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Dieng Geothermal Project: Risk Assessment for the Decision on 60 MW Expansion

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ABSTRACT

Dieng is one of the prospected geothermal fields in Indonesia with an estimated field development potential at 350 MW. At present, one 60 MW power plant unit has been installed and the current production is around 46 MW. Dieng geothermal power plant is owned and operated by PT Geo Dipa Energi (Geo Dipa), a state owned company. Geo Dipa is implementing a phase development for the field. Unit 1 has been in operation since 1998 and now Geo Dipa plans to add another 60 MW, Unit 2. The Unit 2 project is still in feasibility stage and the feasibility study is currently being updated. In the development of Unit 2, there are risks that need to be considered before a decision can be made. Therefore, in this paper, the risks associated with Unit 2 project are identified and appropriate mitigation actions are listed. The key risks are identified as resources and technical risks which are related to scaling and corrosion in production wells, turbine and Fluid Collection and Reinjection System (FCRS). To mitigate the scaling, methods such as hot water reinjection, pH modification, inhibitors, cold water injection and retention tank have to be studied further. Several environmental issues are also considered as extreme risks and should be mitigated prior to a decision on the Unit 2 project.

1. INTRODUCTION

The Dieng Geothermal Field is one of the most prospected geothermal fields in Central Java Province, Indonesia. The area is 63 km^2 with estimated field development potential at 350 MWe. It is a high temperature field consisting of fumaroles, hot spring and acidic mud pools. These manifestations are distributed in three areas, Sileri, Sikidang and Pakuwaja. Sileri is located to the northwest with fluid temperature around 300˚C and acid-sulfate-chloride type of hotsprings. In the centre, there is Sikidang area with fluid temperature around 300˚C and high non-condensable gasses (NCG), mostly CO_2. Sileri and Sikidang are craters that consist of old Dieng volcanic rocks. To the southeast is Pakuwaja area, the youngest volcano in the Dieng Geothermal Field, but it does not have high underground temperature. The upflow areas of the hydrothermal systems are believed to be around Sileri and Sikidang where the fluid flows southeast, northeast and southwest along the faults. These faults will be the drilling targets for future production wells. Since 1975, in total 52 wells have been drilled in Dieng, 27 wells by Pertamina, 20 wells by HCE and 5 slim holes for coring. At present, only 5 production wells and 4 injection wells are operating for power plant Unit 1. Unit 1 is a 60 MW power plant which was commissioned by Himpurna California Energy Limited (HCE) in 1998. In 2002, GeoDipa, a joint venture between PT Perusahaan Listrik Negara (PT PLN) and PT Pertamina took over the ownership of Dieng Geothermal Field. Since 2011, GeoDipa is designated as a State-Owned Enterprise through Government Regulation no. 62/201.

With experience from Dieng Unit 1, GeoDipa plans to do the next phase which is building and operating Unit 2, a new power generation unit of 60 MW. This project is included in the National Energy Plan and PLN Electricity Supply Business License (IUPTL) which reflects GeoDipa's commitment to support the Government of Indonesia's plan to achieve the energy mix target through the development of geothermal renewable energy. In the scenario of developing renewable energy according to National Energy Policy and General Plan for National Energy in Indonesia, electricity production from geothermal energy is targeted to reach 7242 MW by 2025 and GeoDipa will contribute to achieve the target by developing Unit 2.

For the Unit 2 project, the initial feasibility study was conducted in 2006 by Japan Bank for International Cooperation (JBIC) in cooperation with West Japan Engineering Consultants (WestJEC). Later in 2013, PricewaterhouseCoopers (PwC) in cooperation with Electroconsult (ELC) updated the feasibility study for Unit 2. Currently, the feasibility study is again being updated. The target of commercial operation is in 2023. GeoDipa has confirmed its intent to request a loan from the Asian Development Bank (ADB) and ADB has shown a positive intention to finance the Unit 2 project, subject to the outcome of the updated feasibility study. The Geo Dipa management team and employees who have long experience working for the Unit 1 power plant are considered to be very well capable of operating Unit 2 in the future. GeoDipa would directly sell the electricity to PLN, since PLN is the single-buyer for electricity generated from geothermal energy produces in Indonesia. PLN distributes the electricity from Dieng to Java and Bali.

