A PROPOSAL FOR GEOTHERMAL RESOURCE CLASSIFICATION: AN INDONESIAN CASE

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ABSTRACT

As the nature of l resource study, it is not a final study, but it is a continuing process. SO, the result of a resource study at one stage may be reevaluated at another stages. Furthermore, the results of the following stages may be different to those before, i.e. Ray support, be modified or my be totally different and sometimes an interpretation of one author is different with the others. However, generally tho more complete tho data and information gathered, the better a resource study is. To make a common undoretanding of tho term uud,, its necessary that a resource potential bo classified to coincide with its field activities done i.e. exploration and exploitation stages. In this paper five classifications are proposed with each respected criteria, namely: hypothetical, speculative, possible, probable and proven classes. This classification is then applied to calculate all tho Indonesian reserves, and results in the following : 840 MWe for proven class, 1 507 We for probable class, 7 797 MWe for possible class, and 26 000 MW for speculative class.

1. INTRODUCTION

Nowadays thoro is no uniform international standard in tho geothermal reserve classification. It often causes different potential values of the potential areas which have been surveyed by several companies. The different of tho values is caused by different levels of surveys. It is different from tho classification of oil and gas which have the same terms for the same conceptions. For example : people will be able to understand the meaning of "possible reserve" or "proven reserve" quickly because tho terms a n related to the accepted criteria. Based on this condition, the Dinctoratm of exploration and Production of Geothermal MIGAS established a small team consisted of the representatives from Directorate of Exploration and Production of Geothermal, Research and Development Center of Oil and Gas "LEMIGAS", Center for Oil and Gas Human Resources Development, PERTAMINA, Volcanological Survey Indonesia, Directorate General of Electricity and New Energy, and PLN. TO try to develop a geothermal reserve classification which is accepted nationally, or internationally if possible.

2. STATE OF THE ART OF RESOURCE POTENTIAL ASSESSMENT

Resource potential can bo estimated during the early scientific exploration phase. This estimate is baud on thorough assessment of natural heat output and this in turn means that all surface features connected with tho resource must be identified a8 part of the resource, and their thermal outputs estimated.

Estimation of these thermal outputs are very rough, and a small total thermal output does not mean that in every situation that no suitable resource exists, since some economic resources produce very few surface thermal features.

Another method of estimation that occurs early during exploration is by comparison of prospect size with some similar fields. Again thie estimation is very rough.

Estimation of resource potential will improve, if it is possible to deduce the energy content of the resource. In order to do this, it is necessary to know tho geometric extent of the reservoir and the porosity as well as tho fluid content.
To get reliable measurements of these quantities is not easy. The resource boundary is usually determined by some geophysical method such as electrical resistivity. But sometime, eventhough tho resource boundary has boon defined, tho permeability of tho rock in some parte within the boundary is vory poor.

Tho depth of resource is again epeculative, and it may be nearly impossible to define a lower

boundary. It is usually be assumed and this undoubtedly involves a significant error.
Tho nature of tho geothermal system whether wet steam or dry steam may be estimated by geochemistry. Porosity is often assumed based on goological considerations of tho nature of tho reservoir rocks.

All this implies a very wide range of error likely in every estimation. However, tho guiding philosophy is to bo conservative.

When tho above quantities are known or have been estimated conservatively, thoro remains one more parameter to decide on - that is what proportion of resource energy can be extracted for use, tho Recovery Factor. This is even more difficult to determine. However, as more and more information becomes available about the resource so we might bo able to improve tho degree of confidence in our estimates.

A more usual method used In stored hoat estimation is "lumped parameter model", tho equations of which are as follows :

- The total thermal energy in rocks

$$QRO = A \times h \times (1 - \phi) \times Cr \times \rho r \times T \quad (1)$$

- Tho total thermal energy content in fluid

$$QFO = A \times h \times \phi (Sv \times \rho v \times Hv + Sl \times \rho l \times Hl) \quad (2)$$

- The useful thermal energy content in rock8

$$QR = A \times h \times (1 - \phi) \times Cr \times \rho r \times (T-Tc) \quad (3)$$

