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Drilling Professional Skills Transfer: Petroleum Industry Support to Geothermal Development in Indonesia

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DRILLING PROFESSIONAL SKILLS TRANSFER: PETROLEUM INDUSTRY SUPPORT TO GEOTHERMAL DEVELOPMENT IN INDONESIA

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Abstract

Indonesia has an established petroleum industry dates back from 1870 when the first oil well drilled in Majalengka. The long history of petroleum exploration and production in Indonesia has resulted in an established petroleum industry with a lot of local expert. Thus, a wide availability of expert and professional in petroleum industry can be utilized to support government goal for Indonesia development, such as geothermal energy development.

Government of Indonesia (GoI) is planning to increase the installed capacity of geothermal power plant installed capacity from currently about 1,900 MW into 7241 MW in 2025 (RUEN, 2017). Jennejohn (2010) calculated that it needs 4.25 full-time positions and 16 person-years for one megawatt electricity generated from geothermal. Therefore, with the addition of four-fold capacity, the number of personnel needs of staffs and experts in the field of geothermal will require approximately 22,699 jobs with 85,456 person-year employment. The drillers and crew are among those workforces besides geoscientists, engineers, hydrologists and operations personnel which must be prepared before starting a geothermal project (Smillie et al., 2015).

The geothermal drilling manpower needs can be obtained from new job candidate training or transfer from related industries. Many of the workforces in the Indonesian geothermal drilling indeed come from the petroleum drilling because of many similarities on technology and equipment. However, these workforces tend to apply the same approach to oil and gas in the geothermal industry due to some similarities in the drilling process despite there are some fundamental differences between the two. Thus, such approach might create problem in the future, both in drilling safety and operational concern. This paper aim to highlight the existing drilling professional skills in petroleum industry and the adjustment need for geothermal drilling. This paper also aims to provide suggestion in which area the current geothermal drilling skills are lacking and can be improved to help the GoI achieves its target.

Keywords: Human Resource, Skills, Drilling, Petroleum, Geothermal

1. Introduction

For decades, Indonesia was one of the countries with a large amount of oil and gas production, which had become a petroleum exporting country and became a member of the Organization of the Petroleum Exporting Countries (OPEC) since 1962. Indonesia had experienced to produce oil reaching 1.5 million barrels per day (bpd) in 1987 despite currently the oil production is gradually decreasing. The reserves of fossil-based energy sources continue to decline amid high energy consumption in the country. National oil and gas reserves also depletes because the lack of exploration activities. Data from the Ministry of Energy and Mineral Resources (ESDM) show that in 2017, proven oil reserves of 3.6 billion barrels with a production level of 288 million barrels per year are expected to run out in 12 more years. Furthermore, gas reserves of 98 trillion cubic feet (tcf) will run out in the next 33 years with the average annual production is 3 tcf.

SKK Migas (2016) projected that oil production will decline by 6% per year from

786 thousand barrels in 2015 to less than 520 thousand barrels per day in 2020 and beyond. This decline in production will clearly have an impact on the number of workers in the oil industry. For example, during the recent decline in oil prices in 2014 to 2017, around six thousand people or 5% of the workforce lost their jobs in the upstream oil and gas industry as shown in Figure 1 (SKK Migas, 2017).

On the other hand, Indonesia is one of the countries with high geothermal energy potential in the world. Until 2018, only 6% of the estimated maximum potential are used mostly for electricity generation. Hence, there are still many untapped potentials.

The Government of Indonesia has set a target to increase the installed geothermal capacity to 7,241.5 MWe by 2025. Figure 2 shows an overview of the development of installed geothermal power capacity from 1983 and projected installed capacity until 2025. The Indonesian government issued several geothermal regulations to achieve this target such as the National Energy Policy (KEN) that described in Government Regulation No. 79 of 2014. In addition, the Indonesian government is also eager to increase and accelerate the development of geothermal power. The government targets energy independence and national energy security to be achieved by realizing the development of technological capabilities, the energy industry and domestic energy services so that they can be independent and increase the capacity of human resources (HR) to create jobs.

The national energy policy target is described by the achievement of an optimal primary energy mix by 2025, with renewable energy at least 23%, petroleum less than 25%, coal 30% and natural gas 22% for energy supply and energy use. Furthermore, by 2050, the share of new energy and renewable energy is targeted at least 31%, if the economic value is met, petroleum is less than 20%, coal is at least 25% and the role of natural gas is at least 24%.

The Indonesian government continues to strengthen the fields of energy research, development and implementation through the preparation and enhancement of human resource capabilities and the application of technology and security in the energy sector and the enhancement of domestic energy technology through research, development and application of energy-saving technologies. This aims to encourage and strengthen the development of the energy industry to accelerate the achievement of energy supply targets and energy utilization, strengthen the national economy and employment, including by increasing domestic capacity to support geothermal exploration and electricity support industries. The General Plan of National Energy (RUEN) is detailed in the Presidential Regulation of the Republic of Indonesia Number 22 of 2017. The National Energy Board (DEN) as the drafting body of RUEN conducts a series of modeling as references in energy development in Indonesia until 2050. The results of primary energy supply modeling show that the projection of geothermal contribution to New and Renewable Energy (EBT) supply is 21.8 MTOE or 23.6% in 2025 and 58.8 MTOE or 18.6% in 2050. While the results of modeling EBT power plant development show geothermal power plant 7,241 5 MW in 2025 and 17.546 MW in 2050 or 59% of the 29.5 GW geothermal potential.