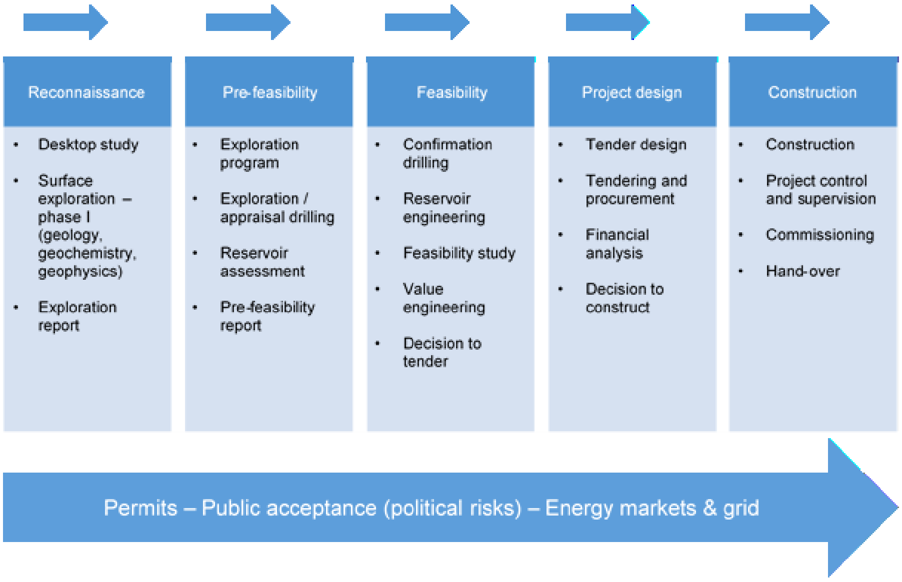
Based on the operational experience from Unit 1, consideration should be given to assess the risks. In this paper, risk assessment and mitigation on resource and technology will be discussed for successful future exploitation and stable operation.

2. DECISION MAKING IN GEOTHERMAL PROJECTS

2.1 Stage Gate Process

Stage gate is a set of methods that are described with identifiable stages where the stages are systematic in the form of a conceptual and operational roadmap to develop the project to the gate or the next decision point. Each gate is characterized by a set of deliverables or inputs, a set of exit criteria and an output. This controls the process, serves as a quality check and controls the results of the process. The project team members carry out the main tasks to collect information needed to run the project from the beginning to the end. All tasks must provide information about the needs that need to be known by management to make the decision to go forward and what actions need to be carried out. This helps to ensure documentation, quality, comparability and improves project effectiveness and efficiency (Cooper, 2016).

In geothermal projects, there are several stages that must be carried out and they require a long time and a complex process. One of geothermal companies that have applied stage gate in geothermal business is Landsvirkjun, the national power company of Iceland.



An example of stage gate process for geothermal projects at Landsvirkjun is shown in Figure 1 (Pálsson, 2017).

FIGURE 1: Stage gate for geothermal projects at Landsvirkjun (modified from Pálsson, 2017)

Based on the Standar Nasional Indonesia (SNI, 1998), there are stages of geothermal investigation and development related to the classification of energy potential based on the results of geological investigations, geochemistry and geophysics, reservoir techniques and estimation of electrical equality. This can be referred as a stage gate which in general consist of exploration, feasibility study, exploitation and utilization.

2.2 Phase Development

In the development of geothermal fields, especially in fields that have great potential, geothermal developers must be able to define the project. Developers need to optimize investment to get the highest income possible from the start of production (Pálsson, 2017). Information regarding geological conditions, available information about resources, institutional and regulatory climate, access to appropriate financing and other factors greatly influence the development of geothermal projects (Gehringer and Loksha, 2012).

In the development phase of a geothermal power plant can take two approaches. The first approach is the single phase development approach where the full capacity/size of the field can be developed. The second approach is a phased development where the full capacity of the field is explored in stages over a period of time. For example, when a geothermal field has high potential, the developer has the option to do the production by installing geothermal power plants to achieve maximum capacity at the same time (single phase development) or do it by installing a geothermal power plant in several relatively small phases (phase development), in this case several power plants gradually. Development in the next phase generally has a lower risk based on the experience that has been done in the initial phase (Pálsson, 2017).

2.3 Risk and Return

In geothermal power projects, there are two main risks which are interlinked: resource risk/exploration risk and financing risk. Resource risk relates to the difficulty of estimating the capacity of geothermal field resources. Financing risk relates to a long lead time (time lag) between the initial investment and the start of revenue where the initial investment capital is very high.

Geothermal project financing increases gradually at each stage of development. Along with the progress of the stages in the project, the uncertainty will decrease. At the drilling stage, the investment costs required for each well are quite high with a low level of certainty, especially drilling in a green field area. The risk of geothermal projects in green field is higher than brownfield, so the risk premium required by investors/financiers is higher in the greenfield area. A high risk premium on capital cost or risk sharing will be required by the financier for the project (Gehringer and Loksha, 2012) and most of the developers not able to fund 100% of the projects. Investors will provide loans for commercial rates and conditions when resources have been proven but when the resources in geothermal projects has not been proven, investors will seek higher returns than their investments with a return range of 22-30% (base leverage-equity) or 14-18% (100% equity base) (Quinlivan et al., 2015).

