GEOLOGICAL AGENCY OF INDONESIA'S EXPLORATION STRATEGY ON NON-VOLCANIC GEOTHERMAL AREAS

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ABSTRACT

Indonesia is endowed by abundant geothermal energy resources, mostly located along volcanic belts. From the total of 324 locations, with estimated geothermal resource potential of about 29 GW, 30% are in non-volcanic areas distributed in Sumatra, Kalimantan, Sulawesi, Maluku and Papua. Currently, the 1436 MW electricity installed capacity generated from geothermal energy is from only 10 locations all associated with a volcanic environment. The geothermal installed capacity is only 5% of the estimated total potential and contributes only 2.9% of the total installed capacity in Indonesia. Indonesia is targeting geothermal energy to contribute 8.97% of the energy mix for electricity generation by 2025. From the projection of 2015-2024 electricity demand, there will be a significant increase in the eastern part of Indonesia where there is currently a low electricity demand and ratio. It seems there is a chance to accelerate utilization of geothermal energy especially in areas where there are no other energy resources.

Since 2001 the Geological Agency of Indonesia (GAI) has increased the budget allocation in focusing more detailed 3G survey works on non-volcanic geothermal areas and some of them have already been drilled to get temperature gradient data at depth. These exploration results are expected to enhance the data quality in supporting the delineation of working areas. The more accurate preliminary data will indeed minimize risks in further exploration and development that possibly may be conducted by private parties.

1. INTRODUCTION

Indonesia, as an archipelago, has a unique tectonic setting where geothermal energy resources can be found in many parts of the country. The location of these prospects are mostly related to Quaternary active volcanism and the remaining approximately 35% is associated with Tertiary volcanic activity and non-volcanic areas. There have been 324 geothermal locations identified with a total potential of around 29.4 GW of which 122 locations are associated with non-volcanic systems. The non-volcanic systems are mostly located in the eastern part of Indonesia such as Sulawesi, Kalimantan, Maluku and Papua. These prospects are very important, especially those situated in poor areas which have no other energy sources such as fossil energy.

Geothermal energy power plants in Indonesia are currently installed in only 10 locations, all associated with active volcanism and mostly located in Java and Sumatra, with a total capacity of 1436 MW. This figure is only 5% of the total geothermal potential and contribute approximately 8.97% in the energy mix of the total installed capacity of 53,065 MW for electricity generation. By 2025, geothermal energy is targeted to contibute 8.97 % in the energy mix for electricity generation. From the projection of 2015-2024 electricity demand, there will be a significant increase in the eastern part of Indonesia where there is currently a low electricity demand and ratio. In fact, a lot of geothermal features are widely distributed in the eastern parts of Indonesia and are promising for development. The inadequacy of infrastructure in the eastern part of Indonesia is an obvious constraint on exploration there since cost and risks will be significant. Therefore, government is expected to share or even take the exploration development risk.

The Geological Agency of Indonesia (GAI) is an institution under the Ministry of Energy and Mineral Resources (MEMR) that represents government and is tasked to conduct a geothermal inventory and exploration and to prepare geoscience data for proposed working areas. According to the new Geothermal Law (UU No.21/2014), the government is allowed to conduct exploration, exploitation, and utilization as well. This is a challenge for GAI to improve its contribution to accelerating geothermal development by increasing exploration works to provide more complete and accurate data for proposed working areas. GAI realized that there will be many obstacles to developing non-volcanic geothermal systems, since there is no experience and limited knowledge and understanding about non-volcanic geothermal systems. However, GAI is about to embark in responding to the demand for the government to more deeply accept the risk of geothermal development in Indonesia.

2. NON-VOLCANIC GEOTHERMAL POTENTIAL IN INDONESIA

The definition of a non-volcanic geothermal prospect in this paper is a geothermal area which is not related to Quaternary volcanic activity. Geologically, a non-volcanic system in Indonesia is associated with an old subduction basin, a sedimentary basin, a geopressure zone, a sedimentary basin radiogenic activity, an active seismic tectonic zone, a Tertiary volcanic system and an intrusive or plutonic system (Figure 1).