- Tho useful thermal energy in fluid

$$QF = A \times h \times \phi (Sv \times \rho v \times Hv + Sl \times \rho l \times Hl) \quad (4)$$

$$Sl + Sv = 1 \quad (5)$$

- Tho fluid mass content in tho reservoir

$$M = A \times h \times \phi \times \rho \quad (6)$$

- Tho electric power capacity

$$P = (W \times RF) / (U \times L \times CF) \quad (7)$$

- Approximation formula for power capacity

$$P = 0{,}2517 \times A \times (T - Tc) \quad (8)$$

Where :

A : tho rourvoir area
h : the reservoir thickness
ϕ : porosity
ρ : density
T : temperature of reservoir
S : fluid content
H : enthalpy
Cr : rock heat capacity
c : cold temperature limit, in this case Tc = 180 ^{o}C
M : fluid mass
RF : Recovery Factor
U : Steam - electricity conversion
P : Power Capacity
CF : electric generator capacity factor
L : life time of electric generator
v : vapor
1 : water

3. THE CONCEPTUAL BACKGROUND

General speaking of oil Industry energy reserves are classified into four classes, based on the level of evidence :

- Resource (011 Province)
- Possible Reserve
- Probable Reserve
- Proven Reserve

Each of tho classes above has its own criteria agreed internationally (Arps.J.J. 1962).
Tho parameters used In geothermal reserve system are different compared to oil end gas reserve system.

Geothermal resource are traditionally associated with volcanic activities directly or indirectly, or associated with depression structure. In this case, meteoric waters penetrate to great depth below the subsurface, heated by magmatic intrusion, and on the way back to the surface geothermal reservoir night be developed with manifestations ouch as geyser, solfatara, fumaroles, etc.
In order to determine the parameters associated with tho geothermal resources, scientific studies such as geology, geochemistry and geophysics are need.

Geological analysis examine emphasizes volcanic activities, structures and volcanic stratigraphy associated with geothermal system. Geochemistry analysis emphasizes the hydrological system, homogeneity and/or fluid system. Geophysical studies examine geometrical structure and subsurface structure of the geothermal system. Based on the three "geosciences" a "basic model" of the geothermal system could be determined, ready to be explored in detail.

4. THE CLASSIFICATION OF GEOTHERMAL RESOURCES

Considering tho conditions mentioned above, a geothermal reserve classification system has boon developed by the team. This new classification system is as described below.

4.1. Hypothetical Potential Class.

This class determination is based on the geothermal prospect associated with the surrounding volcanic belt. The assumed potential is based on the statistical data of geothermal energy yield for similar areas: 10 - 15 MW/Km2 and the area indicated from regional volcanism.

4.2. Speculative Potential Class.

This class be determined if there has been regional reconnaissance including goological survey and geochemical survey, and surface manifestations such as hot springs, solfatara, fumaroles, rock alteration and mud pools have boon identified.

Potential reserve estimate is determined from equation (8). Tho temperature is obtained by geothermometer (geochemical) of surface manifestation and tho area of reservoir is estimated from the area by surface manifestations. In this case fluids and parameters of reservoir rock are assumed to be homogeneous.

4.3. Possible Reserve Class.

A tentative model of the geothermal system could be simplified based on integrated geoscientific exploration. By using equation (8) geothermal potential could bo determined, geometrical data and reservoir temperature derived from the result of tho surface survey and physical parameters of rock contained, in this caw fluids characteristic is still assumed. The reservoir thickness is coincide with subsurface structures and drilling depth which can bo reached.

4.4. Probable Reserve Class.

This class is determined based on exploration drilling result and the geothermal system can bo described In more detail. Equation8 (1) - (7) are used in obtaining the potential calculation and geometry (particularly reservoir thickness), petrophysical geometry and fluid thermodynamics matched with the available wells data.

4.5. Proven Reserve Class.

This class is established from productive wells. Wells spacing le appropriate with tho prospect area. Potential calculations is based on equations (1) - (7), and rourvoir parameters coincide with the productive wells data and rourvoir continuity established by well touting.

The summary of this classification in relation with its feasibility is shown In figure 1, figure 2 and figure 3.