Risks in operating power plants, such as prolonged breakdown and other downtime generally affect the company's profit and investment. Therefore it is necessary to make a proper prevention and maintenance schedule (Ngugi, 2014). Some geothermal projects have experienced events that have a major impact on the project economy where the most common mistakes are inadequate steam availability or reinjection capacity (Pálsson, 2017).

3. RISK FACTORS FOR GEOTHERMAL PROJECTS

The cost of developing geothermal projects varies greatly between stages. Starting with a low cost in the planning, mapping and survey stages, then it increased significantly during the well drilling stage (up to mUS$ 5-10 per well) and construction of power plants (Figure 2). The probability of success is low in the early stages of development, especially in the exploration stage which has a high level of uncertainty (Pálsson, 2017). The upstream stages and especially the test-drilling stage, are usually seen as the riskiest parts of geothermal project development, reflecting the difficulty of estimating the resource capacity of a geothermal field and the costs associated with its development (Gehringer and Loksha, 2012). After test-drilling, the risk reduce but the cost will become higher since the cost for SAGS and power plant construction reach up to 60% of the total cost the project (Pálsson, 2017).

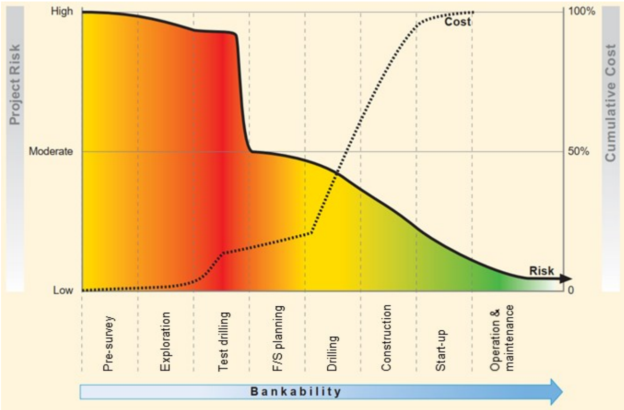


FIGURE 2: Project cost and risk profile at development stages (Gehringer and Loksha, 2012)

3.1 Resource risk

Resource risk is unique in the development of geothermal fields where each field has different development characteristics and challenges. Resource risks which associated with the characteristics of the initial well are as follows (IFC, 2013; Robertson-Tait et al., 2018):

- The well is filled by drill cutting or casing collapse
- Inadequate flow capacity due to permeability and thickness of productive reservoirs that are too low for commercial production
- Inadequate temperature which is the effect of lithological variation and convective heat flow that cause inaccurate temperature projections
- Inadequate pressure where static reservoir pressure is too low and may not be sufficient to allow flow at the commercial level
- Unacceptable chemical problems where the fluid produced can contain high levels of total dissolved solids or non-condensable gases, elements that cause the fluid corrosive and scaling formation in reservoirs or in power generation systems

The risks continue to come from exploration to utilization. Exploration risk is related to geological risk where the certainty of a prospect is the key to a success geothermal project. In the exploration stage, information about the resources size, temperature and permeability is very limited (Ngugi, 2014). Decision making as the key to a successful low risk development can be supported by having design of geoscience strategies, such as rigorous scientific studies at reconnaissance and exploration stages, integration of 3G data, recognition of hazards or barriers to development, and conceptual models to be tested and refined by more detailed work (Bignall, 2013). With an understanding of quality 3G data in the early stages of the project, risks and uncertainties will decrease. Some resource characteristics that can be considered in the construction of power plants are as follows (Matek, 2014; Hadi, 2010):

- Reservoir temperature is obtained from geochemistry data, specifically geothermometry from fumaroles and boiling chloride springs which have direct connection to target reservoir. Geochemistry data is required to understand the estimated resource temperature at depth, origin of the resource, locations of different aquifers, mixing between aquifers, sources of recharge to geothermal system and pathways of discharge from geothermal system. Geochemistry data is also useful to mitigate risks that have the potential to influence the operational activities of power plants, such as scaling, corrosion and non-condensable gases concentration.
- Reservoir size (volume) is based on reservoir area, thickness of the reservoir, and reservoir porosity. Reservoir size can be obtained from a geophysical survey which delineates the reservoir boundary, thereafter proven by drilling.
- Reservoir permeability is a measure of how geothermal fluids can move through a fault/open structure which will be the target in exploration and proven by drilling. It is the pathway in the reservoir where fluids move. Some data required to estimate the permeability are integrated surface and subsurface data and if possible, a correlation with drilling results from similar fields.
- Fluid enthalpy is the amount of thermal energy per unit of mass contained in the reservoir fluid and is governed by temperature, pressure and chemical composition of the fluids. Fluid enthalpy is obtained from geochemistry of fluids from surface manifestations. It is useful for selecting power generation technology, engineering design costs, and number of wells.