Non-volcanic geothermal systems in Indonesia are mostly characterized by low to medium enthalpy with an estimated reservoir temperature less than 225^{o}C, and hence they usually have a small potential (<100 MW). Their surface thermal features are mostly dominated by the presence of neutral hot springs, but the water chemistry may indicate water – rock interaction at depth. The presence of fumarole was never found, with steam vents in only a few areas and rock alteration does not significantly appear. Geothermal systems in non-volcanic prospects usually involves igneous rocks, metamorphic rocks, and/or Tertiary sedimentary rocks with a heat source located in Quatenary dykes. Non-volcanic

geothermal prospects in the western part of Indonesia are generally distributed in the eastern part of the Sunda Shelf. The lithology in this area is dominated by Asia Continental Crust rocks like metamorphic and sedimentary rocks. While in the eastern part of Indonesia, the non-volcanic geothermal prospects are in the "arms and legs" of Sulawesi Island, Maluku Islands and Papua where they involve mostly granite, metamorphic rocks, and marine sedimentary rocks (Nurhadi, 2014).

Most non volcanic geothermal areas in Indonesia are still an in early, preliminary, state of survey. 3G (Geology, Geochemistry, Geophysic) detailed surveys have been conducted at only 34 location. Five of those locations have been drilled for thermal gradient survey. The shallow wells (250m - 700m) were drilled at Laenia (4 wells), Marana (2 wells), Bora (2 wells), Parara (2 wells) and Kadidia (1 well), all located in Sulawesi. The total resources estimated for 122 non-volcanic geothermal prospects in Indonesia is around 3,400 MW (Table 1).