Figure. 1

FLOW CHART OF
GEOTHERMAL EXPLORATION & EXPLOITATION ACTIVITIES
IN RELATION TO RESERVES CLASSIFICATION

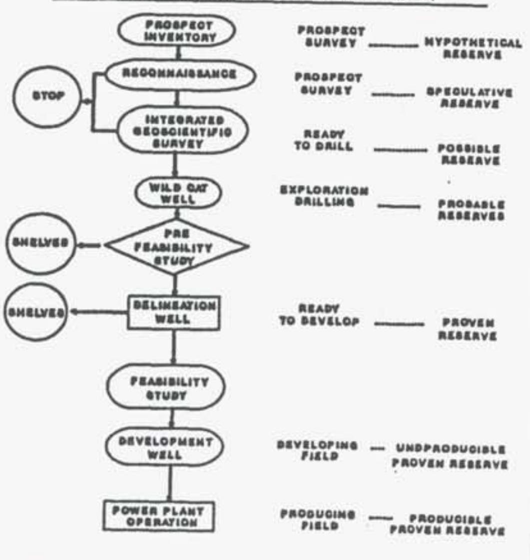


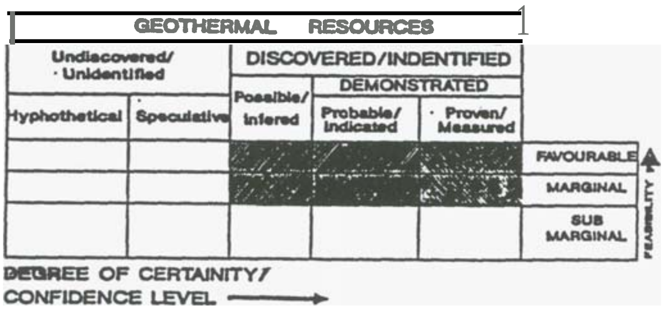
Figure 2

GEOTHERMAL RESERVE CLASSIFICATION SUMMARY

PROSPECT STATUS	RESERVE CLASS	SOURCE OF INFORMATION	CRITERIA	FORMULA
EXPLORATION SURVEY	HYPOTHETICAL	LITERATURE STUDIES RECONNAISSANCE REGIONAL STUDIES	PROSPECT INDICATOR: - THERMAL DISCHARGE - ASSOCIATED WITH VOLVANIC ACTIVITES	ASSUMPTION 12.5 MW/KM2
EXPLORATION SURVEY	SPECULATIVE	RECONNAISSANCE REGIONAL STUDIES CHEMICAL ANALYSIS OF THERMAL DISCHARGE	- CHEMICAL/GAS ANOMALY - GEOTHERMOMETER - ASSOCIATED WITH VOLCANIC ACTIVITIES	STORED HEAT CALCULATION Q = 0.2317*A*^T
READY TO DRILL EXPLORATION	POSSIBLE	INTEGRATED GEOSCIENTIF SURVEY	- TENTATIVE MODEL - GEOTHERMOMETER - TEMPERATURE GRADIEHT	STORED HEAT CALCULATION
EXPLORATION WELL	PROBABLE	INTEGRATED GEOSCIENTIFIC SURVEY EXPLORATION WELL	- TENTATIVE MODEL - TESTED WELL	STROREO HEAT CALCULATION
READY TO DEVELOP	PROVEN	INTEGRATED GEOSCIENTIFIC SURVEY EXPLORATION WELL	- MAKE UP MODEL - TESTED WELLS	STORED HEAT CALCULATION
OEVELOPINQ FIELD	PROVEN	INTEGRATED GEOSCIENTIFIC SURVEY EXPLORATION WELLS	- MAKE UP MODEL - TESTED WELLS	STORED HERT . CALCULATION
PRODUCING FIELD	PROVEN	INTEGRATED GEOSCIENTIFIC SURVEY EXPLORATION WELLS DEVELOPMENT WELL8	- MAKE UP MODEL - TESTED WELLS - PRODUCTION DATA	STORED HEAT CALCULATION SIMULATION

FIGURE 3

GEOTHERMAL RESOURCE CLASSIFICATION



5. INDONESIAN CASE

At present, it has boon recognized that Indonesia ham 217 of goothermal prospects. To which various surveyed has been done by the Volcanological Survey of Indonesia and PERTAMINA with different degree of intenmity i.e from reconnaissance survey to detail integrated survey. Geological survey has boon done on 214 prospects, geochemical survey on 200 prospects, geophysical survey on 45 prospects, and drilling on 10 prospects.

