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Discovering The Potential of Unconventional Geothermal Systems in Indonesia

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ABSTRACT

Indonesia's archipelago is known to have great potential geothermal energy resources since its position in the subduction zone. These geological settings led to magmatism activity that was triggering shallow intrusion in the subsurface. Those shallow intrusions act as a heat source in high enthalpy geothermal systems which were the most commonly developed geothermal systems in Indonesia. The Government of Indonesia (GOI) has committed to utilize geothermal energy as one of the national renewable energy mixings. Nonetheless, the resources of these typical conventional systems are limited in recent days. It produces the new opportunity to utilize unconventional technology to extract other unconventional geothermal systems potential.

This paper aims to provide unconventional geothermal systems potential distribution in Indonesia referring to geothermal play-based classification that consists of several systems (i.e., hot dry rock, geopressured, hot sedimentary aquifer, supercritical, and hidden/blind systems). The study will involve a comparison of unconventional geothermal systems in Indonesia to several fields worldwide as analog-based on literature study with their current method and technologies. This study also reviews regulations of Indonesia that will support for the future unconventional geothermal system development program. In the end, advantages and challenges will be evaluated to examine the feasibility of these unconventional geothermal system utilization in Indonesia.

1. INTRODUCTION

Indonesia's archipelago is known to have great potential for geothermal energy resources since its position in the subduction zone. These geological settings led to magmatism activity that was triggering shallow intrusion in the subsurface, then constructed the occurrence of volcanic arcs, namely Sunda Arc, Banda Arc, and Sangihe Arc. Those volcanic arcs resulted high enthalpy geothermal system, which is commonly associated and has proven to generate electric power generation (Hochstein & Sudarman, 2008). Unfortunately, these typical resources are limited. Though, since the geological condition complexity, there are possibilities for the occurrence of shallow heat flow that has not correlated with volcanism-magmatism activity directly. This condition requires another method of extraction and exploration technology. These system types could be considered as unconventional geothermal systems.

CSIRO (2012) defined the unconventional geothermal system is typically natural heat stored, which has a conductive heat flow mechanism for both solid and fluid phases. This system type is thought to have insufficient permeability. However, this definition does not seem to lead to a clear conclusion. This is due to the fact that some of the existing geothermal systems that have been developed using conventional technology also have insufficient permeability and involve fluids too. Moreover, the recent definition is opposite with the definition of geothermal system itself. According to Hochstein & Browne (2000), geothermal system is all-natural heat transfer from heat source to the heat sink, which is usually in the surface. Thus, the redefinition of the unconventional geothermal system is also the main focus of this research.

The Government of Indonesia (GOI) through Ministry of Mineral and Energy Resources (MEMR) committed to involve geothermal energy in one of the national renewable energy mixings. The Government of Indonesia (GOI) committed to achieving Net Zero Emission (NZE) 2060 and involved geothermal energy as the main player. This idea then led the GOI to develop geothermal power plant of up to 18 GW by involving advanced geothermal system and unconventional geothermal system utilization (MEMR, 2022). Therefore, preliminary research about the existence of unconventional geothermal systems in Indonesia is needed recently. As an example, R&D program for harnessing unconventional geothermal system has been initiated in Italy by UGI (national geothermal association in Italy) to prepare the geothermal era for the next decades (Cataldi et al., 2013).

2. DATA AND METHOD

The research method of this study is using a literature review regarding the unconventional geothermal system worldwide, then to be adapted to Indonesia's condition. The data was obtained from previous publish literature and open-source data from MEMR. The key research questions to achieve the goal of this research have been listed as follows:

a) What does the suitable definition of unconventional geothermal system?
b) How is the overview of the unconventional geothermal system in Indonesia?
c) What kind of typical resources can be classified into the unconventional geothermal system in Indonesia?

d) What types of developed extraction technologies worldwide?
e) How about the available regulation regarding unconventional geothermal system utilization?
f) What are the advantages and challenges to develop unconventional geothermal system?

3. RESULT AND DISCUSSION

3.1 Unconventional Geothermal System Definition

Agreed with a clear definition by Hochstein & Browne (2000) about the geothermal system, this definition is used as the basis before classifying geothermal systems into conventional and unconventional. The primary term conventional commonly is used for geothermal systems, which are extracted using conventional drilling-well technology. In Indonesia, some of the fields have been extracted using conventional drilling-well and are able to generate power electricity such as Kamojang, Darajat, Dieng, Ulubelu, etc. Those fields are typically volcanic-hydrothermal geothermal systems. Though, along with the technological developments and various types of geothermal systems, these conventional drilling is not sufficiently capable to extract another potential resource and/or handling natural problems such as lacking permeability and fluids. Therefore, the breakthrough in extraction method for geothermal development is important. This idea led to the unconventional geothermal system definition refinement, the unconventional geothermal system is all geothermal systems, which requires an unconventional extraction method to extract natural heat from subsurface to surface.