According to Sanyal (2010), there are several merit measures that can be designed for the risk of geothermal resources, such as potential resource base (MW) and drilling success rate (%). In principle, the greater the resource base, the greater the potential for development and the higher the economic scale. The success rate of drilling is defined as the percentage of successful wells in a series of drilling activities in a field. The success of drilling can also be calculated from the average drilling cost per MW capacity achieved in the drilling program. In addition, there is also a unit capital cost ($/kW) which is the capital cost per MW of installed power capacity. These costs consist of drilling, well testing and other resource supply costs as well as power plants and SAGS.

Average drilling success rate by project stage (exploration, development and operation) have improved from 1960s to 2000s (Figure 3). It means that time to time, geothermal developers and drilling companies are more capable to handle the risks in drilling, so the risks are decreasing from time to time (IFC, 2013).

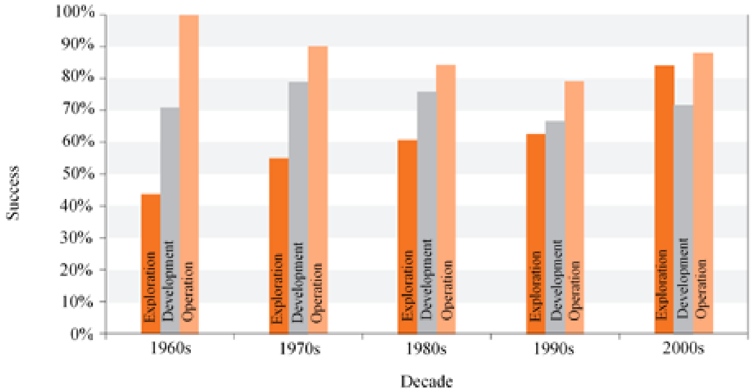


FIGURE 3: Drilling success rate (modified from IFC, 2013)

3.2 Technical risk

In geothermal utilization, there are some technical problems to be addressed. Risks from casings and pipelines are found, such as casing damage due to thermal stress or bad cementing, leaks on wellhead flanges and valves, and leaks on valve glands and flanged connections (Thorhallsson, 2018).

Common problem in some geothermal fields is scaling that blocks flow. Scaling and corrosion in wells and surface installations relates to the chemistry of geothermal fluids and flow properties such as pressure, velocity and flow pattern (laminar, turbulent etc.). Fluids containing high concentrations of minerals and gases typically cause such problems (Gunnlaugsson et al., 2014). Geothermal fluids have different chemical characteristics and conditions. The chemical conditions depend on several factors including geological resources, temperature, pressure and water sources. The major scaling is usually in the form of sulphide, calcium and silica which is formed due to the concentration, fluid pressure, temperature and pH of the system. The most difficult and challenging scale types occurring in geothermal operation is silica as it will form an amorphous silica scale.

In flashed-steam systems, there is usually a significant drop in fluid pressure from the well to the turbine. In many cases, the geothermal fluid becomes supersaturated with silica as it is cooled. A pressure drop that exceeds the saturation limit can cause super-saturation followed by silica deposition in geothermal surface facilities. Further cooling can lead to higher silica saturation in disposal brine, so that greater scale silica precipitation will occur in reinjection wells, piping, heat exchangers and other production facilities. Risk of silica scaling around the turbine is related to minor concentration in the steam which causes the blockages, thereby reducing electricity production. Therefore, the separator needs to be designed as well as possible to avoid incomplete separation. Silica scaling formation and deposition is slower than carbonate scale but far more difficult to remove from the facilities (Koenig, 2016).

Corrosion attacks occur in some geothermal operations and causes damage to equipment which results in product loss, inefficient operation and downtime for equipment maintenance and replacement and increased production costs. In general, these problems are mostly localized in geothermal construction and installation, especially in brine gathering system, injection lines and wells. Therefore, a proper material selection, operation and maintenance is important for the design of geothermal utilization to prevent the corrosion (Datuin and Gazo, 1989; Miller, 1980 in Gunnlaugsson et al., 2014).

Another issue is steam purity caused by non-condensable gas (NCG) in the steam. Insufficient gas extraction capacity of NCG vacuum equipment will reduce the vacuum and affect the conversion efficiency. The gas is very toxic, especially hydrogen sulfide (H_2S) and carbon dioxide (CO_2). NCGs, may need to be disposed of in certain circumstances and this situation needs to be carefully considered and allowed for the design. Proper atmospheric dispersion is most common but some countries are required by regulation to install gas abatement system (Hochwimmer and Kretser, 2015; Thorhallsson, 2018).