Of 217 prospects one prospect has been producing since 1983 (Kamojang), five prospects are in developing stage (Dieng, Lahondong, Salak, Derajat, and Wayang Windu), and four prospect8 are ready for exploration drilling (Bali, Patuha, Karaha, and Sibayak).

Based on these data, the calculations result show that tho potential of geothermal resource of

FIGURE 4

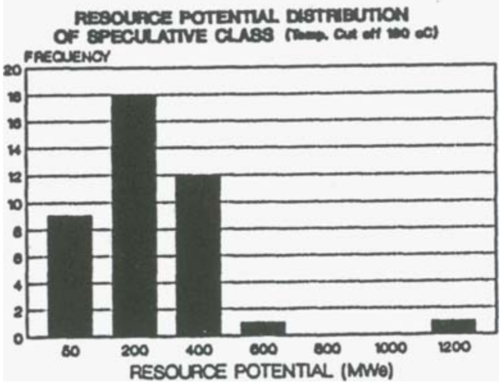


FIGURE 5

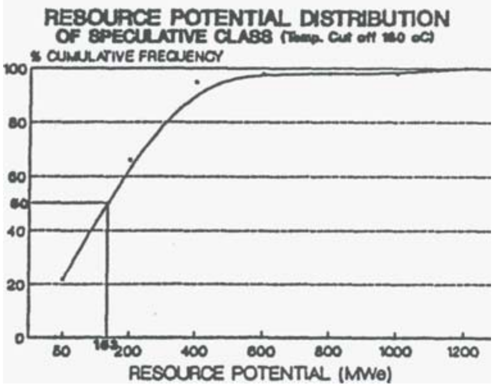


Figure 6

The Potential of Geothermal Resource of Indonesia
Year 1990

No.	Province	Class Potential, MW				
		Hypothetic	Speculative	Possible	Probable	Proven
1.	DI ACEH	-	2161	-	-	-
2	NORTH SUMATRA	-	918	1777	-	-
3.	WEST SUMATRA	-	2339	186	23	-
4.	J A M B I	-	812	28	79	-
8.	SOUTH SUMATRA	-	765	93	-	-
6.	BENGKULU	-	1606	-	-	-
7.	LAMPUNG	-	1480	1042)	-	-
8.	WEST JAVA	-	4407	2289	849	488
a.	CENTRE JAVA	-	306	464	162	227
10.	YOGYAKARTA	-	-	-	-	-
11.	EAST JAVA	-	306	ai1	-	-
12.	B A L I	-	306	232	-	-
13.	WEST NUSATENGGARA	-	459	21	-	-
14.	EAST NUSATANGGARA	-	1998	382	93	-
15.	NORTH SULAWESI	-	3755	957	301	125
18.	SOUTH SULAWESI	-	-	-	-	-
17.	SOUTH EAST SULAWESI	-	1692	-	-	-
18.	M A L U K U	-	2490	14	-	-
19.	IRIAN JAYA	-	-	-	-	-
	T O T A L	-	26000	7797	1507	840

Indonesia are a8 follow :

- Proven	:	840	MW
- Probable	:	1 507	MW
- Possible	:	7 797	MW
- Speculative	:	26 000	MW

However, since tho data of hypothetic classes were very limited, their potential wore not calculated yet. It is also should be noted here, that not all of tho prospects of speculative class could be calculated by using formula (8), so to those prospects their potential were assumed to be equal to tho average value of the class. Figure 4 and Figure 5 show how tho average value of this class was determined. The geothermal resource potential of each province is shown in Figure 6.

6. ACKNOWLEDGEMENTS

Tho Authors would like to acknowledge tho Director General of Oil and Gas for his permission to publish this paper. Thank are also due to tho Director of Exploration and Production of Geothermal for his encouragement and suggestion in preparing this geothermal resource classification.
This paper is prepared based on the discussion result of the small team, the members of which are Messr: I.A.Takhyan (coordinator), H.Zayadi, Suroto,Sayogi Sudarman, F.Djazuli, M.Panggabean, Z.Permana, S.Witono, D.Waluya, D.Sirait, B.Hutabarat, K.Panggabean, H.Purnomo, S.Bachri, A.Situmorang, R. Maulana, S.Hasni, and S.Hassan. Tho author8 would like to acknowledge tho members for their contributions in preparing this proposal.

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