Figure 1 is the mind map that could be used for classifying geothermal systems into conventional and unconventional, especially regarding the existing potential resources in Indonesia. The conventional geothermal system is divided into the volcanic, non-volcanic, and blind system. The volcanic group system consists of several volcanic types that occur in three main settings i.e., caldera type, mature composite cones type, and basaltic volcanoes in active rifting (Wohletz and Heiken, 1992). We assumed those systems could be extracted using conventional drilling-well as well as operated in Indonesia volcanic-hydrothermal fields. The non-volcanic group system is placed by a fracture-fault zone system that has heat and sufficient permeable and fluids to flow convectively using conventional drilling-well. Meanwhile, the blind system is connected with a dashed line. This condition is considered by the definition of blind system, which is a geothermal system with lacking surface manifestations caused this system also need different approach in term of exploration than conventional geothermal system. Furthermore, the geothermal systems that need advance technology of extraction and could be classified into unconventional geothermal system, namely hot dry rock, hot sedimentary aquifer, geopressured, and superhot/supercritical systems.

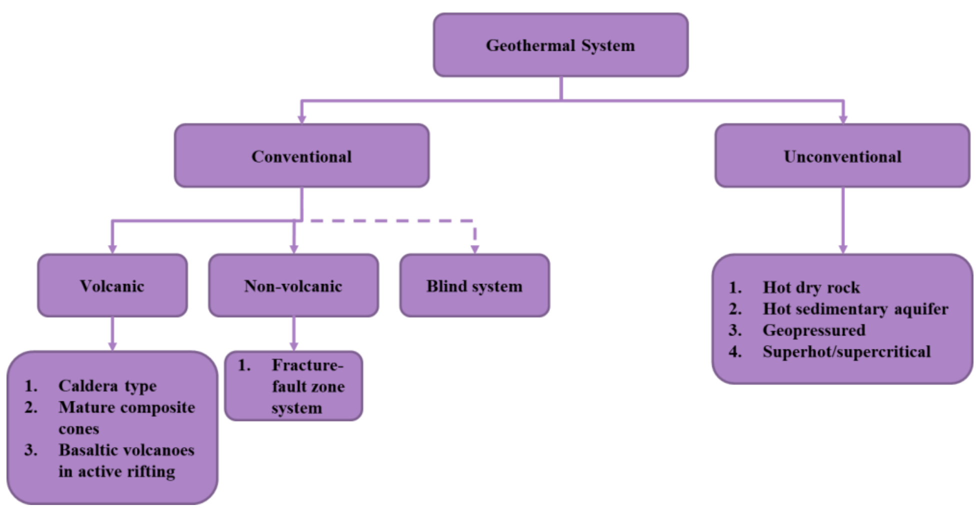

Figure 1 The Schematic mind map to classify the unconventional geothermal system in Indonesia; The basis of conventional-unconventional division is based on the extraction method.

3.2 Overview of Unconventional Geothermal System in Indonesia

Some unconventional geothermal systems are considered to be present in Indonesia. This condition is controlled by the regional geology setting of Indonesia, which allows the potential heat flow beside from volcanic or magmatic source. Moreover, the application of geothermal play type is considered to recognize the potential of the unconventional geothermal system (Moeck, 2014). The followings are the section of highlighted unconventional geothermal system in Indonesia related to the characteristics and its potential area.

3.2.1 Hot Dry Rock

Hot dry rock geothermal system (HDR) is terminology for hot fractured rock because of either the need to fracture the virtually impermeable formations or the presence of natural fractures in the hot reservoir (Goldstein et al. 2011). The occurrence of this system is commonly seated at the deep part of rock formations in the order of 5 to 6 km with various temperatures ranging from 150°C to 500°C (Breede et al., 2013). Most of these systems do not contain sufficient fracture permeability and tend to be dry. Therefore, it needs advanced technology to utilize. While if the formation does not completely dry and contains some fluid, it is known as Hot Wet Rock (Breede et al., 2013). The suitable type of rocks in the HDR system are commonly granite or other crystalline basement rock (figure 2). To enhance permeability of the basement/crystalline rock requires fracturing stimulation by injecting high-pressure fluid to the subsurface. Moreover, to extract the heat was needed artificial fluids injection such as water or CO_2 that allow the heat flowing from subsurface to surface.

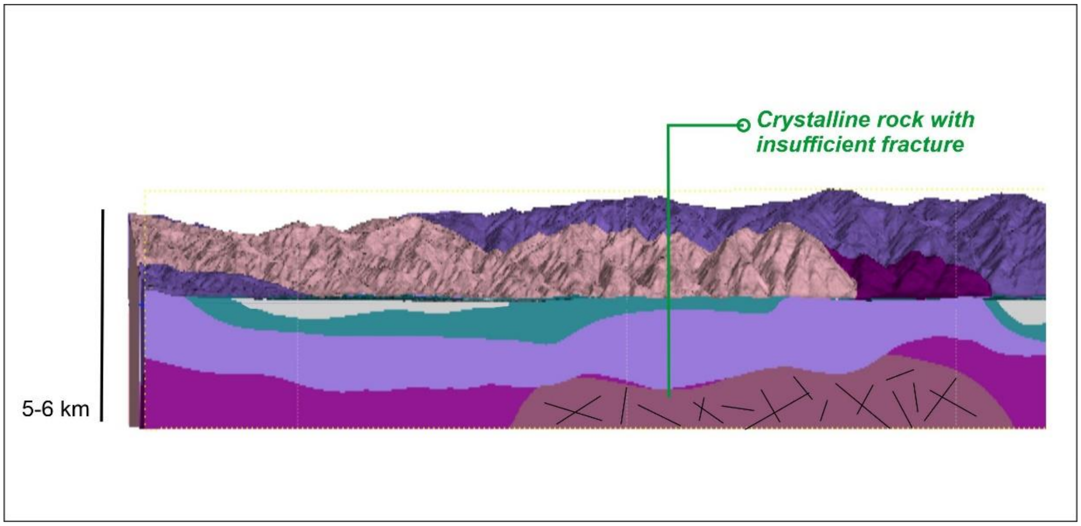

Figure 2 The schematic model of Hot Dry Rock Geothermal System

The presence of HDR systems worldwide can be found in various tectonic regimes, Moeck (2014) has summarized several research about HDR worldwide i.e.:

a. Fenton hill New Mexico, USA, which is associated with a magma chamber under a young caldera with normal faulting.
b. Rosemanowes, UK, which is associated with batholith with normal faulting.
c. Soultz, France, which is associated with horst-graben to strike-slip regime.
d. Cooper basin, Australia, which is associated with inverted basin reverse faulting regime.

The occurrence of HDR system in Indonesia is suspected has correlation with the existence of granitic basement, metamorphic complex, and other potential crystalline basement, which interpreted have sufficient heat flow to produce geothermal system. This idea is supported by the regional geology setting of Indonesia, which is not only comprised by active subduction zone but also resulted from ancient subduction zone. The potential HDR system in Indonesia seems located in South Sumatra basin and Granitic Complex in Kalimantan due to the tectonic setting itself.

<u>3.2.2 Hot Sedimentary Aquifer</u>

Hot Sedimentary Aquifer (HSA) is a typical geothermal system, which present in sedimentary basin. The term of HSA refers to the presence of an extensive aquifer system contained with vast number of hot fluids and permeability, in a relative deep conductive formation (Mijnlieff, 2020). The potential heat source of this system is controlled by conductive heat flow by gradient temperature and/or radiogenic activity (figure 3). In contrast to the common volcanic-hydrothermal system, the capping mechanism of HSA is controlled by the impermeable sedimentary rock formation, faulting trap, and other overburden rocks (King R, 2010). Mijlieff (2020) has divided HSA in 3 (three) conditions, namely:

a. The deep, Hot Sedimentary Aquifer, hydrothermal, conductive, low-enthalpy/temperature play relying on matrix permeability.
b. The deep, Hot Sedimentary Aquifer, hydrothermal, conductive, low-enthalpy/temperature play relying on fault and fracture permeability.
c. Presently ‘not explored for’ or realised, the Enhanced Geothermal System (EGS) in non-porous, non-permeable rocks.

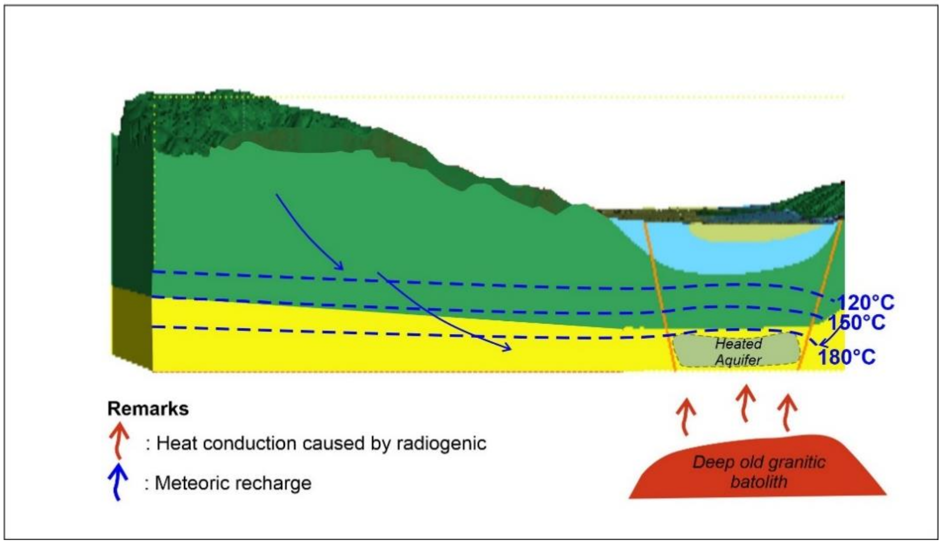

Figure 3 The Hot Sedimentary Aquifer (HSA) geothermal system schematic model.

Based on the various condition of the potential HSA system, it requires advanced exploration technology and extraction method to accommodate the heterogeneity due to the geologic settings. Furthermore, the existence of hot brine within aquifer preserved in sedimentary rock. Although previous research stated that this system can be utilized using abandoned well from oil-gas, but it still requires the advanced geoscience survey approach. There are several pilot projects worldwide to utilize the HSA systems, namely Huabei oilfield, China (Bu et al., 2012), South Texas oil-field, Texas (Davis, 2009), and Pert Basin, Australia (Corbel et al., 2012). Moreover, there is successful sedimentary hosted geothermal field analog that has proven to produce electricity, namely Salton Sea Field and Cerro Prieto, USA (Elders & Moore, 2016). In Indonesia, Suryantini (2021) stated there was a high-pressure high temperature (HPHT) zone within north-west java basin that heating up the brine water within sedimentary aquifer. Moreover, there is also the HSA potential in Arun field, in Aceh (Syarifudin et al., 2016).