In cooling towers, there is a type of problem which is clogging up by sulphitephylic bacteria. From the condenser, some of the condensed steam goes to the cooling tower as make up water. As the condensed steam goes from the condenser to the cooling tower as make up water, deposition of sulfphur compounds and various bacteria thrive can occur. The way to remove the sulphur deposits and bacteria colonies is by using high pressure washing and wet vacuum cleaners periodically to suck up the loosened material (Elíasson et al., 2008; Thorhallsson, 2018).

3.3 Environmental risk

Geothermal activities, both on low-temperature and high-temperature fields have impacts on the surrounding environment. Exploitation stage, especially in drilling operations has the greatest impact to the environment which can cause noise, fumes and dust that has direct effect to humans and animals. Environmental is also affected due to drilling where the construction of access roads to drilling sites can involve forest destruction and vegetation that can cause erosion, especially in tropical regions with high rainfall, such as Indonesia and the Philippines (Hunt, 2000).

Health, Safety and Environment (HSE) risks in drilling activities relate to hazards that have the potential to affect personnel, property and the environment around drilling activities. The risks that affect personnel can be in the form of toxic gas which varies widely from reservoir to reservoir. The major constituents are CO_2 and H_2S which release from the well to the surface. Exposure to atmospheric concentrations of these gases pose potential hazards to public and occupational health. The effect of H_2S depends on the length of exposure, frequency and intensity, where the minimum effect is the odour threshold and the highest is respiratory paralysis, irregular heartbeat, collapse and death. The effects of CO_2 are shortness of breath, dizziness, mental confusion, headache and possible loss of consciousness. Also there are risks to security of equipment and personnel such as exposure to falling objects from overhead works, derrick jobs and drilling personnel exposed to wild animals, especially in remote areas. The risk that affects the environment is the improper disposal drilling cuttings. Drilling cutting is not toxic but the waste is very high from the drilling. Air pollution due to diesel usage also affects the drilling environment in remote areas that have not been accommodated by electricity (Okwiri, 2017).

In the construction stage, high construction risks are also found in the installation of the gathering system in volcanic environments that have high topography and terrain. There might be risks from lahar flow paths, areas of steaming ground, and areas with hydrothermal eruption (Hochwimmer and Kretser, 2015). In the utilization stage, from the side of the wellhead and the generating unit, noise can occur and the presence of toxic gases emitted by the power plant. In addition, cooling tower emission of water droplets containing toxic derived from condensate vapour used as cooling water can cause the phytotoxic effect of vegetation around power plants.

Health risks can also occur in the community around geothermal power plants, such as the inhalation of toxic gases emitted by geothermal power plants and pollution of ground water. Ground water can be contaminated with arsenic which can interfere with public health which usually consumes ground water. With the existence of environmental risks like this, the surrounding community also need to increase awareness of the effects of geothermal operations in their environment.

Conflicts over rejection from the community can also occur around the power plant sites where in general the community denies the power plant operation because of the interests in the tourism industry and farms owned by the local community. The conflicts can lead to the cancellation of the power project. Therefore, developers must pay attention to the needs of the community (Berrizbeitia, 2014; Layton et al., 1981).

3.4 Other risks

Apart from resource, technical and environmental risks, there are some other risks must be considered in geothermal projects, such as political, law, regulation and permits, takeholders, development plans, financial, markets and PPA (Power Purchase Agreement), design and tendering, access and supplies, and contracts. All geothermal projects must comply with law, regulation and permit in the project area, but sometimes a regulation changes in the middle of the project which can cause a delay in the project. Another issue which become one of the main focus in geothermal projects is project financing and tariffs. In all geothermal projects, favorable power purchase contracts are needed. The existence of high risk in the exploration stage causes distrust of banks to finance the projects with loans. Small developers generally try to form joint ventures or equity partnerships, so they can share risks. However, in some countries there is a loan guarantee program from the government to allow several development projects to progress. For the market, developer needs to consider about the access to markets that can be limited by the lack of infrastructure including transmission and distribution networks. Proper preparation for access and supplies is required.

4. RISK FOR DIENG GEOTHERMAL PROJECTS

4.1 Understanding and assumptions

Power plant Unit 1 (60 MW) in Dieng was commissioned by HCE in 1998 but suspended due to Presidential Decree No. 5/98. In 2002, GeoDipa was established and now owns the Dieng field. Since then, GeoDipa began operating Unit 1 where the steam supply was obtained from the existing wells, but only producing around 46 MW due to wellbore problem and lack of steam. GeoDipa also planned to construct Unit 2 but it has been delayed due to financial and technical reasons.