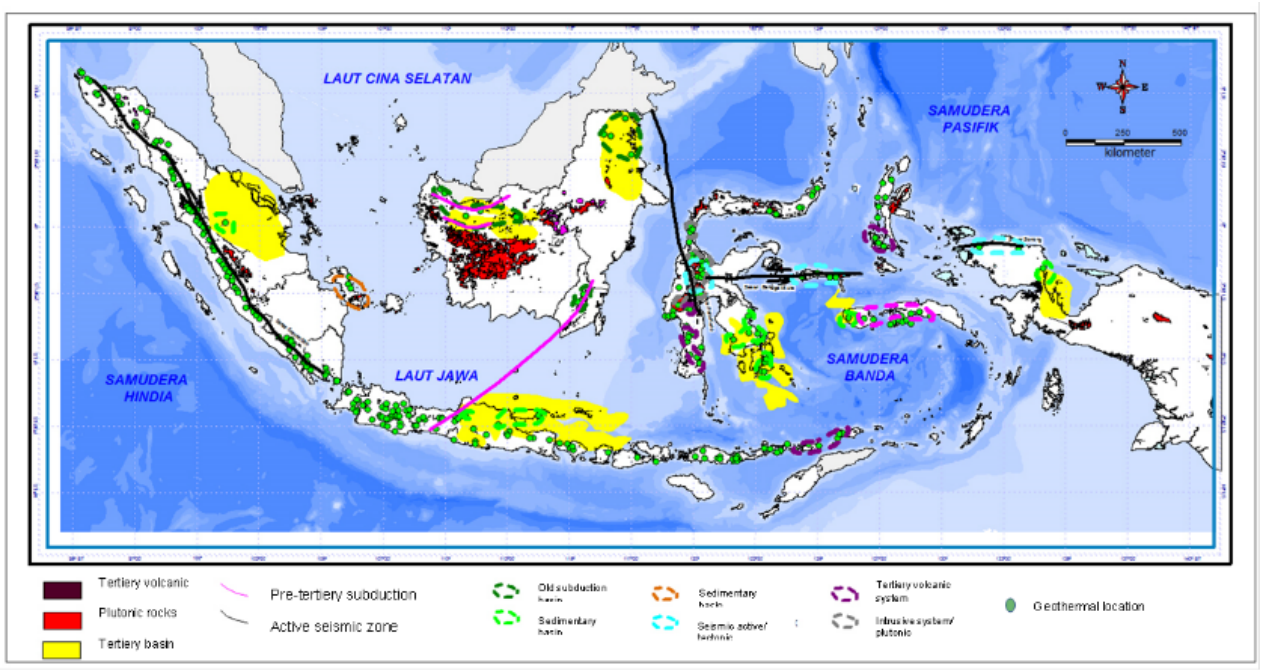

Figure 1. Distribution of non-volcanic geothermal areas in Indonesia (GAI-MEMR, 2015)

3. GAI'S ROLES IN EXPLORATION OF NON-VOLCANIC GEOTHERMAL PROSPECTS

The energy sector has a crucial role in national development, especially in supporting the national economy and sources of state revenue. GAI's role in the energy sector includes conducting geothermal exploration, research data collection and data services. The three important roles that should be carried out by GAI in implementing tasks related to national energy policy are: (i) to increase exploration, (ii) to improve the status of geothermal resources and reserves including updating estimates of geothermal energy resources, and (iii) to prepare data for supporting proposed working areas. The National Energy Policy set a target of geothermal capacity of 7,230 MW (cummulative at the end of 2019). By considering the constraints on geothermal development, GAI set more realistic strategic exploration plans for achievement of up to 3,412 MW, recognising that geothermal development should be directed towards energy independency and national sustainable development (Figure 2)

The 2012-2015 geothermal exploration Roadmap produced by GAI plans to conduct exploration in Quaternary Volcanic Hydrothermal Systems, outside Quaternary Volcanic Hydrothermal Systems (plutonic, tectonics, sedimentary basins, etc.), and non-Hydrothermal Systems (Enhanced Geothermal System). Since 2002, GAI started allocating exploration budget to conduct more detailed 3G surveys in non-volcanic geothermal systems. The inventory of new prospects in non-volcanic systems has significantly increased in the last few years, as can be seen from the increasing number of new non-volcanic geothermal prospects, from 62 locations out of 265 total locations (23%) in 2006 to 122 locations out of a total of 324 locations (37%) in 2015 (Figure 3). Improvement of survey methods conducted in non-volcanic system also helped to enhance both the quantity and quality geoscience data. The more accurate geoscience data will give more confidence in estimates of energy potential, as well as resources and reserves, and thus will also reduce the risk of subsequent development that might be undertaken by the private sector.

Data on the thermal gradients from the wells drilled by GAI at five locations in non-volcanic systems showed positive results consistent with 3G detailed survey data. The drilling results prove the existence of temperature gradient anomalies at depth. The areas where shallow drilling has been conducted, with depths of 250 m to 700 m, are Marana (Central Sulawesi, 2 wells), Bora (Central Sulawesi, 2 wells), Kadidia (Central Sulawesi, 1 well), Parara (South Sulawesi, 2 wells), and Laenia (South-east Sulawesi, 4 wells). Deep exploration drilling is expected to be implemented, starting in 2016.

