Results of Risk Assessment to Support the Development of Risk Mitigation Schemes in Europe and Beyond, the GeoRISK project

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ABSTRACT

The risk register compiled by the GeoRISK project – available also at https://www.georisk-project.eu/georisk-tool/ – aimed to provide a full list of potential risks that could occur during the development of deep geothermal projects. Altogether 52 individual risks were identified, and categorized according to their main nature, the project phase they belong to, and a short description was also provided.

Based on the register a risk assessment using a risk index was performed for reservoirs representing various geothermal plays in France, Germany, Greece, Hungary, Poland, Turkey and Switzerland showing (1) Managerial and Socio-Economical Risks, (2) Geological and Operational Risks, and (3) Drilling Risks in a comparable graphical format.

1. Introduction

Geothermal project development has several risky components; the most important is the resource risk, which may threaten the bankability of a geothermal project during various phases of project development. The short-term risk of not finding an economically sustainable geothermal resource (temperature and flow rate below expectations) occurs in the exploration phase, whilst the long-term risk of the geothermal resource being depleted makes its exploitation economically unprofitable.

To cover the risk of the first drilling (test) is key to accelerate the development of large-scale deep geothermal both for electricity production and heating and cooling. Addressing this challenge, the H2020 funded GEORISK project aims at establishing geothermal risk mitigation schemes all over Europe and in some key target third countries, including Kenya,
Chile and Canada. The GEORISK project focuses on key countries in Europe with different deep geothermal potential and markets:

- Mature market: Turkey, France and Germany
- Juvenile market and market in transition: Greece, Switzerland, Poland, Hungary

These countries have been selected because they have a potential for deep geothermal and projects are already operating or under development. They also present different and complementary geological settings, and some of them already have experience on risk insurance schemes.

This paper presents the concepts and the content of a detailed risk register that was compiled by the GeoRISK project, and the results of the related risk assessment.

2. Establishing the risk register

2.1 Methods

First an extensive list of risks was established based on previous European projects or reports dealing with risks and geothermal energy: the GEOELEC project (Fraser et al. 2013); the DARLINGe project (Nádor et al. 2018); the GEOWELL project (Lohne et al. 2016) and Gombert et al (2017). This was complemented by a broad review of literature survey comprising more than 70 documents, summarized in Le Guénan et al (2019). This resulted an initial list of appr. 200 individual risks, which were merged into a final list of 52 individual items.

2.2 Structure of the risk register

For each risk, identified by an individual numerical code, the register contains (a) the phase the risk belongs to, (b) short description, (c) the type of consequences, (d) possible or existing technical or financial mitigation tools, as well as (e) a comment field for more details. These fields are discussed briefly below. In addition, the risks were grouped in six different categories, such as (1) External hazards (natural or anthropogenic), (2) Risks due to uncertainties in the external context, (3) Risks due to internal deficiencies, (4) Risks due to subsurface uncertainties, (5) Technical issues, (6) Environmental risks.

2.2.1 Phases

Four project phases were identified, in which each risk occurs (in one, or several project phases:

- Identification / exploration
- Drilling / testing
- Exploitation/ development
- Post-closure

These phases do not describe only the activity performed, but also represent the progress of the project. The first phase (identification and exploration) consider all the risks that may happen before the main drilling activity has started. The second phase (drilling, testing and development) includes all risks that may happen during the main period of exploration. The
third phase represents exploitation, while the forth, post-closure phase includes all risks that may happen after the exploitation is completed and includes the decommissioning and abandonment of the wells.

2.2.2 Description

Each risk is characterized by a concise description. A comment field is also included in the register in order to be able to include more details regarding each risk.

2.2.3 Consequences

It does not correspond to the detailed consequences of an event, but to the type of consequences in 2 main categories:

- Economic / performance
- Health, Safety, Environment (HSE)

Hence, for each risk, the field only indicates if the consequence is more of economic nature / related to the performance, or if it is more an impact on health, safety and environment. Note that most HSE risks have also an economic impact. Therefore, for many risks, both consequences are indicated.

2.2.4 Mitigation measures

The goal of this field is to specify for each risk the possible mitigation measures that can lower the risk, which can be technical and financial. In the simpler version of the register, only the possibility of financial mitigation measures appears for each risk, whereas in the detailed view, a list of potential technical mitigation measures is also apparent.

2.3 Content of the risk register

The list is presented by categories. The difficulty in building the list was to find the correct level of details: if it is too detailed, the list becomes impractical; if it contains too little details, some important aspects may be missing. A guideline for deciding the correct level of details was to look at the mitigation measures. Risks which share similar mitigation solutions could be grouped together, while risks requiring different solutions should appear separately in the register.