3.2.3 Geopressured

A geopressured system occurs in a deep sedimentary basin environment where deeply buried fluids contained in permeable sedimentary rocks are heated in a thermal gradient by their great burial (Sanyal, 2010). Similar with HSA system, the geopressured system is well developed in sedimentary basin environment. Figure 4 illustrated that the existence of geopressured system is controlled by the thick overburden rock with the confined fluids within sandstone formation is heated up the great burial due to lithostatic pressure. Although this system tends to has sufficient thermal fluid and permeability, but the depth occurrence of resource is significantly challenging. The striking characteristics of chemical fluids within this system is probably saturated with methane due to chemical reaction contribution (Santilano et al., 2019).

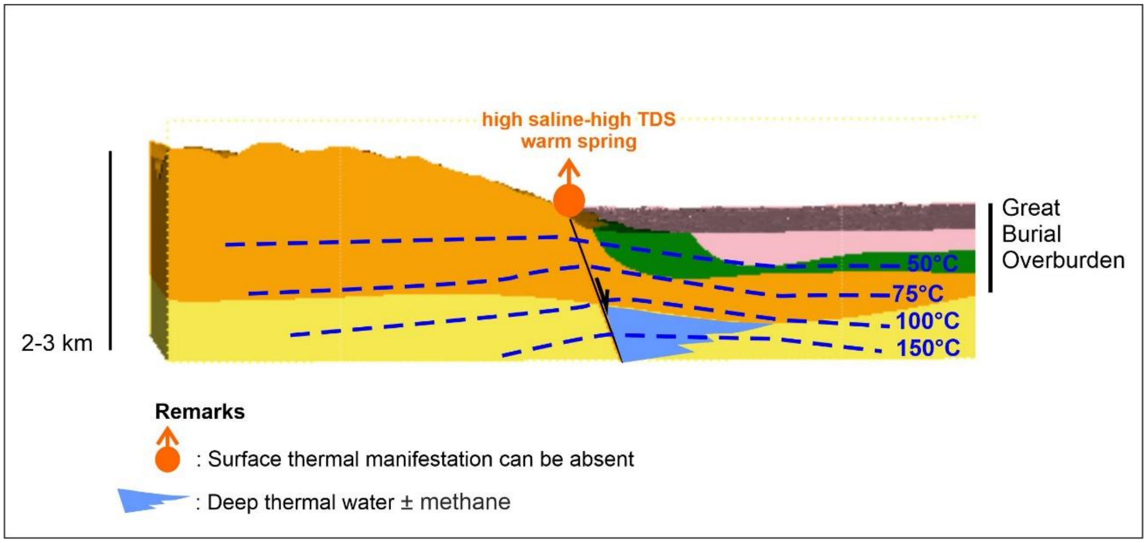

Figure 4 The conceptual model of geopressured geothermal system, there is amount of fluid within confined sedimentary rock formation

The preliminary research to observe and evaluate this typical system has conducted in several area such as in Hungary, Texas, and Louisina Gulf (Lund, 2008). However, this system is still not feasible to be utilized economically because the depth of resource occurrence. Several research reveals that potential geopressured in Indonesia located in Southeastern of Kalimantan Island, characterized by the presence of warm spring on the surface, and potentially to form low enthalpy system (Yushantarti, 2020).

3.2.4 Supercritical

Supercritical geothermal systems are very high-temperature geothermal systems that are located at depths near or below the brittle–ductile transition zone in the crust where the reservoir fluid is assumed to be in the supercritical state (Reinsch et al, 2017). The critical point for pure water occurs at 374 ◦C and 22.2 MPa, but is higher for solutions containing dissolved salts 405 ◦C and 30.2 MPa. An aqueous hydrothermal fluid at supercritical conditions with a temperature of 400 ◦C and a pressure of 25 MPa has more than five times the power-producing potential of liquid water at a temperature of 225 ◦C (Elders et al, 2014; Stimac et al, 2015).

Nowadays several countries started the pilot project to utilized the supercritical geothermal such as Iceland, Japan and New Zealand. Later on, the paper also discusses about the challenge and advantages of this system. Hill (2021) already simplify the comparison between today's commercial geothermal with superhot rock or superdeep geothermal that utilizing the supercritical condition of geothermal system and stated that the pilot project to utilized this system can be started in the place that has shallow intrusion, Figure 5 illustrated the supercritical condition that can be found in the volcanic system deep beneath in the volcanic area that are usually found in Indonesia. Based on Hill (2021) to initiate the project of superhot rock geothermal, it should be started in the magmatic zone such as Indonesia, Iceland, New Zealand, and Japan that have the geothermal system related to the active volcanoes. In Indonesia, there are several geothermal fields that have high temperature that already in development phase such as Salak, Sarulla, Ulubelu, Sorik Marapi, and Karaha Geothermal area. However, to start the supercritical geothermal pilot project need a team work between government, developers, and academics.