However, the government policies mentioned above do not specify much about the development of human resources as a step to achieve the target of building geothermal power plants. However, the RUEN explained several strategic steps that must be taken for geothermal development. This includes improving the quality and quantity of potential resources and geothermal resource surveys, preliminary surveys and exploration assignments by government agencies or business entities and assignments of State-Owned Enterprises (BUMN) or Public Service Agencies (BLU) to develop geothermal energy.

The need for the number of personnel for geothermal development is logically adjusted to the installed capacity. Jennejohn (2010) estimates that each MW capacity will create 4.25 full time positions and 16 people * years for direct, indirect and induction work. Therefore, the additional capacity target of 5,433 MW by 2025 will create around 23,000 jobs with 87,000 jobs per year. Smillie et al., (2015) states that these human resources include geologists, geophysicists, geochemists, drillers, engineers, hydrologists, and other skilled personnel for operations and maintenance that must be prepared before starting a geothermal field development project.

2. Filling the Needs of Geothermal Workforces from Oil and Gas Industry

The conventional way to meet the needs of geothermal personnel is to train and develop newcomers into qualified professionals. This can be done with formal education in vocational schools, polytechnics, and universities to introduce scientific aspects of the use of geothermal energy in the school curriculum. This can also be achieved by training and certification at an accredited and standardized training center. However, this method has several weaknesses, especially the length of time needed to train skilled workers who are ready to work. Another disadvantage is the limited geothermal training program available in Indonesia for young staff to become experienced.

There are three strategies that can be used to overcome the shortage of geothermal human resources, namely to grow technical skills for newcomers in the industry, improve skills for those who are already in the industry or change from similar industries, and bring in skilled workers from outside. This strategy was applied in the Oil and Gas Industry for the geothermal industry in New Zealand in 2009 by NZGA. EHE (2015) recommends this approach for the development of geothermal human resources in Indonesia for long-term goals as well as for short-term solutions to supply shortages of geothermal resources.

The first strategy is to develop newcomers into qualified professionals, and technicians. This can be done with formal education in vocational schools, polytechnics, and universities to introduce scientific aspects of the use of geothermal energy in the school curriculum. This can also be achieved by training and certification at an accredited and standardized training center. This strategy can be applied in Indonesia to prepare geothermal power in the future and long term. Several universities such as the Bandung Institute of Technology (ITB), the University of Indonesia (UI), and Gadjah Mada University (UGM) have held geothermal majors for bachelor's and master's degrees, while 16 other universities in Java and Sumatra have had geothermal programs before or are currently involved with geothermal underground capacity development projects (EHE, 2015).

The second strategy is that people who meet the requirements of other industries such as oil and gas will provide the resources needed in a short time with short internships or training specializing in geothermal studies. Brotheridge (2009) explains that workers who take part in training at work have good initial knowledge, so they are expected to have higher safety standards, higher productivity, and lower downtime.

However, the oil and gas industry currently show the signs of a resurgence with a steady rise in crude oil prices since 2016 and is expected to remain stable at equilibrium prices of around $ 60 a barrel for the next two years (EIA, 2018). In Indonesia, the oil and gas industry are currently also showing signs of resurgence as shown by five of the ten working areas (WK) successfully auctioned off to contractors in the upstream oil and gas industry cooperation (KKKS) in 2017. Previously, there were no contracts in 2015 and 2016 due to unattractive oil prices coupled with economic constraints (SKK Migas, 2018). This may be an obstacle in the transfer of oil and gas experts to the geothermal sector in the future.

For this second strategy application, EHE (2015) proposes the following steps:

a. Conduct training and development courses to gain professional and technical skills for experienced newcomers from outside the industry.

b. Develop a coordinated program for the delivery of university workers and technicians.

c. Develop new postgraduate programs, expand existing programs, and invite guest lecturers in industry (national and international).

d. Develop programs to help assess and analyze abilities and gaps.

e. Expand the ability of the trainer (including existing trainers plus training for new trainers by sending trainers for technical courses.

f. Promote partnerships with international training providers.

g. Promote research opportunities.

h. Encourage the placement of international experts within Indonesian training institutions.

i. Establish a certification body program

j. Identify institutions for accreditation of training courses, technical committees to oversee the development of courses with national and international expert members from industry and training institutions.

k. Develop a quality training framework.

l. Support DIKTI in making the required curriculum, and SKKNI in planning to set competency standards for all courses.

