DEEP

Innovation for:
De-Risking Enhanced
Geothermal Energy Projects

Deliverable

Deliverable 5.5:

Applicability of the guideline for risk governance of EGS operations to the Dutch conventional doublet systems.

Additional Dutch Deliverable

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1 Introduction

DEEP: Innovation for De-Risking Enhanced Geothermal Energy Projects, has developed a best practice guideline aimed at minimizing the risk of induced seismicity in Enhanced Geothermal System (EGS) projects. This guideline offers recommendations on evaluating, monitoring, mitigating, and communicating the risks associated with induced seismicity, making it a valuable resource for EGS stakeholders, including operators and regulators (Zhou et al., 2024).

Geothermie Nederland (GNL), branch organisation of all geothermal operators in the Netherlands, was listed as industry partner and was part of the development of the guidelines and tools. Hence, contributing to safety & uniformity in EGS operations.

1.1 Dutch Market: focus on conventional

Along the duration of the DEEP project, focus of Dutch geothermal operators and developers concentrated on conventional geothermal projects ranging from 1 to 3 kilometres in depth. While Ultra Deep Geothermal (UDG), which involves drilling beyond 4 kilometres into the Earth's crust, offers significant potential for the future of renewable energy, it faces several substantial challenges. The high costs associated with drilling to such depths and the difficulty of accurately imaging the deep subsurface are key barriers to its current implementation. Seismic imaging at these depths often results in blurry images, making it challenging to plan drilling operations safely and responsibly.

Given these challenges, the Netherlands is advised to focus on the currently viable forms of geothermal energy. By leveraging existing expertise and technologies in conventional and shallow geothermal projects, the country can make meaningful progress toward a sustainable energy future. This approach not only supports economic growth and innovation within the geothermal sector, but also ensures a balanced and realistic transition to cleaner energy sources. By building on the foundations of conventional geothermal energy, the Netherlands is laying the groundwork for future exploration and the eventual adoption of advanced technologies like UDG when the timing and technology are more favourable. This focus aligns with recommendations from state energy company Energie Beheer Nederland (EBN), which suggest prioritizing feasible and well-understood geothermal options over more complex and ambitious endeavours like Ultra Deep Geothermal (UDG). The reasoning behind this recommendation is explained in an interview with Herman Exalto, business unit director Heat transition at EBN (Exalto, EBN, 2023).

1.2 Additional Deliverable DEEP

In the Netherlands similar modules of the Induced seismicity risk management framework (ISRMF) proposed by DEEP are in place by regulation for conventional geothermal energy. Conventional geothermal energy is considered in the Netherlands as: geothermal heat production from matrix-dominated reservoirs of 500-4000 meter depth. The actual risk and impact associated with conventional geothermal projects compared to that of enhanced and ultra deep geothermal projects is significantly lower or highly unlikely (Trutnevyte and Wiemer, 2017; Wiemer et al., 2017). Research by TNO (Buijze et al., 2019) shows that no perceptible earthquakes had been observed worldwide when using this type of geothermal energy. However, there are a lot of valuable elements in the DEEP study that can be implemented for conventional. As ISRMF's and associated protocols & tools should be evolving in time when new data & knowledge become available, the DEEP study gives new insights and ideas for the geothermal sector to increase safety, public support and secure principles of equality and fairness.

The following chapter will elaborate on multiple elements of the DEEP EGS guideline that currently hold, and may continue to hold in the future, significant value for all geothermal stakeholders in the Netherlands. The focus has been placed on communication, monitoring and financial mitigation.

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2 Application for conventional

2.1 Risk tolerance

Geothermal energy can be safely conducted in the Netherlands, provided that the initiative passes an assessment against certain criteria before starting. This is explicitly the national principle underlying the regulation of geothermal energy extraction. The Mining Act and associated regulations have established a framework to ensure that only safe projects qualify for a permit.

Although it is expected that no perceptible earthquakes will occur, it is still important to proceed carefully and to make it clear that geothermal energy extraction in the Netherlands does not involve unacceptable risks. Therefore, a safety standard has been established, and several safeguards are in place to ensure that only safe projects are undertaken.

As stated in the guideline and national annex, a local personal risk threshold is mandated by law for geothermal energy projects (and other mining activities) in the Netherlands (Zhou et al., 2024; Muntendam-Bos & Zhou, 2024).