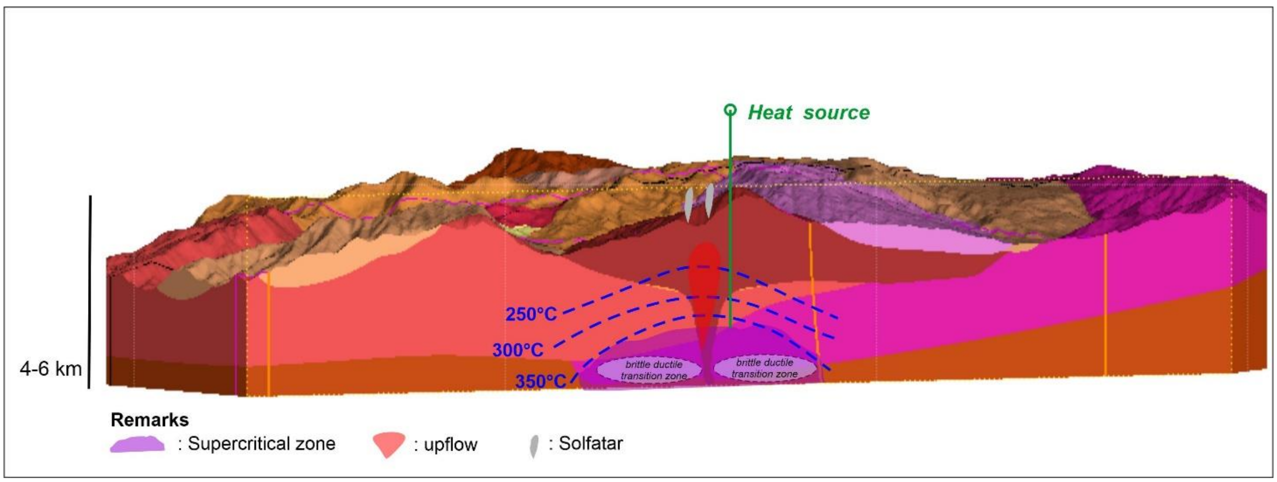

Figure 5 The schematic model of supercritical geothermal system.

3.2.5 Hidden/Blind Geothermal System

Hidden/Blind Geothermal System is hydrothermal system that lacks surface thermal manifestations. However, they share many features in common with conventional hydrothermal systems (Garg et al., 2010; Dobson, 2016). Many hidden/blind geothermal systems were discovered accidentally - i.e., exploring for water, oil & gas, or minerals (Garg et al., 2010; Faulds et al., 2016; Dobson 2016). Most of the actual discoveries using various combination of normal geothermal exploration methods (Dobson, 2016), however it's important to utilize the most innovative technologies in these exploration methods to be developed and tested to identify the favorable geothermal play as proxies to discover these blind systems (Faulds et al. 2016). The absence/lack of thermal manifestation in the surface may be caused by these following factors (compiled by Dobson, 2016):

a. Thicker, better-developed seals (i.e., thousands of feet of sediment, lava, etc)
b. Blockage of associated permeable fault (i.e., being buried by younger rocks, deposition of hydrothermal minerals)
c. Depressed water tables.
d. Obscured by an overlying cold-water aquifer.
e. Is a small system from the bigger system in the same geologic setting.

Undiscovered geothermal resources potential in the US (which are mostly hidden) is estimated over three times from identified geothermal resources on the same region (Wiliams et al., 2009 in Dobson, 2016). Indonesia which is located in the ring of fire and host of many geothermal systems allow for the large potential of hidden geothermal resources that have not been discovered. Based on our quick review, some of the fields that include to government exploration program such as Gunung Endut, Tampomas, Sembalun, Guci, Lokop, Gunung

Galunggung, Banda Baru, Klabat Wineru, and Lainea might be classified as a hidden geothermal system. However, there is no detailed study yet that really addresses to the possibility of those hidden/blind systems.

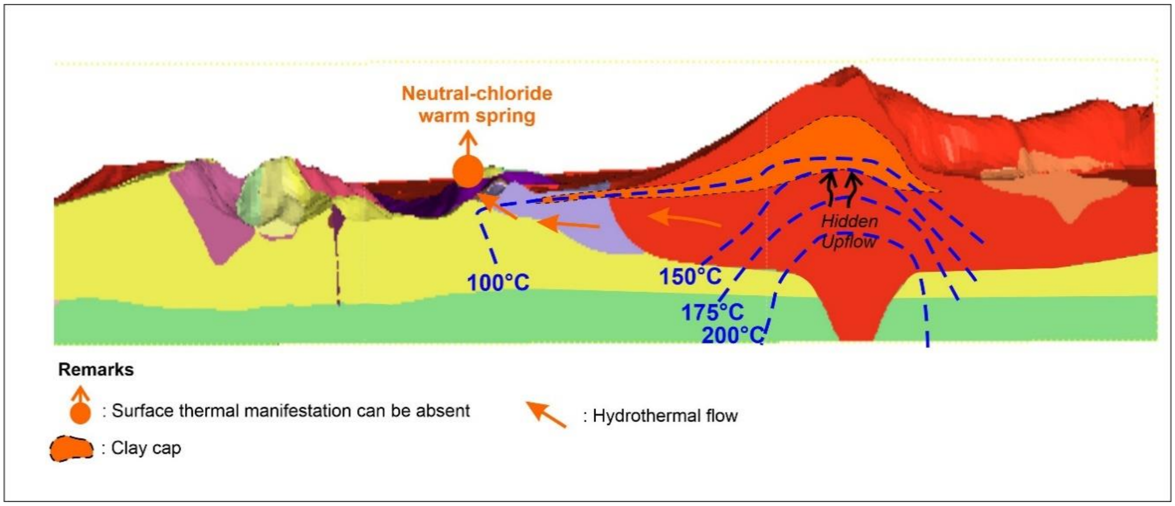

Figure 6 The schematic model of hidden-blind geothermal system.