The third strategy is to bring in experts from abroad who are more experienced in geothermal development. Generally, these experts are brought in as consultants, mentors and trainers for local workers, and for managerial positions. However, recruiting people from abroad will increase overall production costs, because most of these experts are attracted by high salary offers. However, this is often unavoidable due to the scarcity of expertise, which is accompanied by the increasing demand of experts in the world. The use of foreign workers is common in the oil and gas industry, especially in exploration and drilling operations. On the other hand, the use of foreign workers in the development of geothermal energy is very limited by the government to encourage the use of domestic labor. The use of foreign workers is only permitted to transfer knowledge such as consultants or experts accompanied by Indonesian workers. Therefore, this strategy is certainly not expected to support the geothermal development target in the short term.

Of the three strategies above, the second strategy or HR migration is the strategy chosen in the writing of this paper. However, there are some differences that must be identified for further HR capacity building before this workforce is ready to be used to work in geothermal energy, namely the difference in drilling techniques and the required competencies.

3. The Difference between Oil and Gas and Geothermal Drilling

Visser et al. (2014) conducted a comparative analysis of 21 geothermal wells and 21 petroleum wells, and interviews with geothermal and oil and gas drilling experts. They found that the main challenges of geothermal drilling were loss of circulation, special mechanical energy, selection of the right rig and equipment, technical drilling programs, proper cementing practices and time management evaluation. The study also shows the opportunity to apply the practice of drilling petroleum fields to the geothermal industry and vice versa. They further explained that in relation to oil and gas drilling the challenges facing the geothermal industry are competition for resources, technological knowledge, human expertise, and adequate practices to handle geological lithology, which are challenges inherent in creating geothermal wells.

Drilling is one of the most important and expensive phases in the development of petroleum and geothermal fields. Anderson et al. (2011) estimates that drilling for exploration and production accounts for more than 42% of the total cost of developing geothermal. Petroleum drilling technology was developed more than 150 years ago, while the first geothermal well was drilled in the early 20th century. Therefore, geothermal drilling adopts many technologies from petroleum drilling. The ability of drilling engineers to identify various challenges in drilling is a key factor in the success of this operation.

However, drilling for petroleum and geothermal is not the same in all respects. Indeed, Tilley et al. (2015) found that geothermal drilling usually takes longer and spends more money on the same depth due to harder rocks and larger holes. The main difference between the two is the location and type of resource where geothermal fluid - often occurs in fractures and cracked volcanic formations - while petroleum is in the pore space of the sediment formation (Capuano, 2016). To date, most geothermal drilling equipment is used and experienced workforce from oil and gas drilling. Some significant differences between drilling conditions in the oil and gas industry and geothermal are described below.

3.1 Rock Formation

Oil and gas drilling target the formation of porous sediments consisting mostly of sandstone and mudstone, so drilling is relatively uncomplicated and fast in terms of penetration. These sediments are formed by erosion such as clay or sand and weathering of rocks by biochemical activities such as calcareous rocks or may also be formed from the evaporation of salts and gypsum from old lagoon buried under a layer of rock. These are formed due to the compression, heating and packing of natural rocks, which from time to time make the sediment initially solid rock. Furthermore, a tectonic geological process produces folds that can lead to the formation of major mountain ranges and sea trenches which lead to the formation of anticlines, synclines and fractures where oil and gas can be trapped (Rouzaut et al., 2011).

On the other hand, geothermal liquids are usually formed in pathways such as fractures and fractures in frozen and hard metamorphic rocks due to the formation of volcanic formations. In geothermal drilling, Watson (2013) explained that various types of rock that are expected to be found include strong brittle rocks in compression but weak in tension, and rocks with cracks arising from stress concentrations due to imperfections in rock microstructure such as rhyolite, andesite, diorite and greywacke. In addition, other concurrent structures that can be used as geothermal drilling lines are secondary mineralized rocks, which have changed due to the flow of geothermal fluid, so that the rock becomes plastic and is easily damaged.

Geothermal regions are formed due to tectonic pressure which results in wide range errors and fractures. The presence of fractures and fractures shows great permeability, but often causes loss of circulation, which is a major problem in geothermal drilling. Another obstacle is that existing fractures can extend naturally and may also form during drilling because of pressure on the hole and can occur throughout the wellbore. Thus, the main differences in geothermal drilling and petroleum drilling are geological complexity in the environment of geothermal reservoirs and poor geological map capabilities that make exploration drilling for geothermal development wells relatively blind (Tilley et al., 2015). In addition, poor interconnection of geothermal rocks and hard volcanic igneous rocks that may exist from the surface to total depth will affect bit selection and penetration rate (ROP). As a result, drilling equipment for oil and gas exploration will not provide the same results in geothermal exploration (Capuano, 2016).

3.2 Reservoir Pressure

Reservoir pressures in oil and gas drilling can be very high due to compaction effects, diagenetic effects, differential density effects and fluid migration effects (Bourgoyne et al., 1985). Devold (2013) explained that the pressure from the oil and gas reservoir can reach 90 MPa, but the specific crude oil weight of 790 to 970 kg per cubic meter will reduce the pressure on the wellhead to one MPa per depth of 100 meters from the well. As a result, the wellhead's static pressure is much lower and will drop further due to production.