No	Location name	Regency	Resources MW)		Reserve (MW)			Survey Stage
			Spect	Hypot	Poss	Prob	Prov	
1	Meranti	Aceh Timur	25					PS
2	Brawang Buaya	Aceh Tamiang	25					PS
3	Lokop	Aceh Timut	5	45				Detail 3G TDEM
4	Kaloi	Aceh Tamiang	10	15				Detail 3G AMT
5	Sibubuhan	Sibubuhan	100					PS
6	Pasir Pangarayan	Kampar	25					PS
7	Sungai Liat/Pelawan	Bangka	25					PS
8	Pangkal Pinang/Pemali	Bangka Tengah	25					PS
9	Air Tembaga/Terak	Bangka Tengah	25					PS
10	Buding	Belitung Timur	5					PS
11	Nyelanding	Bangka Selatan	5					PS
12	Permis	Bangka Selatan	5	5				PS
13	Dendang	Bangka Barat	10					PS
14	Malingping	Lebak		13				Detail 3G,MT
15	Pamancalan	Lebak		48				Detail 3G
16	Gunung Pancar	Bogor	50					PS
17	Jampang	Sukabumi	225					PS
18	Gunung Kromong	Cirebon	25					PS
19	Krakal	Kebumen	25					PS
20	Kuwuk	Grobogan	25					PS
21	Klepu	Semarang	25					PS
22	Bumiayu	Brebes	25					PS
23	Parangtritis	Bantul			10			Detail 3G
24	G.Pandan	Jombang			60			PS
25	Tirtosari	Sumenep	10					PS
26	Sibetuk	Sintang	25					PS
27	Jagoi Babang	Bengkayang	10					PS
28	Meromoh	Bengkayang	10					PS
29	Sape	Sanggau	15					PS
30	Nanga Dua	Kapuas Hulu	5					PS
31	Batubini	Hulu Sungai Slt	20					PS
32	Tanuhi	Hulu Sungai Slt	10					PS
33	Hantakan	Hulu Sungai Tgh	20					PS
34	Sebakis	Nunukan	5					PS
35	Sajau	Bulungan	10					PS
36	Semolon	Malinau	10					PS
37	Mengkausar	Malinau	5					PS
38	Sungai Betuk	Mahakam Hulu	7.5					PS
39	Dondang	Kutai Kartanegara	10					PS
40	Maranda-Kawende	Poso	30		50			Detail 3G,MT
41	Kadidia	Sigi			60			Detail 3G, MT, TGW
42	Langkapa	Poso	25					PS
43	Kalemago-Wanga	Poso	60					PS
44	Torire-Katu	Poso	54	26				Detail 3G,TDEM
45	Toare	Donggala	50					PS
46	Pangangolemba	Poso	25					PS
47	Marana	Donggala			70			Detail 3GMT,TGW
48	Bora	Sigi			93			Detail 3G, MT, TGW
49	Pulu	Sigi			30			Detail 3G
50	Sedoa	Poso	15					PS
51	Lompio	Donggala			30			Detail 3G
52	Tambu	Donggala			15			Detail 3G
53	Wuasa	Poso	25					PS
54	Watuneso	Poso	25					PS
55	Papanlulu	Poso	25					PS
56	Ranang-Kasimbar	Parigi Mautong			10			Detail 3G
57	Kuala Rawa	Sigi		26				Detail 3G, MT
58	Wedaka	Banggai	5					PS
59	Pulodalagan	Banggai	5					PS
60	Tatakalai	Banggai Kep.	5					PS
61	Mambosa	Mamuju	25					PS
62	Somba	Majene	25					PS
63	Mamasa	Mamasa			2			Detail 3G
64	Riso-kalimbua	Polewali Mandar	20	41				Detail 3G
65	Alu	Polewali Mandar	25					PS
66	Tapalang	Mamuju	30					PS
67	Karema	Mamuju	10					PS
68	Ampalas	Mamuju	40					PS
69	Kona-Kaiyangan	Mamuju	10					PS
70	Panusuan	Mamuju	5					PS
71	Doda	Mamuju utara	5					PS
72	Limbong	Luwu Utara		11	13			Detail 3G. MT
73	Parara	Luwu Utara			30			Detail 3G, TGW
74	Pincara	Luwu Utara		12				Detail 3G
75	Sangalla	Tana Toraja	25		12			Detail 3G
76	Watansoppeng	Soppeng	25					PS
77	Sulili	Pinrang		30				Detail 3G
78	Malawa	Pangkajene	25					PS
79	Baru	Barru	25					PS
80	Watampone	Bone	25					PS
81	Todong	Bone	25					PS
82	Kampala/sinjai	Sinjai		20				Detail 3G
83	Maseppe	Sidrap			80			Detail 3G
84	Sengkang/D.Tempe	Wajo	25					PS
85	Lamosusu	Pinrang	10	12				Detail, TDEM
86	Sewang	Bone	5					PS
87	Mangolo	Kolaka		10	14			Detail
88	Parora	Konawe Utara	25					PS
89	Puriala	Konawe	25					PS
90	Amohola	Kendari	7	18				Detail 3G, AMT
91	Loanti	Konawe Selatan	25					PS
92	Laenia	Konawe Selatan			70			Detail 3G, MT, TGW
93	Torah	Buton Utara	25					PS
94	Kalende	Buton Utara	25					PS
95	Kanale	Buton Utara	25					PS
96	Wonco	Buton Utara	25					PS
97	GondaBaru/Sampolawa	Bau-bau+ Buton			1			Detail 3G
98	Kabungka-Wening	Buton	25					PS
99	Sumbersari	Konawe Selatan		12				Detail 3G
100	Kramat	Kepulauan Sula	10					PS
101	Losseng	Kepulauan Sula	30					PS
102	Auponia	Kepulauan Sula	20					PS
103	Bruokol	Kepulauan Sula	5					PS
104	Waisekat	Buru Selatan		6	14			Detail
105	WaPSalit-Waeapo	Buru	45		50			Detail, MT
106	Batabual	Buru	25					PS
107	Larike	Ambon	25					PS
108	Taweri	Ambon	25					PS
109	Oma-Haruku	Maluku Tengah	25	30				Detail
110	Saparua	Maluku Tengah	25					PS
111	Nusa Laut	Maluku Tengah	25					PS
112	Tehoru	Maluku Tengah			35			Detail 3G
113	Banda Baru	Maluku Tengah		33	21			Detail 3G, MT
114	Pohon Batu	Maluku Tengah	37	13				Detail 3G
115	Kelapa dua	Maluku Barat	25					PS
116	Warmong	Maluku BaratDaya	30					PS
117	Esulit	Maluku BaratDaya	25					PS
118	Lurang	Maluku BaratDaya	20					PS
119	Karbubu	Maluku BaratDaya	10					PS
120	Makbon-Sorong	Sorong	25					PS
121	Ransiki-Manokwari	Manokwari	25					PS
122	Kebar	Manokwari	25					PS

