Geothermal Potential Estimation Using its Classification System, According to the National Standarization Agency of Indonesia

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ABSTRACT

Indonesia is made up of more than 17,000 islands of varying sizes, located between 6º North and 11º South Latitudes, and 95 º - 141 º East Longitudes, at the eastern end of Mediterranean and western side of Pacific Volcanic Belts. This fact makes Indonesia is one of the most active volcanic region with its geothermal resources widespread among The Indonesian Archipelago.

The central question for discussion is how much the geothermal potential is available and how can its estimation be established.

This paper briefly describes a national standardization of the methods used to estimate geothermal potential for identified geothermal prospect areas and describes its methodology for geothermal resources all over the country.

Introduction

Over 250 locations of geothermal prospect areas have been identified by the Geological Agency of Indonesia (prev Volcanological Survey of Indonesia / VSI).

In order to use geothermal terms with precision and common understanding and to compare resource data effectively, a working group of geothermal experts has been appointed by the Department of Mine and Energy (DME) in 1994. Its member consists of engineers, scientists, government officials and private industry as well as all geothermal communities in Indonesia. The close collaboration, sharing of ideas and intensive discussion has developed a standardized, definitive, broadly applicable classification system to derive uniform, coordinated resources estimate based on the recognized technology.

Unlike the coal and petroleum industries the standardization of geothermal classification has no recognized references. The U.S. Bureau of Mines and U.S. Geological Survey (USGS) have established a coal resources classification system (USGS Bulletin 1450) for the coal industry, and similarly the oil and gas industry has developed several standardizations. Among of them is that developed by the Committee for Coastal and Offshore Geosciences Programmes (CCOP) in East and South East Asia, which established a Petroleum Resource Classification System in this region.

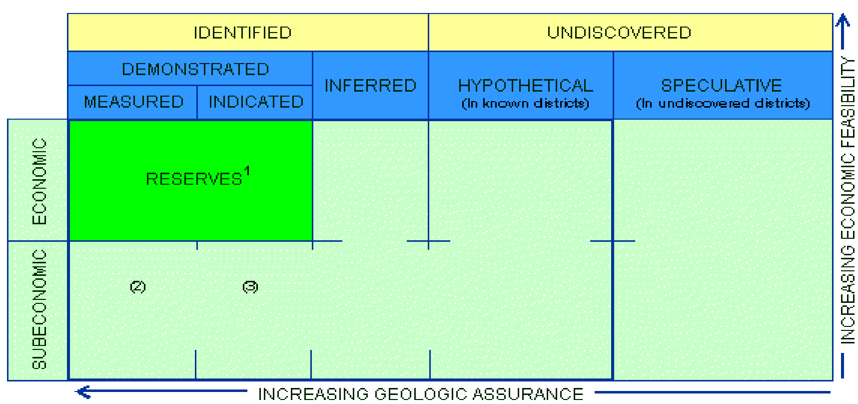

Figure 1. USGS Bulletin 1450: Coal Resources Classification System.

Geothermal Classification Its Terminology

Project Phases and Its Activities

The precise characteristics of geothermal resources can not be determined from the surface prior to drilling and flow testing. To control investment risk, geothermal development project are typically undertaken in phases.

The US Department of Energy (1995) divides geothermal development phases into several activities as follows: (1) Reconnaissance: do geological, geochemical studies, (2) Discovery:

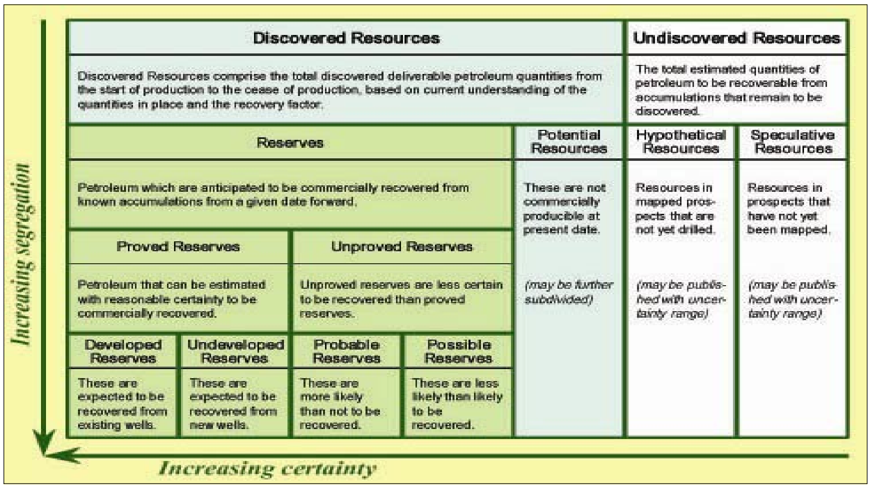

Figure 2. The major principle and a schematic description of the petroleum resources categories in the CCOP classification system.