2.2 Induced Seismicity Risk Management Framework

The ISRMF suggests in § 2.3.2 to set learning targets before each project phase (exploration; planning; drilling; stimulation; circulation; post operation) and these should be reported to the regulator and the public by the end of each phase. A recent paper of Terrier et al. (2022) is cited for these learning strategies. Examples are given for two phases:

Before the exploration phase:
1) Are the population and infrastructure vulnerable to induced earthquakes?
2) Is the site geologically susceptible to induced earthquakes?

Before the drilling phase:
1) What data needs to be collected during drilling?
2) At what depth is it likely to encounter faults and fractures?

Individual operators have their own learning workflow, yet it would be valuable to share their gained knowledge to the public after each phase for transparency. Through careful translation that ensures it is understandable for the public and avoids creating unnecessary concerns.

In addition setting learning targets collectively among and for all operators and implement and improve these after each phase/project would increase the learning curve even more. In particular in the densely populated and built-up Netherlands, where geothermal licenses are bordering each other. Local new information about the geology should be shared among others to increase safety but also to reduce other exploration risks and to prevent disinvestments. Publishing a consistent and well-tested explanation of these learning targets would greatly enhance understanding, especially for those who may not be very familiar with the topic. These targets could for example be shared before and after each phase, for example on the project and/or operator website. Sharing data and insights among operators and regulators would require another platform, such as a common database.

2.3 Communication and outreach

2.3.1 Communicating earthquake risk

According to § 7.2 of the guideline, recent research of Dallo et al. (2022) suggests that the most effective way to communicate earthquake risk is by using a combination of numerical and verbal descriptions of probability. Verbal descriptions alone should be avoided, as they can be interpreted in various ways. Since it can take experts some time to determine whether an earthquake is natural or induced, it is crucial for operators to promptly communicate that the nature of the event is under investigation, even if they have not yet determined whether it is related to geothermal activities.

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It would be valuable to determine the most effective combination of numerical and verbal descriptions. The experience in the Netherlands with public perception, is that numerical descriptions can also be difficult to understand and can be subject to misinterpretation. As mathematics, physics, and statistics are often more challenging for most people to grasp a clear visualization often helps. A follow up would be to investigate the best combination of descriptions and could be added to the ongoing study: Social support framework for geothermal energy near inhabited areas (Warming^{UP}GOO) (2024)).

Also, the direct communication of any felt earthquake by the operator is desirable. This should be noted in the communication plan submitted for a license to operate. A standard communication plan, with the possibility to add extra elements, among all operators in the Netherlands would be unambiguous and efficient. Paragraph 2.3.6 will elaborate on this standard communication plan.

2.3.2 Local champions

The guideline describes in § 7.1 that local politicians are key stakeholders due to the high level of trust they often receive from the affected population. Local politicians play a crucial role in bridging the gap between the public and other stakeholders, providing valuable insights on how best to communicate with the community. Politicians at the state and national levels are also important, as they can support project developers in meeting broader environmental objectives set by their governments. However, relying solely on political support is insufficient; the legitimacy of any project ultimately depends on gaining public approval. Chavot et al. (2019) state that identifying “local champions” who can advocate for the project is essential, as their involvement can significantly shape public perception.

While geothermal projects for horticulture in the Netherlands have faced minimal resistance from local residents, project developers are concerned that urban areas, which often have lower levels of local social cohesion, might experience more significant opposition. Numerous energy and CO_2-reduction techniques & projects in the Netherlands pulled the plug due to public and political resistance. In recent years, it has become evident among project developers in the Netherlands that engaging local (non-)political champions, heroes, or ambassadors is crucial for boosting public support. Recently an initiative among distinctive geothermal developers has started to implement these local champions on a more regional scale. The main objective is to transparently share experiences and implement best practices, with emphasis on stakeholder communication and legislation, among civil servants and local/regional politicians across municipalities and provinces.

2.3.3 Comparison geothermal relative to other energy’s

The guideline in § 7.1 emphasizes the importance of presenting the benefits and risks of deep geothermal projects in relation to their overall contribution to energy production, specifically in comparison to other energy sources. Doing so helps reduce the risk of the public perceiving the information as biased.