However, in geothermal drilling, reservoir pressure is usually inferior or may be lower than hydrostatic pressure compared to hydrocarbon reservoirs, because the stored liquid is still liquid. Pressure will form when the liquid phase turns into gas. Tilley et al. (2015) asserts that this low pressure coupled with errors can cause other problems such as loss of circulation of drilling fluids during drilling and cementing operations with a probability of 33-50%.

In short, the use of sludge as drilling fluid in geothermal drilling may not be feasible due to sub-hydrostatic pressure in the reservoir. In addition, sludge can cause irreversible damage to formations by reducing or destroying permeability if the gel sludge is lost to productive fractures. Therefore, it is recommended to use compressed air, soda water or mixed mud as drilling fluid for geothermal drilling (Capuano, 2016).

3.3 Reservoir temperature

In contrast to reservoir pressure, the typical temperature in a petroleum reservoir is usually lower than a geothermal well. Although oil and gas drilling tools have temperature limits, this is generally not used as a constraint parameter due to the flexibility of drilling fluid selection. Oil and gas usually form at a depth of 3000-4000 meters, but the depth of the oil well can be more than 6,000 meters, while the temperature in the reservoir increases with increasing depth to more than 200ºC (Devold, 2013).

On the other hand, the formation of geothermal reservoirs at equal depths is hotter than sedimentary formations from most oil and gas reservoirs with temperatures from 160 ° C to above 300 ° C. Finger & Blankenship (2010) explains that rock types are common in reservoirs Geothermal is hot, hard, abrasive, cracked heavily and under pressure. These rocks are mainly granite, granodiorite, quartzite, greywacke, basalt, rhyolite and volcanic tuff. This condition shows that geothermal drilling is more challenging because of the low penetration rate, fast bit rate and fast corrosion rate.

High temperature factors in the geothermal environment pose challenges in drilling and other geothermal operations, because it can pose a risk of explosion and boiling which must be included in the design of geothermal development (Tilley et al., 2015). High temperatures from the geothermal reservoir can also cause the temperature of the drilling fluid to rise when returning to the surface. Therefore, the quality and durability of cementing, casing, drilling equipment, materials and equipment must be able to withstand this temperature.

The differences mentioned above under drilling conditions conclude that there are also differences in drilling methods and equipment and equipment involved. These differences, if not fully understood by drilling personnel, can cause potential problems in drilling operations. Table 1 summarizes the differences in geothermal drilling and petroleum drilling.

Because of the differences mentioned above, the drilling method and its challenges may not be comparable. Different drilling operations also increase certain risks or hazards in geothermal drilling. Therefore, workers who want to move from oil and gas to geothermal drilling must be sure to have adequate competencies to avoid risks that can cause accidents, and financial losses and development time in a wider scope.

4. Competencies Standard on drilling

The drilling competency standards have been applied in Indonesia. Despite the application is still limited in oil and gas drilling, the scope is cover for both geothermal and hydrocarbons. The mapping of competencies that established by the Minister of Manpower (2015) mentions that there are fifty core competencies in onshore drilling. However, this competency mapping does not mention the qualifications of personnel. In the previous decree of the Minister of Manpower and Transmigration (2007), there are five qualifications of work that can be gained. From fifty competency units, this regulation also divides competencies into three competency types, namely general competencies which consists of seven units, core competencies that consists of 40 units, and the special competencies that consists of three units.

These two policies of competency standards are genuinely to be used for both oil and gas and geothermal drilling. However, the adoption of competence units is more preferred for oil and gas drilling. To simplify the comprehension, these 50 standards are organized into nine groups/tasks according to the main job as shown on table 2

Although using the same standards, both industries determine a competency is more important than other competencies. The differences between oil drilling and geothermal can be seen from the ranking of each activity that shows the level of importance. The following table 3 shows the ranking of each competency unit between oil and gas and geothermal.

Obeying legislation is the first and main competency in both geothermal drilling and oil and gas drilling. The regulation covers occupational health safety requirements such as fire prevention and suppression, first aid on accidents and implementation of emergency conditions. Furthermore, the policies of environmental protection such as environmental pollution prevention in the workplace of drilling and regulations on the oil and gas mine and geothermal should also be obeyed.

Competencies about casing and cementing comprise the ability to develop casing program, design casing and cementing program, and perform casing installation and cementing. This competency is the most important capability in geothermal which ensures successful drilling of geothermal wells and its utilization for the long term. The selection of materials for the casing can be very crucial regarding to the wells conditions such as temperature cycle and corrosive fluids. In addition to metals damage due to acidic properties, geothermal fluid can also cause scaling due to its mineral content. On the other hand, the cementing job is usually done just after the installation of the casing. This will require a husked additive that is resistant to the hot well conditions. Cement placement techniques also require high skills because the challenge at the geothermal well is the number of loss zones that might fail to return to the surface if the cementing job is not appropriate. Hence, casing and cementing are the most important assets in geothermal production. If these fails due to misplaced or design error, this will result in cessation of production that will be difficult to fix.