drill 1 to 4 deep holes at best site to find hot fluid and do initial flow tests. (3) Confirmation: drill more deep wells to prove field can support the application and conduct additional flow tests. (4) Design: design and cost plant and fields. (5a) Production drilling: drill production and injection wells. (5b) Plant construction: build the plant. (6) Operation: operate and maintain system. Drill replacement wells as needed.

Indonesian practice is to divide the development of a successful geothermal energy project in Indonesia into the following stages:

(1) Reconnaissance / preliminary exploration; review existing data and do geological mapping and preliminary geochemical investigations. Products include reconnaissance geological map, distribution of geothermal manifestations, surface and subsurface temperatures and other parameters.

(2) Advance reconnaissance / advance preliminary exploration; do geological, satellite imagery, geochemical and geophysical surveys to produce geological map, chemical and fluid anomaly, and geophysical and hydrogeological maps.

(3) Detailed exploration; integrated geoscientific survey, geological map (1: 5,000), geochemical surveys, and geophysical survey and thermal gradient wells. These gradient wells provide the first, strong and direct evidence of the location and intensity of thermal energy

(4) Exploratory drilling (wildcat); drilled in a new geothermal prospect, it allows collection of all types of geologic, chemical, physical and reservoir related information. Its success or failure will strongly influence commitment of funding for further work.

Phases one through 4e are considered to comprise the prefeasibility study stage of geothermal assessment.

(5). Delineating drillings; drilled in a triangular arrangement to provide three dimensional data interpretation for reservoir confirmation purposes. This phase include careful well testing to determine the suitability of each well for production or injection. The data accumulated during this phase is used is the foundation for the feasibility analysis, the milestone for the construction funding.

(6) Development drillings; drilled a number of production wells to produce the quantity of energy needed to fulfill power plant requirement. Seven MW per well is considered to be the economic limit in Indonesia. However, for many wells in geothermal fields, produce much more than 7 MW (Darajat-2/81.3 MW installed 2001, have been producing 41 MW from single well, Wayang Windu 1/110 MW installed 2001, producing 40 MW from single well, Wayang Windu 2/110 MW under construction producing 40 MW from single well.

(7) Utilization of geothermal resources: 30 years in operation

Classification System

In order to have a consistent system, the classification system for geothermal potential is entirely based on the exploration stages of geothermal development.

