the geothermal potential of a prospect area in 1 of 5 categories defined above ranging from "Speculative Resource" (the least certain category of geothermal potential) to "Proven Reserve" (the most reliable estimate of an area's geothermal potential). A Proven Reserve is the economically recoverable geothermal energy potential which have been proven by at least a drilled and tested well to confirm reservoir characteristic.

The preliminary "Speculative Resources" category should cover the full potential of the area and form the base reference figure for the resource of the potential geothermal field. Eventually, further investigation of this resource may allow parts of the "Speculative Resource" to be upgraded to "Proven Reserve". However, the total "resource capacity" does not increase in this upgrade In other words, the proven reserves does not increase the estimate of the geothermal resource as a whole (for detail, see Fauzi, 2013).

Using the methodology proposed in Fauzi, 2013, the geothermal resource potential of Indonesia is revised to be about 24,000 MWe, some 5,000 MWe less than the 2012 national estimate (Table 2).

Table 2: Revised Total Geothermal Resources and Reserves in Indonesia

Location	Resources (MWe)		Reserves (MWe)			Installed (MWe)
	Speculative	Hypothetical	Possible	Probable	Proven	
Sumatera	10,961	2,427	6,849	15	380	122
Java	7,250	1,826	3,708	658	1,815	1,135
Bali	354	58	226	-	-	-
N.Tenggara	1,314	359	787	-	15	-
Kalimantan	145	-	-	-	-	-
Sulawesi	2,725	119	1,374	150	78	80
Maluku	995	97	429	-	-	-
Papua	75	-	-	-	-	-
TOTAL	23,819	4,886	13,373	823	2,288	1,337 (2012)
	23,819					

Resummation Speculative Resource Based on Geological Agency Data

4. CLASSIFICATIONS

The resource location, the impression of thermal features, and the calculated subsurface temperatures have been used to classify Indonesian geothermal resources in this paper. The first two indicators are strongly related to geological characteristics in terms of confirmation of a subsurface heat source and extent of a Geothermal Resource. They are known or interpreted from specific geological evidence and knowledge. Many geothermal areas described in this paper are known physically well to the author having been visited while working at Pertamina. In addition, other information related to the three indicators was obtained from the data published by Directorate General of New and Renewable Energy and Conservation Energy, and the Geological Agency.

4.1 Resource Location

Classification based on the location of geothermal resources can be divided into two kinds of resource origin: volcanic or non-volcanic. Volcanic resources can be further subdivided into areas that are directly related to the volcanic activity itself as a heat source (upflow areas) or as indirect heat sources (outflow areas). Resources located near the heat source (upflow areas) can be justified to be high-temperature resources compared to those located within or near an outflow. There is thus a range of temperatures that can be produced.

Of the total geothermal resource locations identified in Indonesia, about 70% of them are associated with active volcanic systems: Sumatra (90 locations), Java and Bali (77 locations), Nusa Tenggara (22 locations), the Moluccas (30 locations), and North Sulawesi (5 locations). The other 30% are located in a non-active volcanic environment, i.e. in other parts of Sulawesi (60 locations), Bangka Belitung (7 locations), Kalimantan (12 locations), and West Papua (3 locations).

The 70% of the resources associated with active volcanic systems provides a potential of about 14,500 MWe that may be appropriate for Conventional Steam Turbine (volcanic heat sources), and 5,800 MWe that are more applicable to Binary Power Plants or other (outflow areas). The remaining 30% of Indonesian geothermal resources (equivalent to about 3,700 MWe) are associated with non-volcanic environments that may be appropriate for Binary Power Plants or other (Table 3).

4.2 Calculated Subsurface Temperatures

In general, geothermal resources have been classified as low, medium, and high enthalpy resources according to their reservoir fluid temperatures. Sanyal (2005) classified resources into seven categories based on temperature: non-electrical grade (<100°C), very low temperature (100°C to <150°C), low temperature (150°C to 190°C), moderate temperature (190°C to <230°C), high temperature (230°C to <300°C), ultrahigh temperature (>300°C), and steam fields (~240°C).

There is no general agreement on the temperature ranges used. In this paper, classification of a geothermal resource by its reservoir fluid temperature is simplified into 2 classes: low to moderate temperature (<200^{o}C), and high temperature (>200^{o}C), which is related to the Generation Designation as end user. The prospects with reservoir temperatures below 200^{o}C are considered marginal and not appropriate for Conventional Steam Turbine applications.

Based on the calculated subsurface temperatures, using chemistry geothermometers of known geothermal resources, approximately 14,800 MWe may likely be appropriate for power generation by Conventional Steam Turbine and, 9,000 MWe by Binary or other (Table 3). It is interesting to note that about 3,500 MWe of the 9,000 MWe are resources classified as non-electrical grade (<100°C) to very low temperature (100°C to <150°C) resources (Sanyal, 2005). Approximately 7,500 MWe of the 9,000 MWe are classified as low temperature (150°C to 190°C) or below (Table 4).

Therefore, the geothermal resources in Indonesia available for power production are estimated to be approximately 14,800 MWe of high enthalpy resources (appropriate for Conventional Steam Turbine) and 1,500 MWe (9,000 minus 7,500 MWe) of low enthalpy resources (appropriate for Binary or other).

The question is, in the context of cut-off temperature adopted/agreed by geothermal scientists and engineers (~180^{o}C), how can these non-electrical grade, very low temperature and, lower temperature resources be efficiently converted into power (MWe).