It was also crucial to avoid gaps rather than to have some overlaps. Indeed, some risks were voluntarily worded in a broad manner in order to encompass a large variety of situations, and some more specific risk in the list can thus be a particular case of a broader risk. It can also happen that several risks belong to the same risk scenario.

2.3.1 Risks associated with external hazards

The risks in this category are external to the organization and are mostly of physical nature (i.e. they can damage the plant):

- External natural hazards damaging the infrastructure
- Anthropogenic hazard damaging the infrastructure
2.3.2 Risks due to uncertainties in the external context

The risks of this category are also external to the organization, but are more related to the non-physical environment: e.g. laws, regulation, policies, economic context:

- Changes in policies, laws, taxes and regulations put development/economy in jeopardy
- Lack of financing for the next phases
- Low social acceptance puts barrier to development
- Public opposition against nuisances from the exploitation
- Unanticipated delays and costs in operations (materials, services, maintenance)
- Lack or loss of clients
- Significant changes of energy costs

Note that the “public opposition” risk is slightly different from the “low social acceptance” one. In the former case, it highlights the situation where the initial acceptance was not necessarily low, but degraded due to some perceived nuisances (noises, odour, etc.).

2.3.3 Risks due to internal deficiencies

In this category risks are mainly directly related to the responsible organisation, and most of them can be avoided by adopting best practices:

- Low financing for work leading to low safety standards
- Suboptimal design of well leads to reduced flow rate
- Best practices not applied leading to incidents or decreased performance
- Unsuitable contracts (roles and responsibility not clearly defined) leading to suboptimal performance or exploding costs
- Human error leading to failure during drilling / work
- Wrong choice of stimulation fluids or techniques damaging the reservoir/well
- Organization is not experienced / financially robust enough for the challenge
- Demand analysis and forecast are inaccurate

2.3.4 Risks due to subsurface uncertainties

These risks are also called sometimes “geological risks”. There are two different main types: (1) short-term risks related to suboptimal in situ geological conditions prior to drilling, and (2) long-term risks related to reservoir degradation over time.

- Flow rate lower than expected (reservoir)
- Flow rate degrades over time
- Temperature lower than expected (reservoir)
- Temperature degrades too quickly
2.3.5 Technical issues

In this category, the risks are mainly of technical nature.

- Mud losses leading to severe technical issues
- Not able to lower the casing string
- Trajectory issues (deviation from target)
- Drilling is more complicated/more expensive than anticipated
- Technical failure during drilling
- Rig issues
- Issues in transporting/handling radioactive sources for logging
- Technical failure of the equipment
- Well casing collapse
- Wrong choice of mud density leading to damage to well/reservoir

2.3.6 Environmental risks

This last category overlaps partly with others, as these risks are generally due to internal deficiencies, or technical issues. The main difference is that the risks of this category have a potentially high impact on external elements and not just on the project.
- Blowouts
- Fluid communication between different strategic formations/reservoirs due to bad isolation of the well
- Induced seismicity
- Subsidence or uplift
- Toxic emissions due to gases and fluids produced in-situ
- GHG emissions due to gases produced in-situ
- Lack or loss of integrity of the well/subsurface equipment
- Loss of integrity of surface equipment

2.4 The online risk register tool

The online version of the risk register is available at: https://www.georisk-project.eu/georisk-tool/. Once the user selects one or several categories and one or several phases, the tool displays the corresponding risks.

3. Risk assessment

After identifying the potential risks, i.e. completion of the risk register, the next step was the evaluation of these risks with respect to the current market situation. The fact that throughout the target countries of the GeoRISK project considerable differences exist in geological, political, regulatory and market conditions, it became necessary to include these factors into the risk evaluation process.

The risks were assessed via a Risk Matrix (degree of damage x likelihood) within each target country. The risk matrix includes all the risks presented in the Risk Register and allows an average estimation of the risk influence on the development of geothermal projects. It must be nonetheless noted that the content of the risk matrix is not designed for direct utilization of insurance companies. The goal was to provide an overview of the challenges present in different countries that hinders further exploitation of their geothermal resources. The Risk Matrix is therefore a tool to raise awareness on the most relevant issues and means to properly address them by e.g. relevant risk insurance funds.