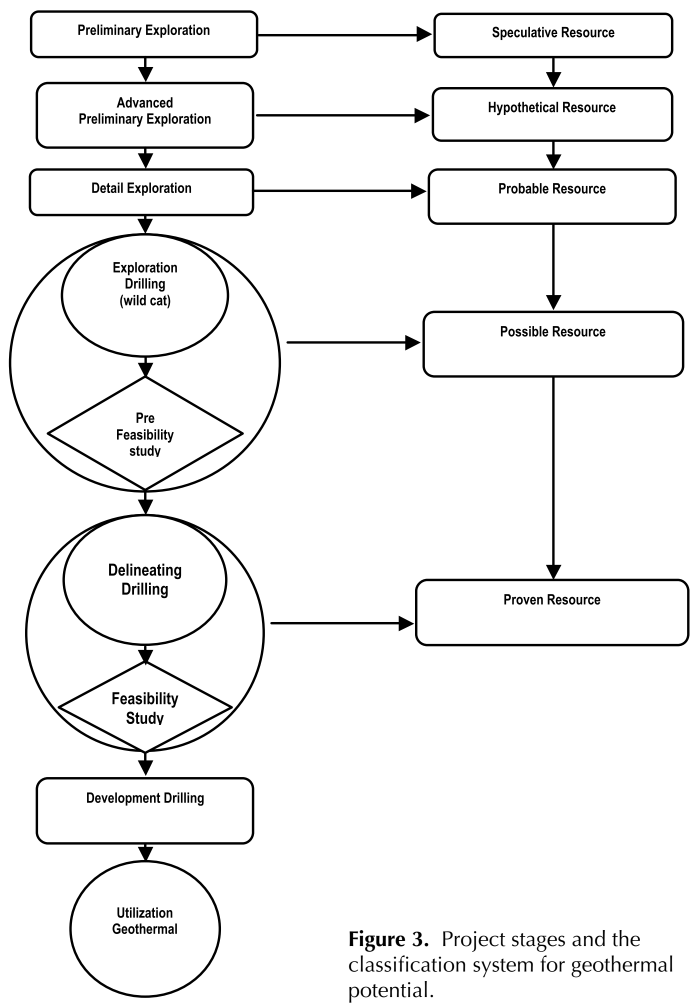

Figure 3. Project stages and the classification system for geothermal potential.

Preliminary exploration gives a resource potential which further is subdivided into *speculative* and *hypothetical* resources. Detailed exploration gives a *reserve potential* which is further subdivided into *probable, possible* and *proven* resources.

A standard terminology relating to geothermal energy (ASTM Designation : E 957-98) does not give any definition for geothermal resources potential, while geothermal reserves are defined as the amount of energy anticipated to be economically recoverable from a geothermal facility over a specified time period using existing technology.

Methodology

Potential Estimation

The classification system defines several recognizable formulas to establish a quick way of potential estimation for serial ranking geothermal projects at varying stages of maturity, The resource potential of a speculative resource, an undiscovered geothermal prospect area which is identified from preliminary exploration, is estimated using the following formula;

$$H_{el} = A \times Q_{el}$$

Where:
H_{el} = energy potential (MWe)
A = prospect area (km²)
Q_{el} = power density (MWe/km²)

While for a hypothetical resources, probable, possible, and proven reserve potentials are calculated using the following formula;

$$H_e = Ah\left[(1-\Phi)\,P_r \times C_r \times T + \Phi\,(P_L U_L S_L + P_v U_v S_v)\right]$$

Where:
H_e = thermal energy (kJ)
A = prospect area (m²)
h = thickness of reservoir (m)
T = temperature of reservoir (°C)
S_L = saturation of liquid (fraction)
S_L = saturation of vapor (fraction)
U_L = energy of liquid (kJ/kg)
U_v = energy of vapor (kJ/kg)
Φ = porosity of rock (fraction)
C_r = capacity of rock thermal (kJ/kg²C)
P_r = density of rock (kg/m³)
P_L = density of liquid (kJ/m³)
P_v = density of vapor (kJ/m³)

However for proven geothermal reserves, the calculation is expanded from conceptual to a complex two or three dimensional numerical model, including:

- Conceptual geologic modeling to define the geometry and physical properties of the system;
- Numerical simulation of reservoir behavior under production and injection conditions;
- Geochemical modeling to analyze changes in reservoir fluids and rocks and to predict the movement of chemical fronts through the reservoir in response to production and recharge;
- Computer analysis of well test data to determine key reservoir parameter; and
- Well bore simulation to analyze fluid flow heat transfer inside the well

Procedure of Calculation

The volumetric estimation is derived from the following formula:

- The initial energy potential ;

$$H_{ei} = Ah\,[(1-\Phi)\,\rho_r C_r T_i + \Phi\,({}_L U \rho_L S_L + P_v U_v S_v)$$

- The final energy potential

$$H_{ef} = Ah\,(1-\Phi)\,\rho_r C_r T_f + \Phi\,(\rho_L U_L S_L + \rho_v U_v S_v)$$

- The maximum utilization energy :

$$H_{th} = H_{ei} - H_{ef}$$

- The real energy utilization

$$H_{de} = R_f .\ H_{th} \qquad \text{(kJ)}$$

$$H_{re} \quad \frac{H_{de}}{t \times 365 \times 24 \times 3600 \times 1000} \quad (\text{MW}_{th})$$

- The potential energy for t year

$$H_{el} = \frac{H_{de}.\eta}{t \times 365 \times 24 \times 3600 \times 1000} \quad (\text{MWe})$$

Where:
T_i = the initial temperature of reservoir (°C)
T_r = the final temperature of reservoir (°C)
H_{ei} = the initial of energy potential of rock and fluid (kJ)
H_{ef} = the final of energy potential of rock and fluid
H_{th} = the maximum of geothermal energy (kJ)
H_{de} = geothermal potential (MWth)
H_{re} = the maximum of utilizable geothermal energy at the certain duration (MW$_{th}$)
H_{el} = geothermal potential (MWe)
R_f = ability factor (fraction)
t = time duration
η = conversion to electricity energy (fraction)

Discussion

Recently 252 locations of geothermal manifestation have been identified, distributes across the Indonesian Archipelago. However, it must be recognized that most of identified prospect areas are still under preliminary stages of explorations.