Drilling operations in geothermal are ranked third because the geothermal drilling is aimed at massive loss circulation zone due to fault or fracture. This is the main distinction from oil and gas drilling which tends to avoid loss circulation. Another factor which makes this competency more important than others is because of the greater chance of stuck pipe in the geothermal drilling. This is mainly due to the drilled formation that formed of hard rock is abrasive and easy to crumble. Thus, the ability to analyze the situation and make the right and quick decisions is critical at this stage.

On the other hand, well control is the major competency required in oil and gas drilling. This is coupled with the competency to design mud program which is an important part to control pressure inside the well so that both get a high rank. Hydrocarbon wells typically have very high pressures and can be very dangerous because they are flammable and can cause an explosion when it is failed to be controlled. Conversely, the pressure in the geothermal well is commonly not very high and the steam kick tends to be easier to control with just cold water. The formation pressure of geothermal well is generally equal or even smaller than the hydrostatic pressure of the drilling mud. Thus, well control in geothermal drilling is not significant.

Further, evaluation of the program is useful for fix the problems when they are observed so that they can be anticipated in subsequent drilling. The ability of log interpretation of drilling data and problem handling during drilling operations in geothermal drilling is essential. Oil and gas drilling, on the other hand, more prioritize well completion because this is important in relation to the success of oil and gas production through tubing while in geothermal, the well completion process is simpler because the geothermal fluid is sufficiently produced through the casing.

Lastly, special competencies including fishing jobs and the prevention of toxic gases are added value in geothermal and oil and gas drilling. Therefore, this competency gets the lowest rank in both industries. From the description above, although the units of competence are the same, the priority of each competency unit is different between oil and gas and geothermal.

5. Result and Discussion

Generally, there are three types of companies involved in drilling operations: drilling contractors, operating companies and service companies. In Indonesia, drilling contractors and service companies usually work in oil and gas, and geothermal fields. Thus, the human resource shift from oil and gas to geothermal and vice versa cannot be avoided. Actually, labor migration is nothing new in the drilling industry in Indonesia, although additional conversion training is very little, which can lead to a wrong approach. This migration can also help provide a lot of staffs into the geothermal sector.

Several experts have been contacted for their professional views on the needs and possibilities for converting oil and gas drilling technicians and operators to geothermal. Much of the expert feedback came from the requirements for drilling. In general, experts from the government and geothermal companies in Indonesia believe that there are competency gaps between oil and gas and geothermal drilling workers. An expert from Star Energy acknowledged that geothermal drilling is indeed slightly different from oil and gas drilling. Thus, people with geothermal drilling experience are more desirable to be recruited by the companies for geothermal projects. However, he added that the companies in Indonesia commonly have no other choice than to enlist experienced oil and gas workers, due to the scarcity of experienced geothermal personnel.

Furthermore, an expert from MBCentury agreed that besides a qualification, enough experience in geothermal drilling is also essential to become a geothermal drilling engineer. For instance, ten years' experience of drilling geothermal wells is generally required to be appointed as a drilling supervisor. It is also compulsory for a drilling supervisor to understand drilling standards and to have a satisfactory safety record. On the other hand, he recognized that some of petroleum drilling qualifications might still be useful for geothermal drilling, particularly for specific competencies like well control. This is because currently there is no geothermal version available for this qualification.

In line with this, an expert from Geothermal New Zealand Inc. confirmed that the drilling engineer should have a certain level of experience and at least a certification of blow-out prevention (well control) methods from the International Well Control Forum (IWCF), which is also a typical requirement in oil and gas drilling. However, he argued that in practice oil and gas well control is practically irrelevant to geothermal drilling and could direct to a completely wrong procedure for geothermal drilling.

In terms of workforce migration from oil and gas drilling to geothermal drilling, he suggested that the idea that the workforce with petroleum experience can directly shift into geothermal drilling can be "particularly hazardous and often results in extremely expensive mistakes". Hence, he proposed that there should be a geothermal course and certification relevant to geothermal drilling for these migrants.

A drilling expert from KS Orka Renewables also concurred that at the supervisor level of drilling, such as driller and toolpusher, there is a strong need to comprehend the control method of steam kick in a geothermal well. He also mentioned that an initial response to the indication of the problem such as a stuck pipe and lost circulation is crucial in geothermal drilling. Additional vital subjects would be: assessment of rig stability from a geotechnical perspective, the management of rig mobilization, and special methods of geothermal drilling such as aerated drilling, water drilling, and blind drilling.

An expert from Geothermal Associates NZ added that engineers' competencies on health and safety should be upgraded to specifically meet geothermal requirements that are slightly different from oil and gas. He gave an example that blow-outs in geothermal wells tend to develop faster, but with lower explosive dangers than oil and gas wells. Moreover, he added that besides safety performance, an understanding of the elements of NZS 2403 (NZ Standard code of practice for deep geothermal wells) is also important for the drilling engineers. Therefore, specific training and certification for geothermal drilling are important for migrants from the oil and gas industry.