Governments and project developers should carefully weigh the different alternatives for heat supply and energy sources for each specific use case. It's essential to consider all aspects of the alternative energy options over the course of the project, including feasibility, public and individual financial pros and cons, sustainability, applicability, environmental risks and benefits, health risks, impact on the built environment, possibilities for expansion, and future prospects. Careful considerations about alternatives are also important in the communication towards the public. This has not been sufficiently implemented in the Netherlands so far, and it remains a topic requiring attention.

2.3.4 Monitoring public perceptions & adapting the communication strategy

The guideline in § 3.1.5 advises using surveys to gather quantitative data on public attitudes and concerns. For deeper insights into how the local population perceives the project, face-to-face meetings, focus groups, or interviews are recommended. These surveys and meetings should be conducted repeatedly as the project advances to track changes in public opinion over time.

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According to i.e. the World Health Organization (WHO) there are generally considered to be three main objectives of risk communication:

- To offer information that helps people make well-informed decisions.
- To alleviate fear and anxiety regarding potential hazards.
- To foster trust between the organization/project and the public.

To effectively communicate about seismicity and other risks involved with geothermal projects you need to have an idea of the prior knowledge and attitude of the public. Different goals, audiences, concerns and fears require tailored communication strategies. The first step is to critically listen before providing information.

To monitor public perception and gather quantitative data on public attitudes, conducting online surveys at various stages of each geothermal project would be beneficial. These surveys should be geographically targeted, focusing on regions near the geothermal projects. Cousse et al. (2021) provides an example for such a survey.

Survey results can guide communication strategies and help adapt approaches to effectively engage the public. As a sector organization, GNL maintains contact with all stakeholders in geothermal energy in the Netherlands and is well-positioned to collaborate with operators to exchange best practices for public communication.

The Warming^{up}Goo project is in the progress of testing how surveys and various survey strategies affect public perception of geothermal energy. It would be valuable to monitor public perception in various stages of running projects in future Warming^{up}GOO studies.

2.3.5 Familiarity technique

§ 7.2 of the guideline highlights the importance of recognizing that technologies are perceived as riskier when their consequences are more "unknown" (i.e., unobservable or delayed effects) and when they evoke a sense of "dread" (potentially catastrophic and uncontrollable negative outcomes) (Slovic 1987; Bassarak et al. 2017). In light of this, increasing public familiarity with underground environments and drilling activities is crucial. Law et al. (2021) suggests organizing events where the public can explore the underground through videos or virtual reality, as well as offering interactive or live information sessions, or incorporating geothermal energy lessons into educational curricula.

Research shows that people have not developed clear preferences for deep geothermal energy because it remains a relatively unfamiliar technology (Blumer et al., 2018). Dubois et al. (2019) and Volken et al. (2018) found that when people are informed about the potential impacts of deep geothermal energy, as opposed to the case of solar or wind, their preference for it drops significantly. Knoblauch et al. (2019) found that the use of familiar technologies has a positive influence on the perception of geothermal energy, in general.

Since geothermal energy remains a relatively unfamiliar source of heat in the Netherlands, highlighting its benefits and the lower risks compared to the well-known risks associated with oil and gas production, along with sharing success stories from existing projects and emphasizing familiar technologies like heat pumps, should help improve public perception of conventional geothermal projects.

Local public that is directly affected, for example by geothermal district heating or exploration and drilling activities nearby, can be more directly involved through events aimed at positively informing the parties involved and improving their familiarity with the processes in the subsurface. For example, by providing interactive/live information tailored to the specific context and audience, modern technologies like virtual reality (VR) and 3D videos can be of great value here to provide a sense of scale of a geothermal project.

Positive media coverage about repeated success stories in conventional geothermal projects, proven sustainability and the expansion of the geothermal network, will familiarize the public and should increase national public acceptance for possible future UDG and EGS applications.

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2.3.6 Calling tree / communication plan

Paragraph 7.2 of the guideline recommends establishing a 'calling tree' to ensure that project management is promptly notified in the event of seismic activity. The institution responsible for seismic monitoring in the region or country should immediately inform the relevant stakeholders about any seismic events. Additionally, the details of this 'calling tree' should be made accessible to the public (Pankow et al., 2023).