Currently Indonesia geothermal has 860.8 MWe of geothermal power plants, with an additional 290 MWe under construction. The largest unit of geothermal is at Wayang Windu 1 (110 MW), West Java.It became operational in 2001 with a largest single production well of 40 MW. Wayang Windu

2 (110 MW), which is now being installed, also has a 40 MW well. The largest production well, 41 MW, is at Darajat 3 (81.3 MW), West Java which began operation in 2001

Geothermal potential estimation using this standardized method of assessment concluded that the total potential capacity of Indonesia is 27, 469 MWe with the detail estimation as shown in the Table 1.

Table 1. Estimated Geothermal Potential in Indonesia.

	Resources (MWE)		Reserve (MWE)		
Island/Archipelago	**Speculative**	**Hypothetical**	**Probable**	**Possible**	**Proven**
Sumatera	5,730	2,433	5,419	15	499
Jawa	2,325	1,641	2,850	603	1,722
Bali	75	-	226	-	-
West Nusa Tenggara & East Nusa Tenggara	340	438	531	-	14
Sulawesi	1000	125	632	110	65
Maluku	275	117	142	-	-
Papua	50	-	-	-	-
Kalimantan	50	-	-	-	-
Total	**9,845**	**4,790**	**9,800**	**728**	**2,300**

This estimate of the geothermal potential of Indonesia does not include additions to potential development which may be possible through utilization of Enhanced Geothermal Systems or Hot Dry Rock technology.

Table 2. Present Geothermal Capacities.

Plant Location	Installed Capacity(MW)	Turbine/ Generator	Commen Cement Date	Power Plant Operator	Steam Filed Operator
AWIBENGKOK SALAK					
1	60 (2006) up rating from 55	ANSALDO	1994	PLN	CHEVRON/ PERTAMINA
2	60 (2006) up rating from 55	ANSALDO	1994	PLN	CHEVRON/ PERTAMINA
3	60 (2006) up rating from 55	ANSALDO	1997	PLN	CHEVRON/ PERTAMINA
4	65 (2006) up rating from 55	FUJI	1997	CHEVRON/ PERTAMINA	CHEVRON/ PERTAMINA
5	65 (2006) up rating from 55	FUJI	1997	CHEVRON/ PERTAMINA	CHEVRON/ PERTAMINA
6	65 (2006) up rating from 55	FUJI	1997	CHEVRON/ PERTAMINA	CHEVRON/ PERTAMINA
KAMOJANG					
1	30	MITSUBISHI	1982	PLN	PERTAMINA
2	55	MITSUBISHI	1987	PLN	PERTAMINA
3	55	MITSUBISHI	1987	PLN	PERTAMINA
DARAJAT					
1	55	MITSUBISHI/ FUJI	1994	PLN	AI/PERTAMINA
2	81.3	MITSUBISHI	2001	AI/PERTAMINA	AI/PERTAMINA
DIENG					
1	60	ANSALDO	1998	PERTAMINA	PLN & PERTAMINA
LAHENDONG					
Binair	2,5	Thermodyn	1991	BPPT	BPPT
1	20	ALSTHOM	2001	PLN	PERTAMINA
SIBAYAK					
1	2	Geothermal Thermal Co.	1996	PERTAMINA	PERTAMINA
Wayang Windu					
1	110	FUJI	2001	CHEVRON	CHEVRON/ PERTAMINA

BPPT: Agency for the Assessment and Application of Technology.

