Harmonising the management of potential adverse effects from seismicity in deep geothermal projects

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Modification of natural seismic activity during a deep geothermal project's initial development and operation can be a concern for regulatory authorities and communities. The evidence of geothermal plants in operation indicates that this is, however, generally not an issue. Indeed, most of the geothermal plants in Europe, and after many years (amounting to decades for Italian, Icelandic, and French-Paris Basin plants) of operation, did not create problems related to seismicity. Nevertheless, there have been a few exceptions. As these isolated incidents could generate public misconceptions, it is essential to ensure robust response mechanisms.

Besides rules establishing general protection of territories and infrastructures, liability, and contingency plans, seismic adverse effect is mitigated mainly by applying best practices and guidelines.

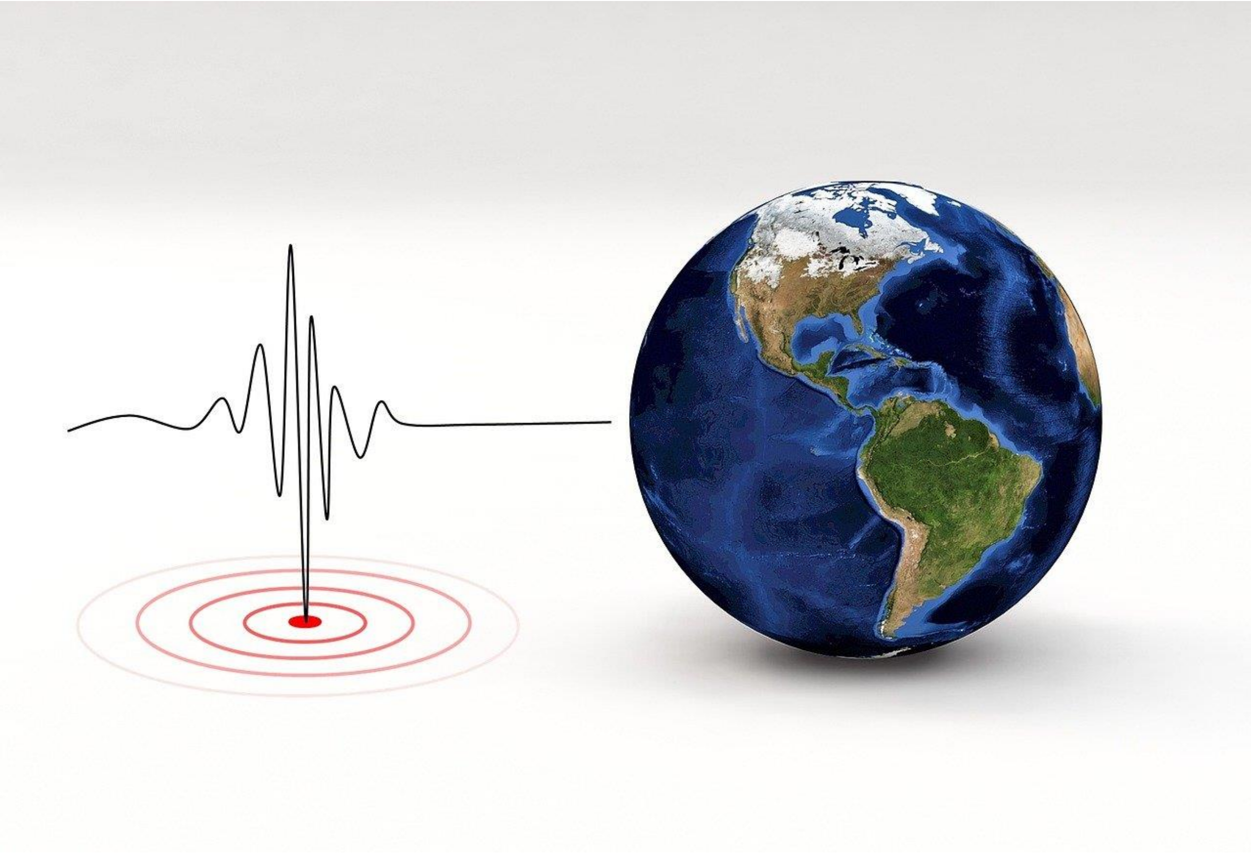

Fig. 1 synthetises the situation in the countries mapped in the GEOENVI analysis, which includes some of the participating countries to the GEOENVI consortium, Switzerland, and Palatinate region in Germany, in view of the seismicity concern of some projects in these areas. More details can be found in the GEOENVI report D4.2 "Compilation of Recommendations on environmental regulations"[1].

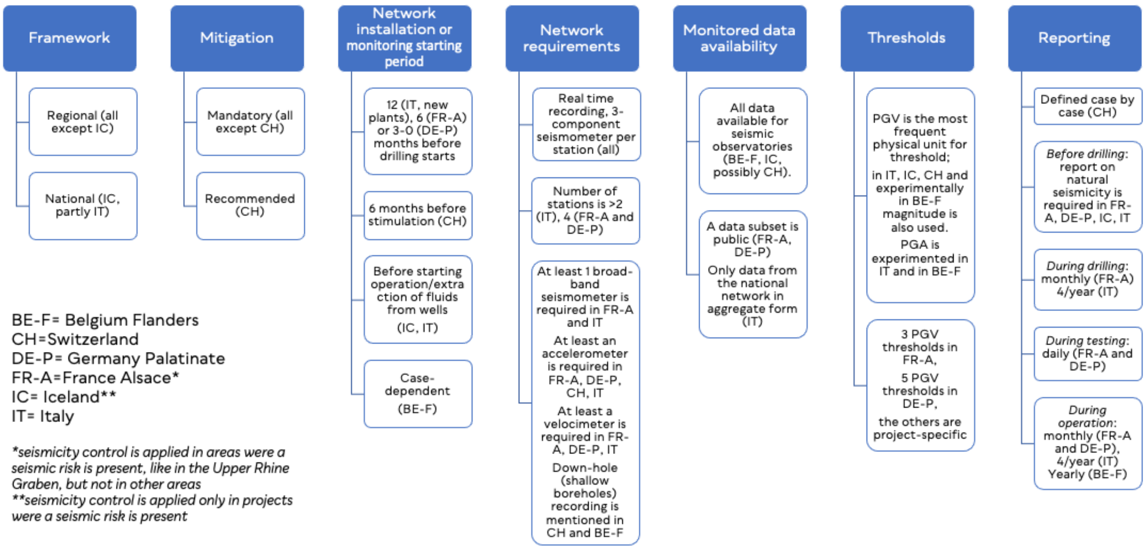

Figure 1 Diagram showing in synthesis how regulations and solutions for safety issues are established at the national level in the GEOENVI participating countries to mitigate the potential modification of natural seismic activity.

The collected data analysis showed that real-time data monitoring is required in all the countries mapped in the analysis except Iceland, where it is required only on selected cases, depending on circumstances. Monitoring practices show, however, some differences:

- The time of installation of the monitoring network is variable: 12 months (Italy new plants), 6 months (France -Alsace) or 3 months (Germany-Palatinate) before drilling starts; 6 months before stimulation in Switzerland; before operation in Iceland and Italy;
- The minimum number of stations and details are variable;
- The number (3 in France- Alsace, 5 in Germany-Palatinate, project- or region-specific in others) and threshold values vary;
- Data availability varies among countries, as does the frequency of reporting to the authorities.

[1] https://www.geoenvi.eu/wp-content/uploads/2021/04/D4.2-Recommendations-on-environmental-regulations-GEOENVI_300421.pdf

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Recommendations

1. Providing a comprehensive description of the status of seismicity in the developed geothermal areas

Creating a list of all geothermal plants, the duration of their operation, and an history of noted seismic events in the area will help to clarify the level of the effects. The operational parameters increasing the seismicity and ways to handle it in geothermal should be described. Such a document will provide correct information and great transparency for the public and administrations.