In Indonesia, more consideration of oil and gas workforce transfers to geothermal work is given to the supervisor level than the operator level. Several trainings intended for managerial levels have been delivered such as at ITB in cooperation with the Geothermal Institute and lately a well drilling course commissioned by MFAT in cooperation with BPSDM (an educational body under MEMR Indonesia). The latter was a 3 days training course that was delivered in early 2017 with the goal of increasing the number and overall competency of geothermal well drilling practitioners available to work in Indonesia's geothermal sector.

At the technician level, an expert from MB Century, suggested that there is no particular additional training would be required for conversion at lower level apart from on-the-job work induction due to the differences between geothermal and oil and gas drilling at this level not being prominent. However, there are several distinct duties and responsibilities for higher level such as a derrickman and upwards. Thus, there is the need for additional learning for these levels which can be done by formal training or mentoring at the workplace. On the other hand, for a driller, he insisted that much internal training and supervised work would be needed to accustom a new geothermal senior driller to the specific geothermal rig in use, as every rig has different characteristics. Hence, much of this training could be combined and done on-the-job and under supervised work conditions.

An expert from KS Orka Renewables mentioned that there are skill areas that drilling crews must be familiar with to be ready for geothermal drilling. He proposed a list of trainings that would be required for all drilling crew to move from oil and gas to geothermal drilling as follows:

a. An introduction to drilling waste management and geo hazards on geothermal drilling sites include landslides, subsidence, and hydrothermal eruptions.
b. An introduction to a geothermal "steam kick" instead of a "gas kick" that is prevalent in oil and gas drilling.
c. An introduction to common challenges in geothermal drilling includes total lost

circulation, hole integrity, stuck pipe, and corroded drilling pipes. This training should also cover the root of the problems including rock types, formations, packed-off, acidic exposure, and material inspection.

Moreover, an expert from Pertamina Geothermal Energy (PGE) emphasized the importance of water allocation in geothermal well control and unusual H2S hazards that might not be common in oil and gas drilling.

an expert from MITO stated that the industry had recently accepted a common drilling qualification instead of specific strands. He also indicated that the transfer might only require some adaptation to apply their skills and knowledge to the new domain. In terms of the competency standard, he advised that there is a difference in responding to emergencies between hydrocarbon and non-hydrocarbon drilling. Moreover, due to the differences in drilling methods, some competencies needing to be reassessed include:

a. Appropriate drilling methods, systems and processes for specific drilling environments.
b. Drilling systems and processes operation and monitoring, hole condition monitoring, and responding to down hole problems in a drilling environment.
c. Moving drill rig and associated equipment to safely meet workplace requirements.

However, other competencies considered similar between both domains include:

a. Apply risk assessment procedures, and workplace HSE procedures.
b. Interpret and apply client/contract specifications to safely meet operational targets.
c. Provide mentoring and on-the-job training to drill crew.
d. Communicate with clients, internal staff and the public as required to meet relevant workplace policies and procedures.
e. Lead reporting on drilling operations.

For standard competencies required in Indonesia, all experts agreed that existing oil and gas drilling certification can be directly used in the geothermal sector. This is because, in general, the oil and gas industry are considered to have a higher risk and more complicated challenges than the geothermal industry. They also asserted that there is currently no specific documented competency needed for the geothermal industry in Indonesia as this domain is considered relatively new. Hence, experienced people with oil and gas certification will certainly be acceptable to work directly in the geothermal industry.

Results of the expert discussions provide an examination from a different perspective of the previous literature review. It was found that most experts agreed on the need of a learning program or on-the-job experience for people with an oil and gas background to move to geothermal drilling. The difference of interpretation is more to the field of experience than the prevailing standard. For example, in expert opinions, the driller requires only well control adaptation to the geothermal environment since well control is the main consideration in oil and gas drilling but uses a different technique in geothermal drilling.

Furthermore, the literature review and experts also seem to agree that little additional training is necessary at the lower level. Differences exist on views whether this should/could be done best through formal training/qualification or on-the-job training, mentoring and supervised work.

6. Conclusion

There are fundamental differences between geothermal drilling and oil and gas that make drilling methods and challenges impossible to compare. Geothermal reservoirs often occur in fractures and cracks, hard volcanic formations, whereas hydrocarbon reservoirs generally occur in porous spaces of sediment formation. However, this difference has not been recognized by the drilling competency standard in Indonesia, because there is nothing specific for geothermal drilling.

Indonesia has implemented competency standards for drilling that can be used for both geothermal and oil and gas. Based on a literature review of existing qualification standards at technician/operator levels, it was found that the competency standards for oil and gas drilling in Indonesia can also be applied for geothermal drilling qualification standard. However, there are some adjustments that need to be made in the priority of competencies to drill. This is due to the differences between two industry such as rock types, soil conditions, and types of hazards that may arise during drilling.