In order to develop the risk matrix, national workshops were held in each GeoRISK country, where selected experts, representing drilling companies, research institutions, project developers, insurance companies were asked to fill in a questionnaire, where they had to assess risks (as identified in the risk register) in 3 groups: (1) Socio-Economical, (2) Geology/Operational, and (3) Drilling. The respondents had to fill in the region/country as well as the reservoir type that they refer to. This is due to the fact that a country may have multiple geothermal reservoirs with different geology, depth and temperatures. The project type (i.e. electricity / heat) also had to be specified, as these projects often differ in depth and in complexity of realization and therefore, the risks they face. For each risk the table provided pre-defined answers the respondent had to select, which were the following:

Likelihood of the risk: (1) Not likely to occur, (2) Mild chances of occurrence, (3) Moderate chances of occurrence, (4) High chances of occurrence
Cumulative damage level: (1) < 10.000 €, (2) 10.000 € - 100.000 €, (3) 100.000 € - 1.000.000 €, (4) > 1.000.000 €

The Risk Index (RI) is calculated by the multiplication of damage level and likelihood, here is calculated as a sum. Since the likelihood (0.001; 0.01; 0.1; 1) could be represented as a value “a” and degree of damage (1000; 10000; 100000; 1000000) could be presented as value “b” – both powers of 10 then the multiplication could be presented as following:

\[10^a \times 10^b = 10^{(a+b)}\]

As a result, the risks in the matrix can be represented such as:

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Where values are interpreted as follows:

2-4 – Low level of Risk

5-6 – Medium level of Risk

7-8 – Critical levels of Risk

In addition, the risks were assessed by they relevance in each target country, such as: (A): Extremely relevant / Major issue in local geothermal sector (Show stopper), (B): Highly Relevant/ Considerably impedes the development of the projects, (C): Moderately Relevant/ Delays the development of projects, (D) Low Relevance/There is standardized methods of effective solution.

The application of this method allowed a standardized graphical visualization of risk assessment in the target countries. Some examples are shown on Figs 1-3.
Figure 1: Representation of Managerial and Socio-Economical Risks (France)

Figure 2: Representation of Geological and Operational Risks (Molasse, Germany)
4. Conclusions

The risk register compiled by the GeoRISK project comprises 52 individual risks that could occur during the development of deep geothermal projects. These were shortly described, associated with relevant project phases and grouped as (1) External hazards (natural or anthropogenic), (2) Risks due to uncertainties in the external context, (3) Risks due to internal deficiencies, (4) Risks due to subsurface uncertainties, (5) Technical issues, (6) Environmental risks.

Based on the register, a risk assessment using a risk index, calculated by the multiplication of damage level and likelihood for each risk was performed for reservoirs representing various geothermal plays in France, Germany, Greece, Hungary, Poland, Turkey and Switzerland. The results showed that risks of a power generation project rise by 1-2 values of RI, indicating that power generation projects have higher requirements for resource temperature and flow rate and as such are highly susceptible to minor deviations from the prognosis. Additionally, since higher temperatures are located deeper, there are higher challenges for drilling operations. As the deeper horizons are less explored and have more geological uncertainties, the doublet connectivity issue becomes of high concern. Almost all power generation projects (especially EGS projects) have concerns of induced seismicity, with the possibility of easily triggering negative public attitude, which could not only limit the operation capacity of the plant, but significantly slowing down its development. The other difference from heating projects is that power projects are not client dependent, as they feed the power into the grid. Although this is a direct advantage for the operators, neighboring population does not have any benefit from having the power plant in vicinity, but still have to face possible risks, which increase the level of dissatisfaction.

In case of socio-economic risks, almost all countries have given a high value to the lack of finances and instability of the political-regulatory environment, thereby indicating the crucial importance of these two factors in project development.
The survey also highlighted that project developers are sometimes lacking experience, which leads to sub-optimal design and an increased amount of unexpected expenses and unfavorable environmental impacts.

Geological risks, associated with subsurface uncertainties depend heavily on the geological buildup, therefore always have to be assessed site specifically. One of the frequent risks is the inability to secure the geothermal resource, either by not being able to reach the target formation, or the target formation characteristics deviating from the expected parameters, especially in yield. As data density increases (frequently due to the oil and gas exploration), the accuracy of prognosis is improving, therefore the importance of a proper and thorough exploration has to be underlined.

Surprisingly enough, very often the average level of drilling risks was lower than other risks. The reason behind could be lying in the vast experience gathered by the drilling companies in the oil and gas industry. Among procedural challenges, some of the often-seen risks were damage to the wellbore and reservoir, wellbore instability as well as technical failures. All these risks could be minimized if the geological conditions are well known, which further emphasizes the necessity of geological surveys. The technical failures result partially from unexpected geology, but also partially from a lack of experience of the personnel, or lack of financial resources to ensure high drilling standards.

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