According to stage gate, the development of Unit 2 has reached the feasibility study stage since 2006. Feasibility study for Unit 2 was first conducted in 2006 and updated in 2013, but the project could not proceed due to legal issues. In 2018, GeoDipa can handle the legal issue and starts the project by updating the feasibility study. This will be followed by purchasing drilling long lead items, IPM tender and EPC for SAGS and power plant.

The plan for the development of Unit 2 is to drill additional wells and build both the FCRS and the power plant. Some steam is believed to be available from older wells but a few new wells have to be drilled. FCRS will be constructed by considering the silica scaling problems, so the applicable type of FCRS for this project is combination of a two-phase flow type and central separation type. Two-phase flow will be transported from the production wells and separated in a separator station near Unit 2. The pipeline route will be designed by considering the steep slope and it will be shorter for less occupancy area. There will be two kind of pipelines, two-phase pipeline and reinjection pipeline. The diameter of the two-phase flow line pipeline will be designed by considering the corrosion and erosion by fluid. For the power generating facility, there are turbine inlet, steam turbine, condenser, gas extraction system cooling water pipe and cooling tower to be installed (Boedihardi, 1991; JBIC, 2006; PwC, 2013).

4.2 Dieng Unit 1 risks

Based on the operation of Unit 1, five major issues associated with power enhancement have been identified by Meliala et al., (2015). There are production well blockages, silica deposition problem on 2- phase facility and brine reinjection system, options to increase Unit 1 steam supply to full load, assessment of Steam Field Surface Facilities and constraints on monitoring program.

In 2018, a risk assessment was carried out by identifying and analyzing the risks by the different Divisions within GeoDipa Dieng. The identification process is carried out by observing how the identified risks affect the achievement of targets in 2018. During the operation of Dieng Unit 1, GeoDipa has encountered problems in the steam field operation. From the results of Unit 1's risk identification, it can be seen that the highest ranked risk is found in the technical risk section which will be a consideration for the construction of Unit 2. One of the risks which will be the concern is the formation of scaling. Less optimal brine management system causes scaling in production wells, turbine and FCRS.

4.3 Assessment of the Dieng Unit 2 project risks

There are significant challenges to address prior to next stage of development. Before carrying out a project, it is necessary to identify risks that could impact project activities. Risk identification can be used as an early warning system of the project when it likely will deviate from the plan. The category of risks that should be identified are including resource (Table 1), engineering and technology (Table 2), permit and planning (Table 3), market and financial (Table 4), health and safety (Table 5), and environment (Table 6).

TABLE 1: Resource risks for Unit 2 project

No.	Risk event	Risk level			Actions / Risk mitigation
		Feasibility study	Exploitation	Utilization	
R1	Collapse in formation while drilling		High		Detailed studies on geoscientific data, well targeting and well design
R3	Dry wells		High		Detailed studies on geoscientific data
R3	Inadequate steam supply due to scaling and corrosion (production wells, turbine and FCRS)			Extremely High	Comprehensice monitoring program for stream and water quality
					Corrosion inhabitation in steam
					Improved brine management (e.g. hot water injection, modify pH, inhibitors, retention tank, etc.)

TABLE 2: Engineering and technology risks for Unit 2 project

No.	Risk event	Risk level			Actions / Risk mitigation
		Feasibility study	Exploitation	Utilization	
T1	Changes in construction design		High		Select an experienced design consultant who has a good reputation and track record
					Coordination with related parties
T2	Delay in building a powerhouse		High		Monitor and impose strict deadline
					Ensure all materials arrive at the appointed time
					Follow the procurement standard (e.g. FIDIC)
T3	Delay in the engineering and procurement work		High		Coordination with contractors
					Perform progress engineering meetings
					Technical training for the employees
					Follow the procurement standard (e.g. FIDIC)
T4	Equipment does not meet technical specification		High		Strict requirements for equipment manufacturers or providers
T5	The contractor fails to execute the job as required		High		Conduct periodic monitoring and review

TABLE 3: Permit and planning risks for Unit 2 project

No.	Risk event	Risk level			Actions / Risk mitigation
		Feasibility study	Exploitation	Utilization	
P1	Delay in the implementation of the development stage	High	High	High	Create and implement schedules
					Ensure selection of experienced contractors
					Coordination between work functions
P2	Contract dispute	Medium	Medium	Medium	Maintain good communication and coordination with the consortium

TABLE 4: Market and financial risks for Unit 2 project

No.	Risk event	Risk level			Actions / Risk mitigation
		Feasibility study	Exploitation	Utilization	
M1	Project cost overrun	High	High	High	Proper research and development before the project starts
					Keep the project on track and ensure that tasks are executed as intended
M2	Increase in price of equipment, operation and maintenance services	Medium	Medium	Medium	Enter into contract with original equipment manufacturers and service providers for fixed prices for a certain duration of time