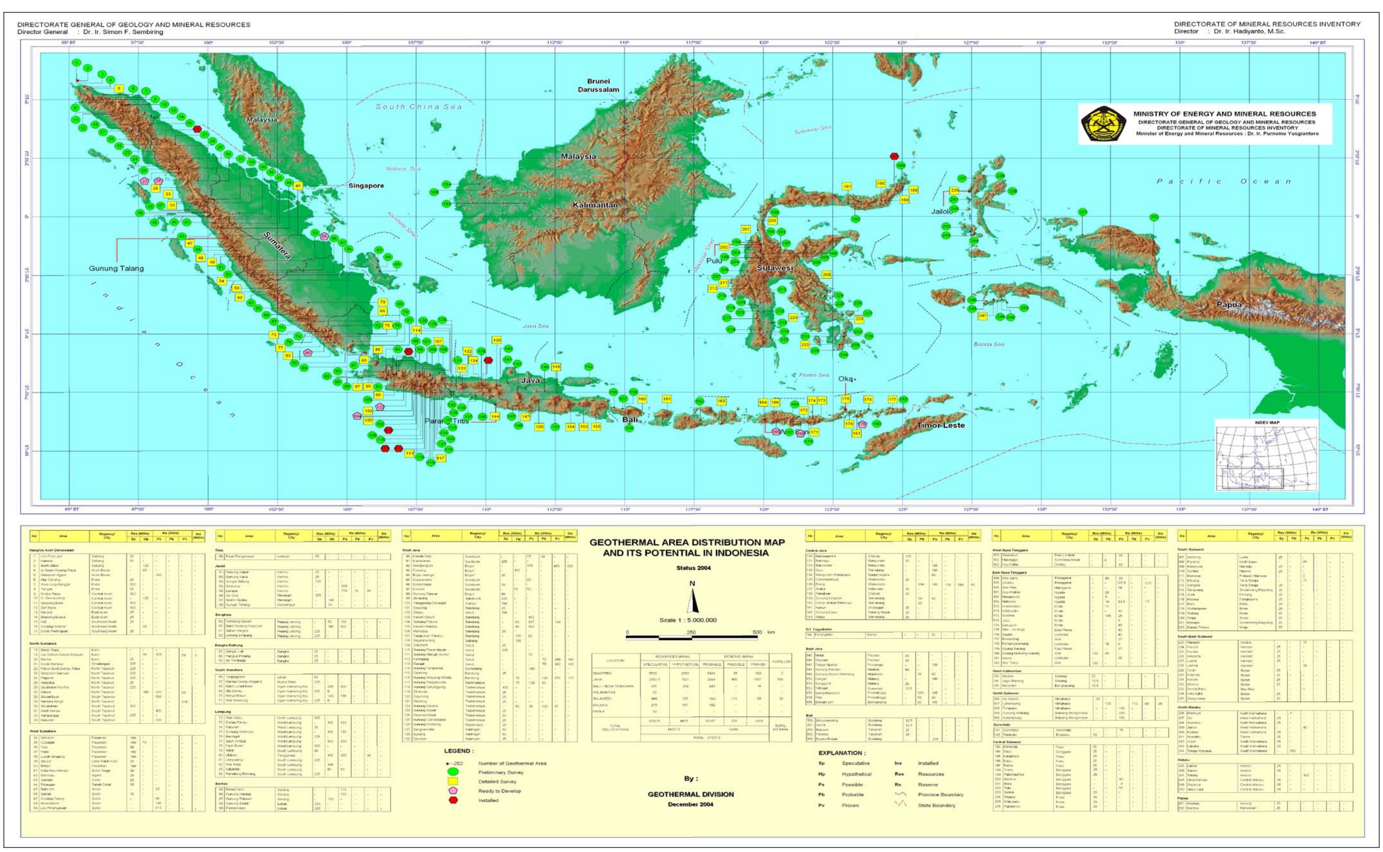

Figure 4. Distribution of Geothermal Area and Their Potential in Indonesia

Table 3. Projects under Construction.

Plant Location	Installed Capacity (MW)	Turbine/ Generator	Commen Cement Date	Power Plant Operator	Steam Filed Operator
Darajat 3	100	Mitsubishi	2008	Chevron	Chevron/ PERTAMINA
Lahendong 2	20	Fuji	2008	PLN	PERTAMINA
Wayang Windu 2	110	Fuji	2008	Star Energy	Star Energy/ PERTAMINA
Kamojang 4	60	Fuji	2008	PERTAMINA	PERTAMINA

Conclusion

The establishment of the classification is based on a simple methodology.. However, as each successive phase resource data accumulation is completed, updating, the knowledge of the resources, the estimation data should also be revised.

Continued study and industry experience provide a dynamic movement of resource classification and changing resource estimates. For example Salak geothermal field, West Java, during feasibility resources indicated 170 MWe's proven reserve. However since its installation from 1994 to 1997 it produced 6 x 55 MWe. And from 2006 up to recently have been producing 3 x 60MWe after diaphragm up rating process.

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