A Seismic Risk Management Plan (SRB) includes two main components: a Traffic Light System (TLS), which provides guidelines on how to act in case of ground motions, and a communication plan specifying who should be informed. A standardized TLS for conventional matrix-dominated geothermal projects has been published by the government. However, a standardized communication plan for the geothermal industry in the Netherlands has not yet been established. Creating a consistent communication plan, with the flexibility to include additional elements, across all operators in the country would ensure clarity and efficiency. Such a plan would simplify the process of contacting the relevant authorities in case of an event and helps ensure clear communication of risks and the current situation to the public. The first steps towards a standardized communication plan in the Netherlands are already being discussed.

2.4 Technical seismic risk mitigation measures

The guideline advises in § 7.2 to work with the authoritative earthquake agency to densify the national/regional seismic network as soon as possible. This involves increasing network density to detect smaller events, establishing baseline measurements, and providing independent assessments of potential induced seismicity. Additionally, Chapter 6 specifies that all seismic monitoring data should be shared according to open and FAIR (Findability, Accessibility, Interoperability, and Reuse) data practices. Data sharing may occur after a brief (optional) embargo period. The guideline also provides a clear overview in table format of the Mc threshold and location precision/accuracy targets, along with their corresponding network parameters for both rural and urban contexts in a general field-scale EGS project.

It is important to note that there is limited data available on seismic activity caused by geothermal energy, which necessitates the use of a model with various assumptions. In the coming years, it will be determined whether there is a need to adjust. It could be the case that over time the SRB and TLS are going to be adjusted as well based on new knowledge gathered from more extensive and long-term experience, along with more and better monitoring data.

From the SRB it is also required that ground motion is continually monitored to ensure they fall within the project's expected parameters. This is assessed based on the initial thorough risk analysis conducted by the project initiator. If more or larger ground motions occur than anticipated during the permit application, this could be a reason for the government to review the permit.

The seismic monitoring agency in the Netherlands, the KNMI (Royal Netherlands Meteorological Institute), operates a seismic monitoring network that tracks and reports seismic activity. The density of this network is concentrated in active mining areas to detect smaller magnitude seismic events. Nationwide, the network can measure any seismic activity with a magnitude greater than 2.0. In regions with known seismic activity, this threshold is lowered to 1.5. In specific mining areas, the threshold is 1.0, while in the Groningen region, seismic events with magnitudes as low as 0.5 are recorded (KNMI, Seismische-meetstations).

However, not all regions suitable for geothermal energy are covered by this more accurate network. According to the TLS, all seismic activity with a magnitude greater than 1.0 must be reported. The national network should densify as soon as possible to be able to detect the smaller magnitude seismic events. However, since expanding the national or regional seismic network takes time, project-specific local seismic monitoring networks might be developed in collaboration with the authoritative earthquake agency. This ensures accuracy, compatibility, and full integration into the national network. By doing so, the seismicity data will be independent, cost-efficient, and reliable.

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2.5 Financial seismic risk mitigation measures

Paragraph 2.1 of the guideline outlines the financial measures for mitigating seismic risk that a project should implement. Key recommendations include developing a damage compensation scheme, obtaining earthquake insurance to cover damages caused by induced seismicity, or contributing to a public guarantee fund (if such a fund is available).

Although as previously mentioned the actual risks associated with conventional geothermal energy in the Netherlands are minimal and sufficient safety measures are in place, it is vital to have a financial compensation plan for handling and following up on damage claims. Even when it is unlikely such a fund will ever be used. Although it is possible to obtain liability insurance for geothermal projects, which generally covers damage from earthquakes, there are several obstacles that hinder sufficient coverage throughout the lifespan of the doublet. One of the obstacles is that the available insurance policies in the Netherlands are only valid for one year. This means that if the risk perception of geothermal energy changes for any reason, the insurance premiums could increase significantly upon renewal.

At present, no such long-term guarantee exists, but geothermal companies in the Netherlands are investigating the possibilities that a collective damage fund, provided it meets the necessary requirements, can fulfil this need. A collective approach also offers the clear advantage of ensuring payments throughout the entire lifespan of geothermal projects, even in cases where the party responsible for any potential damage is unclear. Additionally, the fund can seamlessly align with the procedures of the Commissie Mijnbouwschade (Mining Damage Commission), an existing independent body that also applies to hydrocarbons & salt extraction. Geothermal projects would collectively contribute to this fund, and to further strengthen confidence, the government should act as a guarantor if the fund is not (yet) sufficiently filled. Without additional government backing, such an industry initiative cannot ultimately take off. A financial risk mitigation measure like a fund provides additional security and assurance for the public and the companies involved.

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