Table 1. Non-volcanic hydrothermal prospects in Indonesia

PS = Preliminary Survey
3G = Geology, Geochemistry, Geophysic
TGW = Thermal Gradient Well
Spect = Speculative
Hypot = Hypothetical
Poss = Possible
Prob = Probable
Prov = Proven

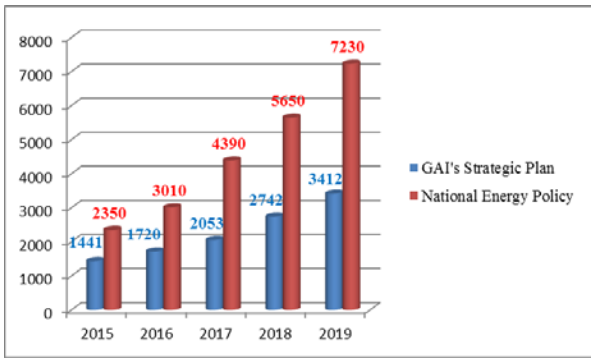

Figure 2. GAI's geothermal strategic plan compare to national energy policy

In 2006, when Indonesia Geothermal Roadmad was launched, there were 19 Geothermal Working Areas (GWA) that are expected to contribute an additional 3,500 MW to the existing production capacity of 852 MW from 7 geothermal fields (Figure 4). This coupled with the expectation of new GWAs can make up a 4600 MW production capacity in 2016. Therefore in 2007 GAI proposed several geothermal green areas to be stipulated as new GWAs. Now there are 65 GWAs which consists of 19 existing GWAs, including the 10 geothermal fields generating electricity, and new 46 GWAs (Figure 5).