Discussion with several drilling experts from Indonesia and New Zealand was also conducted for their professional opinions. This study suggests that learning programs are needed for migration with different durations and materials for each level. These findings are consistent with the results of discussions with experts who generally agreed on the differences between the two drilling areas and indicated the need of training for the migrating personnel, with further training for higher levels of qualification. However, some experts suggested that all levels of migrants needed a general Geothermal-vs-Oil-Gas drilling introductory course to understand geothermal characteristics and challenges such as steam kick, waste management, and geo hazards. However, other experts insisted that on-the-job training, supervised work and mentoring are the best methods to fill the competencies gap. This could be investigated further. The appropriate learning program might also be different from one company to another.

This paper shows that learning programs are needed for migration with different duration and materials for each level. The training program will need to include general introductory geothermal-oil-gas drilling courses to understand geothermal characteristics and challenges such as steam kicking, waste management, and geo hazards. In addition, workplace training, supervised work and mentoring are also needed to fill the competency gap.

7. Recommendation

In a broader study it will still be published, some existing facilities and infrastructure have been identified in Indonesia that can support conversion programs (Umam, 2018). This includes government and private training centers, universities with oil or geothermal departments, and geothermal companies operating in Indonesia. The study mentioned above proposes that PPSDM Migas, as a government training institution, will be used to implement conversion programs. PPSDM Migas has facilities to begin training in geothermal drilling and indeed has a mandate from the ESDM Ministry to promote geothermal training under a new strategic plan from the ESDM Ministry. At present, PPSDM Migas offers several training and certifications for oil and gas drilling qualifications. The center has experience in providing geothermal drilling training for oil and gas workers through a recent course, although this is offered at the engineer level. Therefore, PPSDM Migas is an appropriate organization to facilitate the conversion of drilling technicians and operators from oil and gas to the geothermal sector.

Furthermore, geothermal companies may provide their future employees with training and mentoring programs at the workplace, while universities and training centers can assist companies by providing short courses, workshops and training in geothermal drilling. In this way, unemployment from the oil and gas sector can be reduced while supporting the government's target in 2025. Thus, Indonesia's geothermal HR needs can be met effectively and efficiently.

8. Acknowledgement

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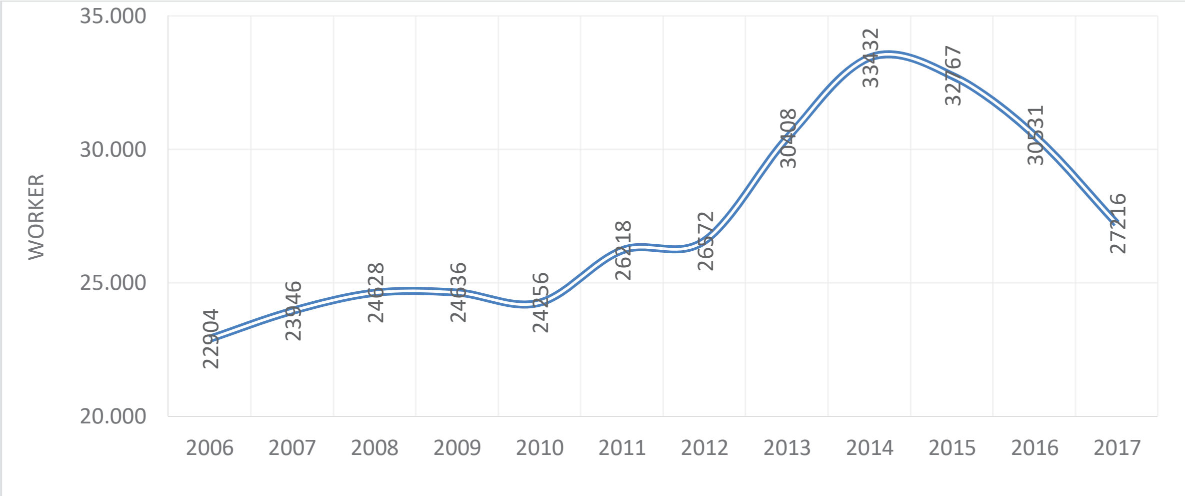

Figure 1. Workforce in the upstream oil and gas industry from 2006 to 2017 (adapted from SKK Migas, 2017)