The Geological Agency of Indonesia under MEMR already conducted the geothermal potential mapping in Indonesia. Figure 7 shows the distribution map of unconventional geothermal system in Indonesia according to exploration report by geological agency. Even so the detailed and more comprehensive research should be conducted to get more information regarding the distribution of this unconventional geothermal system in Indonesia. This information that provided by Geological Agency of Indonesia is the good start of initiation study of unconventional geothermal system in Indonesia.

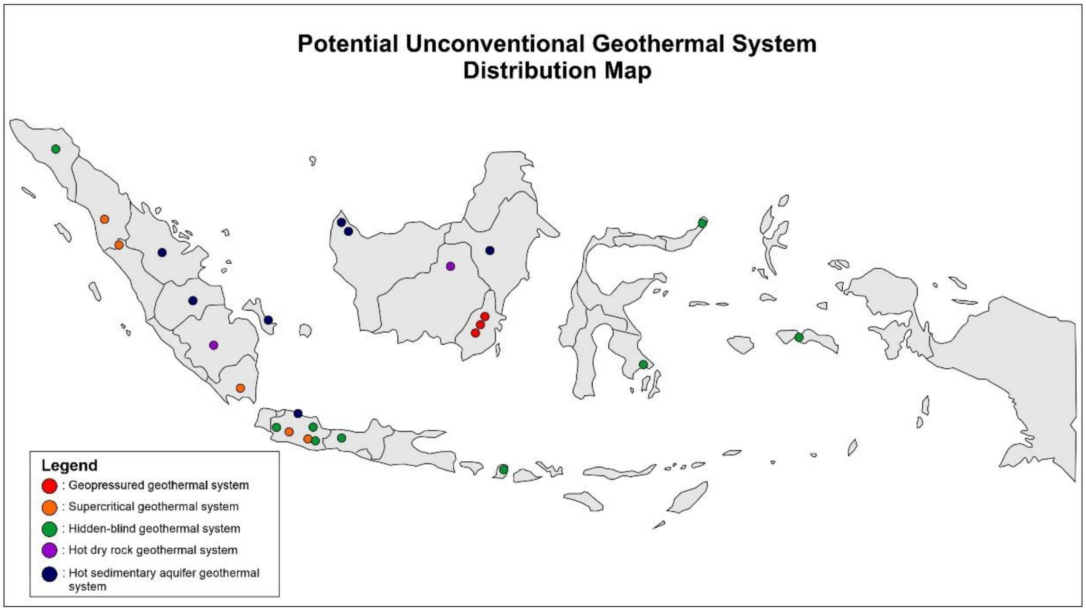

Figure 7 Unconventional Geothermal System Distribution Map in Indonesia

3.3 Current Developed of Extraction Method Worldwide

As the thing that differentiate between unconventional and conventional of geothermal system in this paper is the extraction method of the heat, it is very essential to understand the current developed method of extraction method worldwide. The methods that already proven and some pilot projects in worldwide already using this extraction method in some fields around the world. Even so the geothermal play of Indonesia can be considered to adapted this method to extract those unconventional geothermal potential in Indonesia.

3.3.1 Enhanced Geothermal System (EGS)

The Enhanced Geothermal System (EGS) is a geothermal extraction method on location that has sufficient temperature but low permeability characteristic at drillable depth, therefore, it needs permeability enhancement through technological solution such as fracturing and/or acidizing depends on formation characteristics (William et al., 2011; Breede et al., 2013). Moeck (2014) divided the EGS can be suitable used both petrothermal EGS and hydrothermal EGS. Petrothermal EGS is the condition where the hot host rock has low porosity and permeability to contain fluid naturally, then need hydraulic fracturing and injection fluid. Meanwhile, the hydrothermal EGS where the hot host rock only has low permeability but has sufficient porosity to contain hydrothermal fluids. Therefore, the hydrothermal EGS seems only need permeability enhancement to extract economically. The EGS illustration showed in Figure 8.

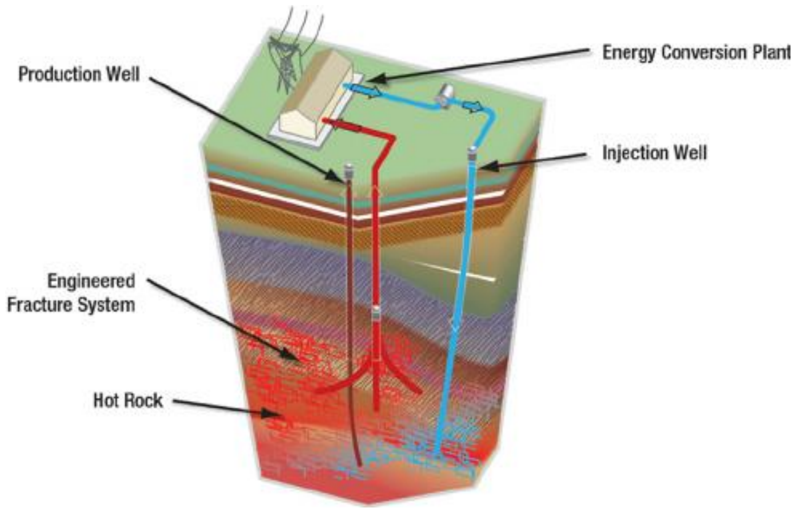

Figure 8 Illustration of Enhanced Geothermal System (EGS) applied in hot dry rock geothermal system (Thiell, 2017)

Available research has been conducted to observe the initial utilization of EGS especially about the external injected fluids type, commonly called as working fluid. At least there are two types of working fluid developed i.e., water itself (H_2O) and CO_2. However, these working fluids also used in Closed Loop extraction method.