Most GWAs are accompanied by geoscience data as the results of preliminary surveys and only 23 GWAs are already in the exploration stage. There is only one of the 46 new GWAs derived from non-volcanic geothermal system, namely, Bora Pulu in Central Sulawesi with an estimated potential of 123 MW. The new geothermal Law (Law No. 21/2014) states that a GWA is delineated based on data from preliminary survey and/or exploration. In order to accelerate the contribution of geothermal utilization from non-volcanic systems, especially in eastern Indonesia, in 2015 GAI plan to propose two new GWAs from non-volcanic systems. These are Kadidia (Central Sulawesi) and Laenia (South-east Sulawesi) with potentials of 60 MW and 70 MW respectively. Laenia already has 4 thermal gradient wells, while drilling at the new Kadidia system commenced in 2015, with a target of 700 m. The exploration results are expected to enhance the data quantity and quality in supporting the more accurate delineation of working areas.

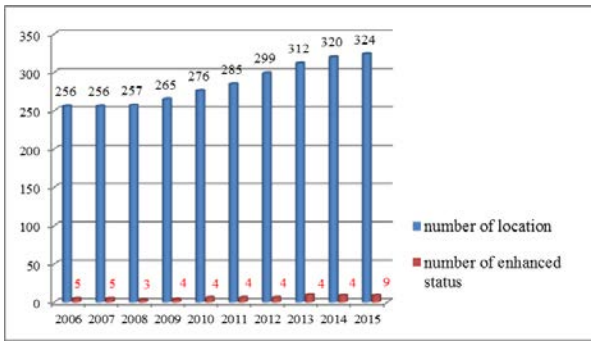

Figure 3. Progress on geothermal surveys by GAI

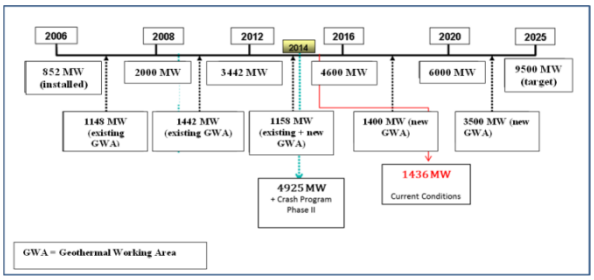

Figure 4. 2006-2025 Indonesia Geothermal Roadmap

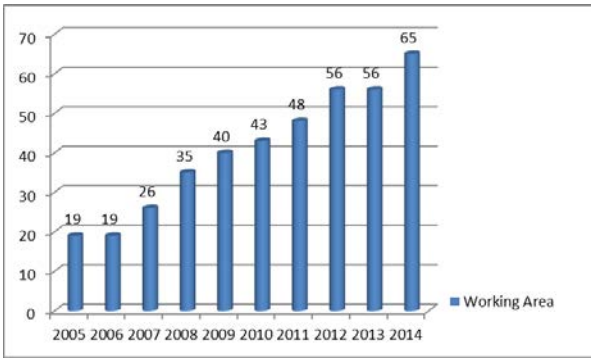

Figure 5. Progress on proposing geothermal working area

4. EXPLORATION STRATEGY ON NON-VOLCANIC GEOTHERMAL SYSTEMS BY GAI

According to the new Indonesia Geothermal Law, the Government, namely the MEMR, should conduct geothermal preliminary surveys, exploration, and even exploitation both in the green areas and inside GWA. GAI, under MEMR, in conducting the exploration surely will give more attention to increasing the number of detailed suveys and exploration in non-volcanic geothermal systems, especially at those located in eastern parts of Indonesia. Therefore, GAI needs a strategy to prepare good plans and effective execution.

As mentioned above, the knowledge of the geoscience of non-volcanic geothermal systems is still very limited. GAI is trying to elevate its human capacity through a series of training schemes and courses. The capacity building is intended to enhance knowledge and skill, both in 3G surveys and exploration drilling. Besides increasing the number of surveys of non-volcanic hydrothermal systems, GAI has the aim of improving the understanding of non-hydrothermal systems in terms of geosciences and survey methodology. A study of the presence of non-hydrothermal geothermal systems has been carried out since 2014, whereas studies of the survey methodology for these systems will start in 2016. The inventory of secondary data related to heat flow, especially from oil and gas wells will be carried out starting in 2016, and then the data will be used as a reference for publishing a map of regional heat flow. It will be a long term job that possibly will be completed with the implementation of final geological or geophysical surveys in 2021 (Figure 6).