TABLE 5: Health and safety risks for Unit 2 project

No.	Risk event	Risk level			Actions / Risk mitigation
		Feasibility study	Exploitation	Utilization	
H1	Work accident	High	High	High	Compliance of activities to procedures, regulations, and HSE work practice
					Sensitization and education on the possibility of hazards during work

TABLE 6: Environmental risks for Unit 2 project

No.	Risk event	Risk level			Actions / Risk mitigation
		Feasibility study	Exploitation	Utilization	
E1	Protests and uprising - Communities and activists are very sensitive to the negative issues of geothermal activity.	Extremely High	Extremely High	Extremely High	Provide information and knowledge (socialization) regarding geothermal benefits
					Implementation of Focus Group Discussion (FGD) that involves all stakeholders particularly the affected villages
E2	Noise causing complaints		Extremely High	Extremely High	Design focus on noise reduction
					Inform local community about activities that will have high noise, e.g. well testing
					Minimize the speed of construction traffic
E3	Surface disturbance during civil works and mobilization		Medium		Conduct monitoring programs for runoff and drainage, soil stability and landslide
E4	Ground subsidence, causing damages to buildings, roads etc.			High	Conduct studies on ground measurement
					Monitor ground elevation

No.	Risk event	Risk level			Actions / Risk mitigation
		Feasibility study	Exploitation	Utilization	
E5	Increased seismic activity		High	High	Design work procedures to minimize risk of injection related seismic event, slow start and slow stop of injection
E6	Ground water pollution		Extremely High	Extremely High	Work procedures to minimize brine, condensed water and drilling water released to the environment
					Monitor if injection boreholes plugging up
					Provide spare of injection wells
E7	Oil pollution from contractors		High		Provide double-skinned oil tank
					Monitor the pipelines
					Consider using electricity for drilling
					Installation of oil trap in sensitive area, e.g. drill pad
E8	Exposure to toxic gases	High	High	High	Monitor toxic gases at potential points around the site.
					Installation of gas sensor and detector
					Use appropriate PPE
E9	Wayleave access for transmission line is canceled by the landowner		High		Ensure the land acquistion is done

From the data in Tables 1 - 6, there are 22 risk events highlighted for Unit 2 project (Figure 4). Six risk events are classified as extreme high risk. These risk events are related to resource and environmental risk and need special attention for the project. Thirteen risk events are classified as high risk and three risk events as medium risk.

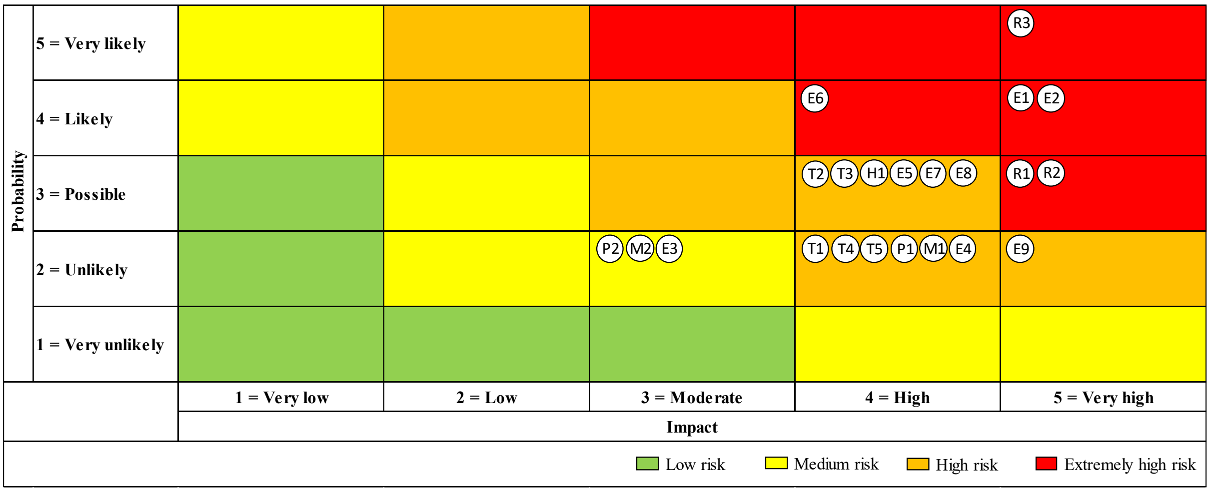


FIGURE 4: Risk profile of the Unit 2 project based on probability and impact assessment; R=Resource, T=Engineering and technology, P=Permit and planning, M=Market and financial, H=Health and safety, E=Environmental