3.3.2 Closed Loop

Closed Loop is a method to extract geothermal energy that using continuously closed wellbore and the closed system to avoid fluid leakage and reservoir blockage (Fallah et al., 2021). Closed loop method requires artificial fluid such as water (H_2O) and CO_2 that injected from surface continuously and circulated back to the ground in the same wellbore, without direct contact with geothermal reservoir and in situ water (Hu et al., 2020). Closed loop well essentially works as an indirect heat exchanger, where the circulating working fluid absorbs the heat energy from rock formation and/or limited thermal fluid as it flows through the well, eliminating the reliance on fractures. The schematic of closed loop well present in Figure 9 with three configurations, namely axial, multiple string design, and u-shaped design (Hu et al., 2020).

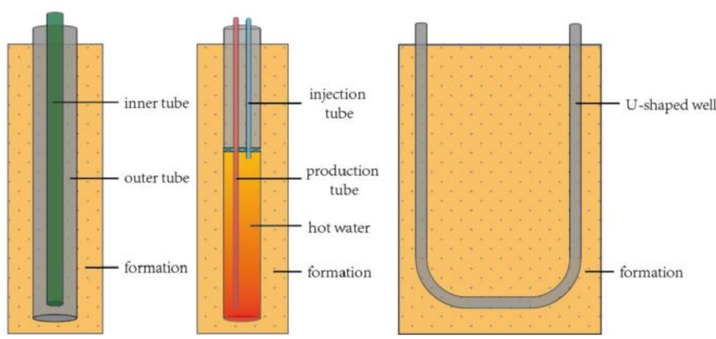

Figure 9 Conceptual design of closed loop configuration, namely (left) co-axial design, (middle) multiple string design, and (right) U-shaped design (Hu et al., 2020).

In addition, the utilization of closed loop extraction method has been applied in deep and shallow geothermal systems. The deep closed loop has operated in Kola Peninsula, Rusia, Weissbad & Weggis in Switzerland, Aachen in Germany, and Hawai (Fallah et al., 2021; Pujol & Aymard, 2020). Therefore, this typical extraction method is likely can be applied in many potential geothermal systems, i.e., Hot Sedimentary Aquifer, Geopressured, and supercritical.

3.3.3 Utilization of Non-Commercial Oil & Gas Well

In case of utilizing non-commercial oil and gas well, could use previous data from oil and gas to identify the water column, thus data that used for oil and gas industry very useful for the extraction method since the subsurface data already comprehensive. Indonesia has a lot of abandoned oil and gas well and this extraction method could be an added value to that abandon well to increase the revenue of the oil and gas industry. Based on Mijnlieff (2020) there are several factors that can be consideration of the utilization noncommercial oil and gas well into geothermal extraction. In mature hydrocarbon fields co-produce large volumes of water, production of water increases with time, oil production decreases. This utilization can be profitable if the water-contact reach almost 100% and reuse of non-commercial oil and gas infrastructure and wells for geothermal energy extraction or reuse abandoned oil and gas wells.

Regardless of the temperature in the oil and gas not as high as the conventional geothermal, but this can be an advantage since the large of volume in the abandoned oil and gas well that combine with the moderate temperature. The combination of moderate temperature and large volumes can be favorable for generating electricity and/or district heating. In addition, utilization of O&G well also reduces non-technical problem such as social issue that common happen in the development of geothermal facilities in Indonesia since this geothermal extraction using the surface facilities of the former oil and gas field.

3.4 Government of Indonesia's Regulation

To facilitate efforts to develop geothermal energy, GOI has established a regulation governing about geothermal within law no. 21/2014. Particularly, chapter 19 verse 1 states that the determination of geothermal working area takes into account the geothermal system. Moreover, the appendix of law no.21/2014 specifies the definition of geothermal system as "a system, which consists of heat source, reservoir, recharge area, clay cap, and upflow or outflow, that meet sufficient geology, hydrogeology, and heat transfer criteria, mainly concentrated in reservoir to form energy resources*"*.

The GOI also realizes that the existence of unconventional geothermal resources is not always having all completely components as stated in the geothermal system definition above. Therefore, the GOI has considered to prepare the necessary regulation that will support the development of unconventional geothermal system in Indonesia. Furthermore, the GOI, together with all stakeholders, also need to identify these untapped unconventional geothermal resources. These efforts are essential steps in achieving the NZE 2060 targets.

3.5 Advantages and Challenges

As the follow up to prepare the utilization of unconventional geothermal system in Indonesia, the followings are summary of advantages and challenges that might be used as the consideration to developed the extraction of unconventional geothermal system in Indonesia, provided in Table 1.

Table 1 List of advantages and challenges of each unconventional geothermal system in Indonesia.