The percentage of the budget allocation for non-volcanic areas is getting bigger every year. An increasing budget has also been allocated for the purchase of deep drilling

equipment. It is prioritized to accelerate deep subsurface data acquisition that will indeed reduce the risk of future development. GAI aims to implement these programs for area of non-volcanic hydrothermal system in the eastern part of Indonesia which have minimal infrastructure availability, low electricity availability, and no other primary energy sources (Figure 7). It is in line with national program to accelerate economic growth there, with the availability of energy becoming a fundamental factor for supporting the program. In fact, there is no utilization of non-volcanic geothermal systems for electricity in Indonesia, and therefore the government must step in to initiate this project (Figure 8).

GAI also established cooperation especially with those which have experience, technology and skills in geothermal development, especially in capacity building for geoscience understanding and transfer of technology, both for 3G survey and drilling. The donation of the latest technology equipment, that is part of a cooperation agreement, is expected to improve the work performance and accelerate the achievement of GAI's objectives in geothermal exploration. In the future, cooperation targets will be emphasized including: capacity building in deep exploration drilling, improving expertise and skill of wellsite geologist, drilling techniques, well logging, well testing, reservoir simulation, management structure, and procurement processes.

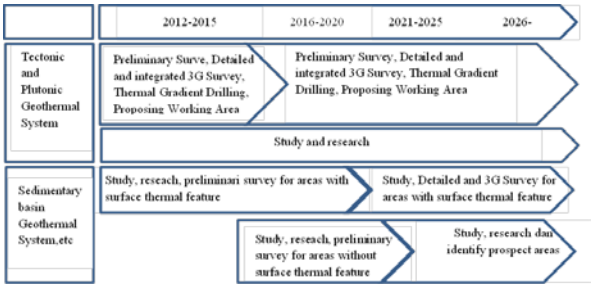

Figure 6. Action plan for exploration strategy of non-volcanic geothermal systems by GAI (Geological Agency of Indonesia, 2012).

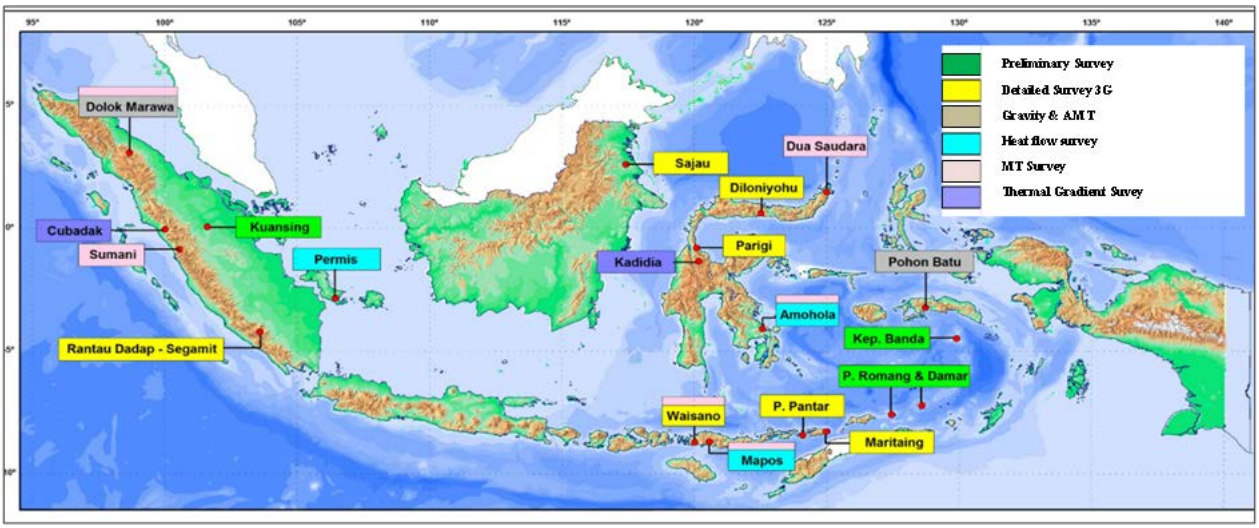

Figure 7. Target exploration locations of non-volcanic geothermal system by GAI in 2015 (Geological Agency of Indonesia, 2015)