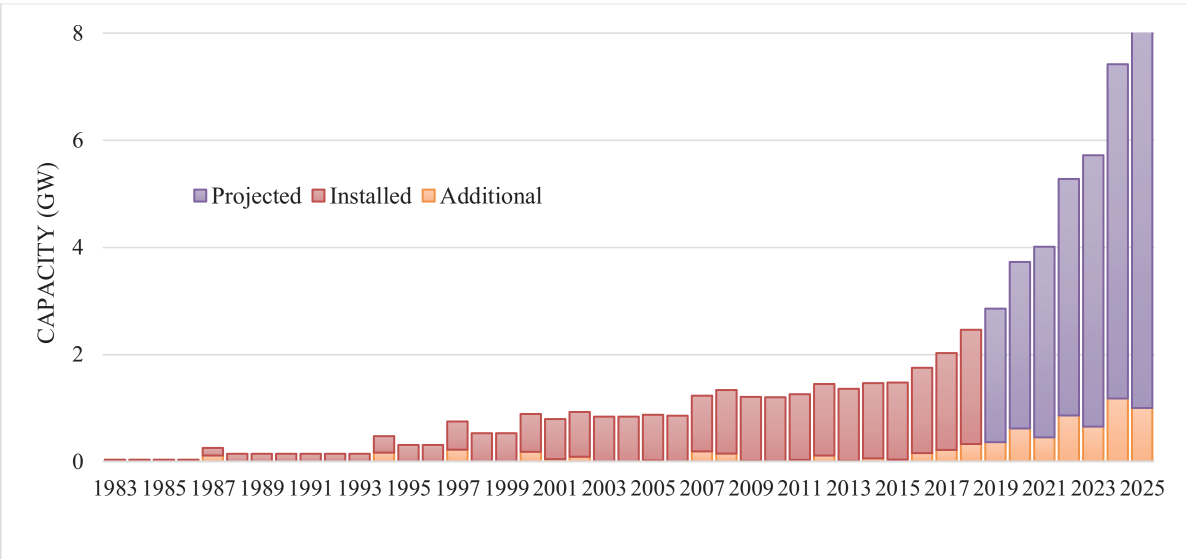

Figure 2. Installed capacity, additions (planned) and projected capacity of Indonesia's geothermal power plants from 1983 to 2025 (Adapted from Darma et al., 2010; Darma et al., 2015; RUEN, 2017; MEMR, 2017)

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Table 1. Summary of drilling in petroleum and geothermal.

Parameters	Petroleum	Geothermal
Rock formation	Mostly sandstone/ mudstone, sedimentation layer	Igneous & hard metamorphic rock (e.g. rhyolite, andesite, diorite, etc.)
Reservoir pressure	High (might reach 90 MPa).	Relatively low, might be lower than hydrostatic

		pressure.
Reservoir temperature	Up to 200°C, relatively low	High temperatures (160°C to above 300°C)
Drilling fluid	Bentonite blends	Aerated mud or water with air or nitrogen mixture
Drilling bits	Typically, Polycrystalline Cutter (PDC)	Roller cone or drag bits, impregnated diamond bits
Drilling orientation	Vertical, deviated, horizontal	Typically, vertical or J-shaped, horizontal drilling is unlikely
Casing	perforated production casing	Slotted liner, large diameter casing
Cementing	protecting casing from hydrocarbon corrosion	Limit casing transformation / deformation due to high temperature, prevent thermal fatigue
Completion	perforating and swabbing with NaCl salt water	Slotted liner installation and swabbing with brine

Table 2. Competency matrix for drilling engineering in Indonesia.

Drilling Task	**Required Knowledge/Skills**
Comply with applicable regulations	Understand the requirement of Health, Safety and Environmental (HSE) protection, cooperation, fire prevention and suppression, first aid on accidents, emergency conditions, pollution prevention, and implement laws of oil and gas and geothermal mining.
Maintain Well Control	Maintain well pressure control and blowout prevention devices including assembling and operation.
Establish the mud program	Design mud program, calculate the mud weight to maintain well control, select acceptable mud types, specify mud properties, assist mud treatment, and operate mud pumps
Develop casing and cementing program	Design casing program, implement casing installation and cementing, design cementing program, and perform casing lowering and cementing job.
Perform drilling operation	Select drilling bit, perform pipe trimming, drilling optimization, core drilling, directional / horizontal drilling, stem test operation, and hydraulic drilling, control solids/gas separators and drilling rig instrumentation, control the tilt, and design a directional well drilling and hydraulics program
Prepare drilling equipment	Specify equipment, design drilling rig mobilization/demobilization, moving, rig-up/rig-down, select and operate prime mover system, hoisting system, rotating system, circulating system, and perform activities before and after drilling operations.
Perform well completion and stem test	Design and Operate drill stem, perform well completion and stem test.
Establish evaluation program	Develop evaluation program, evaluate drilling problems, maintain rotating equipment, and perform daily inspection and daily rig equipment maintenance.

Perform extraordinary activities	Perform special activities such as hazardous / toxic gas prevention and fishing job

Table 3. Comparison of competencies ranking of oil and gas and geothermal drilling

Rank	Oil and Gas	Geothermal
1	Comply with applicable regulations	Comply with applicable regulations
2	Maintain Well Control	Develop casing and cementing program
3	Establish the mud program	Perform drilling operation
4	Develop casing and cementing program	Maintain Well Control
5	Perform drilling operation	Establish the mud program
6	Prepare drilling equipment	Prepare drilling equipment
7	Perform well completion and stem test	Establish evaluation program
8	Establish evaluation program	Perform well completion and stem test
9	Perform extraordinary activities	Perform extraordinary activities