List of Systems	Advantages	Challenges
Hot Dry Rock	• Due to fact that the Indonesia consists of ancient subduction/magmatic chains, the existence of HDR system seems abundant.	• Need advance technology for extraction especially deep drill-well. • Need deep in situ and past stress study to understand the fracture distribution.
Hot Sedimentary Aquifer	• Profitable if the Water Cutt in the well reach almost 100% (Bu et al 2011) • Can use existing well and drilling infrastructure. • Comprehensive Subsurface data could decrease the uncertainty level about subsurface conditions complexity. • Reduce non-technical problem such as social and political issue.	• Hole Size: Need large hole sizes (8-1/2" and more to improve heat conduction and convection processes downhole. • Well integrity: After production stage O&G wells require lots of interventions work to ensure safe operations. • Sedimentary reservoirs generally contain various toxic and flammable materials such as hydrocarbons, heavy metals, hydrogen sulfide, etc. (Purba et al 2019) • Risk of land subsidence. Since production involves the extraction of large quantities of water from underground, there is a high probability of subsidence of the soil surface. (Purba et al 2019)
Geopressured	• Associated with permeable rock formation and trap system has available. • Can be developed hybrid potential between geothermal and methane.	• Specifically, stress field analysis, quantitative structural geology, reservoir geomechanics and reservoir engineering need more assessment for this system (Moeck, 2014). • Similar with HSA system, sedimentary reservoirs generally contain various toxic and flammable materials such as

List of Systems	Advantages	Challenges
		hydrocarbons, heavy metals, hydrogen sulfide, etc. • Abnormal pressure gradient may be encountered during well drilling • Risk of land subsidence. Since production involves the extraction of large quantities of water from underground, there is a high probability of subsidence on the surface.
Supercritical	• Supercritical always available energy source that could potentially be accessed worldwide, just like HDR. • Currently always associated with active volcano. • Supercritical fluids also have high rates of mass transport increase efficiency (roughly five to ten times the energy produced by today's commercial geothermal wells). • Exploiting the higher temperature roots of existing geothermal systems could result in increased productivity and sustainability.	• Exploration methods for better resource assessment. • Adapted deep drilling and completion technologies in supercritical condition (high T and P). • Geohazard prevention due to the system commonly associated with active volcanoes. • Magmatic dominated fluids are found in the hotter plastic rock and hydrothermal fluids circulate through the overlying cooler brittle rock (Reinsch et al, 2017). • Existence of the nature of permeability at high temperatures. • Creation of heat reservoirs in fracture systems in dry superhot rock while avoiding seismic risk (Hill et al, 2021).
Hidden/Blind Geothermal System	• Some of fields in GOI's geothermal exploration program likely classified as the hidden/blind geothermal system.	• There are just a few studies on hidden geothermal systems in Indonesia. The only well-publicized hidden geothermal prospect is Blawan-Ijen (Daud, et al., various years). • The lack of surface manifestations makes it difficult to determine the parameters of the geothermal system such as heat sources and permeability pathways, this causes a high level of uncertainty in the efforts to find the resource. • Conventional exploration methods can be applied with the development of technology and exploration strategies, such as the use of surface thermal kinetic analyses, heat flow surveys, temperature gradient drilling, etc. A comparison of exploration methods that have been successfully applied to hidden systems that have developed worldwide may need to be done to identify the exploration method that can be carried out effectively and efficiently. • Most of the hidden geothermal systems are usually low-medium temperature systems, so the appropriate extraction technology will also need to be adapted if these fields are to be further developed

The technical constraints mentioned earlier will also eventually lead to challenges from the commercial side. This type of challenges will need attention and to be addressed if unconventional geothermal utilization is to be developed further economically apart from this, it is also necessary to pay attention about the advantages of unconventional geothermal utilization.

4. CONCLUSION

To achieve NZE (Net Zero Emission) 2060 target, the GOI emphasize optimizing the use of advanced geothermal system and unconventional geothermal system. The unconventional geothermal system is all geothermal systems, which requires an unconventional extraction method to extract natural heat from subsurface to surface. The conventional geothermal system could be divided into the volcanic, non-volcanic, and blind system. However, the blind system is suspected requires innovative technology to exploration and extraction method. The volcanic group system consists of several volcanic types that occur in three main settings i.e., caldera type, mature composite cones type, and basaltic volcanoes in active rifting. Meanwhile, the geothermal systems that need advance technology of extraction and could be classified into unconventional geothermal system, namely hot dry rock, hot sedimentary aquifer, geopressured, and superhot/supercritical systems.

The research about geological setting of Indonesia at a glance tend to show there are possibilities of undiscover geothermal resources that could be classified as unconventional geothermal systems. Recent developed technology has been able to discover unconventional geothermal system potential worldwide, such as Enhanced Geothermal System (EGS), closed loop, and reutilization of oil-gas well, however to adapt the current technology that already proven around the world more comprehensive research should be conducted to be fitted into geothermal play in Indonesia. To accommodate all potential unconventional geothermal systems with their technology needs, the GOI through MEMR has considered to prepare the necessary regulation that will accommodate and support the development of unconventional geothermal system in Indonesia. The developers and academic role in future geothermal industry of Indonesia also needed to accelerate the pilot project of these unconventional geothermal system in Indonesia.

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