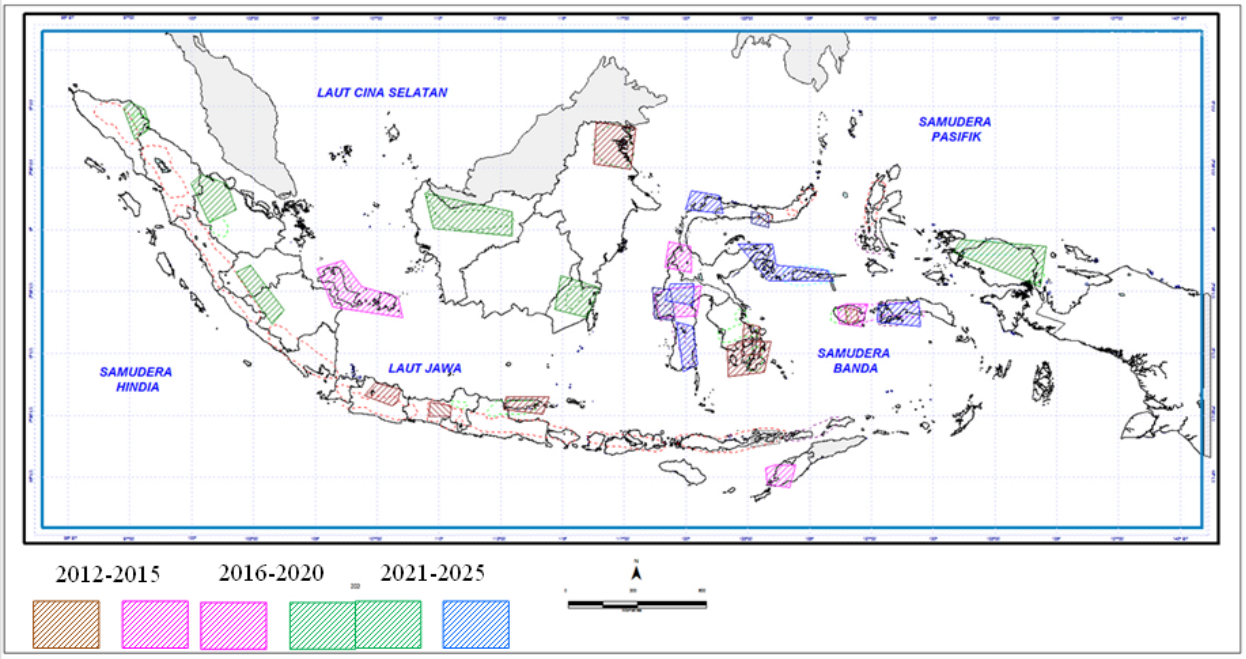

Figure 8. 2012-2025 targets of exploration locations of non-volcanic geothermal systems by GAI (Geological Agency of Indonesia, 2012)

5. CONCLUSION

In order to meet the objectives of energy policy with regard to the contribution of 9,500 MW geothermal energy to the national mix in 2025, a proper strategy is required, including the development geothermal prospects in non-volcanic systems. The government must begin to develop non-volcanic geothermal resources in eastern parts of Indonesia and take all the risks, including the exploration risks, in order to help the program for accelerating economic improvement in those areas. The development of energy derived from non-volcanic geothermal system, requires strategic planning, implementation, monitoring and comprehensive evaluation. Availability of human resources for understanding the characteristics of geoscience in the non-volcanic systems is a very important factor in addition to the mastery of technology and availability funds.

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