4.3 Impression of Thermal Features

The earth's heat is most obvious at the surface in volcanic zones with a full range of thermal manifestations that indicate an upflow area. These thermal features may include: solfataras, fumaroles, mud pools, steaming ground, hot springs and altered ground. The presence of some of these thermal features and the high magnitude of heat and mass discharged through these features is a strong indication of a high-temperature resource. These conditions may be appropriate for generating power using a conventional steam turbine.

On the other hand, prospects that are located at outflows and/or non-volcanic environments are usually limited in thermal features, which commonly consist of hot springs only. This type of environment is a strong indication of low to moderate temperature resources. This suggests that these prospects are low grade resources in terms of power production potential, and, therefore, binary power cycles are likely to be suitable for these areas.

Evaluating the Thermal Features of known Indonesian geothermal resources suggests that about approximately 14,000 MWe of the estimated power capacity may be appropriate for Conventional Steam Turbine and, approximately 10,000 MWe of the estimated power capacity are likely to be Binary or other (Table 3).

Table 3: Classification of Geothermal Resources in Indonesia: Based on Locality, Calculated Temperature and Impression of Thermal Features

Location	Classification Resources (MWe)					
	Locality (A)		Temperature (B)		Thermal Features (C)	
	I	II	I	II	I	II
Sumatra	7,666	3,295	7,831	3,130	7,281	3,680
Java	4,882	2,368	4,972	2,278	4,925	2,325
Bali	226	128	226	128	226	128
N.Tenggara	811	503	812	502	398	916
Kalimantan	-	145	-	145	-	145
Sulawesi	600	2,125	600	2,125	600	2,125
Maluku	355	640	365	630	365	630
Papua	-	75	-	75	-	75
TOTAL	14,540	9,279	14,806	9,013	13,795	10,024
	23,819		23,819		23,819	

I = Conventional, II = Binary or Other

5. DISCUSSION AND CONCLUSIONS

Table 3 shows the results of classifying the known resources according to calculated temperatures of less than or greater than 200^{o}C (Classification B). The results are in a good agreement with resources classified by locality (Classification A) and thermal features (Classification C). The average result is about 14,500 MWe of high-enthalpy reources suitable for conventional steam turbine applications, and about 9,500 MWe of low-enthalpy resources, more suitable for binary cycles. However, this number will be discussed further below.

The critical issue depends on the magnitude of the published resource resulted from calculations using temperature categorized as non electrical grade (<100° C), very low temperatures (100° C to <150°C) and, low temperatures (150°C to 190°C). The cut-off temperature used in the temperature calculation is usually not known / consistent. Regardless, an attempt to classify the potential resources from each of these three groups of estimated reservoir temperatures is discussed below..

The low temperature resources (<190°C) were divided into separate categories according to Sanyal (2005): non-electrical grade - ~850 MWe; very low temperatures - ~2,700 MWe; low temperatures - ~4,000 MWe (Table 4). The total is about 7.500 MWe. This amount should be considered unreliable due to the inappropriate used of cut-off temperature in the calculations. It is proposed that this 7,500 MWe should not be included in estimates of Geothermal Resources.

For example, Bukit Kili (West Sumatra) is an outflow at a distance of 15 km from Gn. Talang, which is the heat source. The estimated potential reserve is 83 MWe. Similarly, Suwawa (Gorontalo-North Sulawesi) located away from any known heat source but has an estimated potential reserve of 110 MWe. Another example is the Ciseeng prospect (West Java), which is a distal outflow of an unknown heat source with calculated reserves of about 100 MWe. This is another example where there is no investor response to the government invitation for Preliminary Surveys. These examples demonstrate that the 7,500 MWe of low temperature resources are not appropriate to include in the total of Indonesian power capacity from geothermal resources.

Based on the three types of resource classification discussed above, it is concluded that the known geothermal resources provide about 14,500 MWe of high-temperature resources appropriate for Conventional Steam Turbine and 9,500 MWe of them to Binary or Else (Table 3).

Based on the whole description above, it is concluded that the resources provides of about 14,500 MWe may likely be dedicated to Conventional Steam Turbine and 2,000 MWe of them to Binary or other, while the 7,500 MWe suggest not to include in the resource. So, the total geothermal resource in Indonesia is about 16,500 MWe.

The presentation and classification above is important for being a basis that is satisfactory to investors and other stakeholders. The successful development of geothermal resources in Indonesia is highly dependent on the interest of investors to a prospect / area; therefore, the most accurate presentation of data is required.

Table 4 : Classification of Geothermal Resources in Indonesia: Based on Temperature Resources Group

Location	Resources Classification (MWe)			
	Low Enthalpy			High Enthalpy
	< 100°C	100°C to < 150°C	150°C to 190°C	> 190°C
Sumatera				
Aceh	25	350	75	782
N.Sumatra	-	25	225	2253
W.Sumatra	-	270	618	728
Jambi+Riau	-	50	174	778
Bengkulu	-	-	60	1005
B.Belitung	-	105	-	-
S.Sumatera	-	50	293	987
Lampung	-	25	365	1718
Java				
Banten	-	-	148	385
W.Java	150	625	360	3261
C.Java	-	235	115	954
E.Java	-	85	-	932
Bali	-	128	-	226
N.Tenggara	-	31	746	537
Kalimantan	65	55	25	-
Sulawesi	485	416	678	1146
Maluku	50	210	293	442
Papua	75	-	-	-
TOTAL	850	2660	4175	16134
	7685			16134

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