4.5 Risk mitigation

In the development, GeoDipa needs to address any technical risks, especially the scale and corrosion problems in order to achieve efficient plant operation. Therefore, GeoDipa should overcome the problems in Dieng Geothermal Field and consider the technology selection in future development of Unit 2. To achieve optimal capacity in production, it is necessary to create a data base compilation with all these information:

- Data from drilling activities consist of depth, drilling history, analysis of cuttings, casings characteristics, logs performed, etc. Summary of production wells productivity (declining history) is useful to evaluate influence of scaling on steam production.
- Data from well testing consist of compilation of physical data (P, T, flow rate etc.) and execution of complete chemical analysis of at list one sample of produced fluids.
- Data from workover operations consist of casing situations (scaling samples recovered during work over as cuttings should be localized by depth and analyzed for chemical and mineralogical composition), casing surveys (caliper logs, cement bond logs, video logs, PT logs) to identify a depth of blockage, flash point, failure portions of casing, etc.

In general, routine monitoring, sampling and analysis of the fluid properties in every production and reinjection well, in the surface facilities (two-phase fluid pipelines, separators, chemical injection equipment, brine reinjection pipeline, power plant drain reinjection pipeline and the emergency pond) is useful to optimize all future activities to prevent scaling. Considering high concentration of SiO_2 and Cl in brine, it is required to have more efficient separators for the future power plants. It is also essential to monitor the WHP and flow rate of both steam and liquid brine from the well head to the separator to verify if scaling is occurring. Chemical analysis of brine and gases discharged from production well and chemical analysis of scale deposition to identify the chemical species and components can be conducted. If the chemical composition is changing then a new sample and complete analysis must be done (PwC, 2013).

For future Unit 2 operation, Geo Dipa should increase the productivity of production wells and separation efficiency of the separator. Sulfide scaling in production wells can be reduced by injection of water, chemical oxidizing agents and inhibitors. Some inhibitors are developed and proven to inhibit sulfide formation. However, in some cases other problem such as corrosion could happen after applying the inhibitor (Ármannsson and Hardardóttir, 2010). Some others methods that can be considered to mitigate silica are pH modification and retention tank.

Silica scaling may occur due to continuous pressure drop caused by the separator orifice. The silica deposition process can be controlled by controlling the pressure of the production separator. This is done in order to achieve conditions where SSI is smaller than 1 so that silica is still in the liquid phase (dissolved state), so that the fluid can be immediately reinjected to the subsurface. After passing through the production separator, SSI tends to increase in super saturated conditions where in this condition the potential for silica deposition will be even greater. To achieve these conditions, production and reinjection wells needs to be located at the same pad. Another way is to flow the separated brine to the atmospheric separator to separate the fluid phase again in atmospheric conditions, then the remaining phase is passed to the pond and left for about 4-5 hours so the silica will be deposited in the pond. After that, the brine can be re-injected into the reinjection well (PwC, 2013; Suwana, 2004).

5. CONCLUSION AND RECOMMENDATIONS

Geo Dipa is currently updating the feasibility study for Dieng Unit 2 project. Prior to taking a decision on Unit 2, Geo Dipa has to classify, identify and mitigate the key project risks. The key project risks are related to resource, technology, permit, 6 risks are classified as extremely high risks, most of them are related to silica scaling issue and environmental impact. Based on the risk assessment, the project should focus on the following key risks and mitigation:

Key risks	Mitigation
Collapse in formation while drilling	• Detailed studies on geoscientific data, well targeting and well design
Dry wells	• Detailed studies on geoscientific data
Inadequate steam supply due to scaling and corrosion (production wells, turbine and FCRS)	• Comprehensive monitoring program for stream and water quality • Corrosion inhabitation in steam • Improved brine management (e.g. hot water injection, modify pH, inhibitors, retention tank, etc.)
Protests and uprising - Communities and activists are very sensitive to the negative issues of geothermal activity.	• Provide information and knowledge (socialization) regarding geothermal benefits • Implement Focus Group Discussion (FGD) involving stakeholders incl. affected villages.
Noise causing complaints	• Design focus on noise reduction • Inform local community about activities that will have high noise, e.g. well testing • Minimize the speed of construction traffic
Ground water pollution	• Work procedures to minimize brine, condensed water and drilling water released to environment • Monitor if injection boreholes plugging up • Provide spare of injection wells

Development for Unit 2 is expected to have a lower risk based on the experience in operating 20 years Unit 1. In spite of this long experience, a more detailed identification of the risks related with silica scaling, corrosion and environmental issues are vital before taking a decision on Unit 2.

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