2. Establishing a European code of best practices for seismicity monitoring and control

Our recommendation is to establish a European code setting-up a sequence of actions to assess, monitor, and handle the seismicity potentially connected to geothermal projects. The topic is covered in some regions or countries, but not at a European level. A harmonization is hardly possible without an extensive and detailed study of existing practices. It is important to clarify that rule should be flexible and account for different geological and technical conditions. Topics that are site/geological basin specific and those relevant at the European level should be distinguished. Otherwise, there is the probability of jeopardising the geothermal projects where the seismic adverse effect is minimal, as is the case in most plants.

The process to establish this Code must be transparent and participatory, including mining authorities, experts in seismicity and civil engineering, experts in geothermal, oil &gas, mining industry, and civil society. A preliminary list of actions the Code should consider is included in the Box.

3. Harmonising guidelines and application of the European code to all reference sectors

Since seismicity relates to different sectors associated with the subsurface activities (e.g., geothermal, oil & gas, waste disposal, mining), it is necessary to have a consistent set of rules among industries.

4. Ensuring access to data on seismicity

Transparency of monitoring and operational data of reference, with diversified level of access for administrative, scientific and public recipients, is crucial for this topic.

Main recommended actions the code should consider

- Describe good practices for fluid production, injection or reinjection to be adopted (flow rate, reservoir overpressure, reservoir temperature and geology, location, etc.);
- Prescribe seismic hazard analysis, based on available data;
- Define thresholds to identify the level of hazard and risk and a) exclude projects of low hazard from further actions, b) establish further actions based on the levels of hazard or risk.

Further actions to be considered in case of hazard:

- Define contingency plans, respecting local liability regulation;
- Conduct and regularly update predictive modelling with available data (e.g., slip and dilation tendency if regional stress regime is known, orientation of faults by seismic reflection data in some geological context);
- Define a seismic velocity model for the project and the layout of a suitable monitoring network, install it, and control that it remains operative;
- Conduct seismic baseline (natural background seismic level before operation) measurements with an installed local network or use data from an existing seismometer network for at least 6 -12 month before drilling or stimulation or operation;

Once wells are available:

- Update the seismic velocity model performing sonic log or Vertical Seismic profile or check shot (standard in shallow oil and gas well, but not in deep wells);
- Update predictive modelling (flow-temperature-mechanical models of the geothermal system) of reservoir and surface installations to define the preferred operating window of the geothermal plant and preferred plant design (such as measures to be taken to avoid stress-shocks (flow, temperature or gas-related), positioning of sensors, and well design;
- Conduct stress-strain analyses on the wells; refine reservoir model, redo the seismic risk analysis if needed; if enough events are recorded, assess the Gutenberg-Richter law associated to local seismicity to assess the presence of structures nearby;
- Set-up a control system, e.g., a traffic light system (TLS) based on (quasi)real-time signal processing, correlation of events with production data and forward modelling. It should be operated solely by skilled and trained staff;
- Adapt preliminary thresholds for further actions. Depending on the hazard analysis, the control system may either be required for the entire lifetime of the geothermal system or limited to certain project phases;
- Evaluate the seismic activity at given points in time (e.g., after an event flagging a threshold’s pass; after 12 months of operation; during shutdown for workovers/maintenance) and adapt the monitoring/control if needed. During all operation phases, update the Gutenberg-Richter law associated with the local seismicity.

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This document is part of a series conducted in the framework of the GEOENVI project. Its aim is to respond to the need for harmonisation of environmental regulations and to address concerns about potential environmental effects of geothermal projects in Europe.

GEOENVI strives to facilitate the incorporation of geothermal energy in Europe's energy transition, while respecting sustainability and creating a robust strategy to answer environmental concerns. The project developed a unique Life Cycle Assessment methodology for evaluating geothermal projects.