

○ **Toward a European Code to assess, monitor, and handle the seismic risks**

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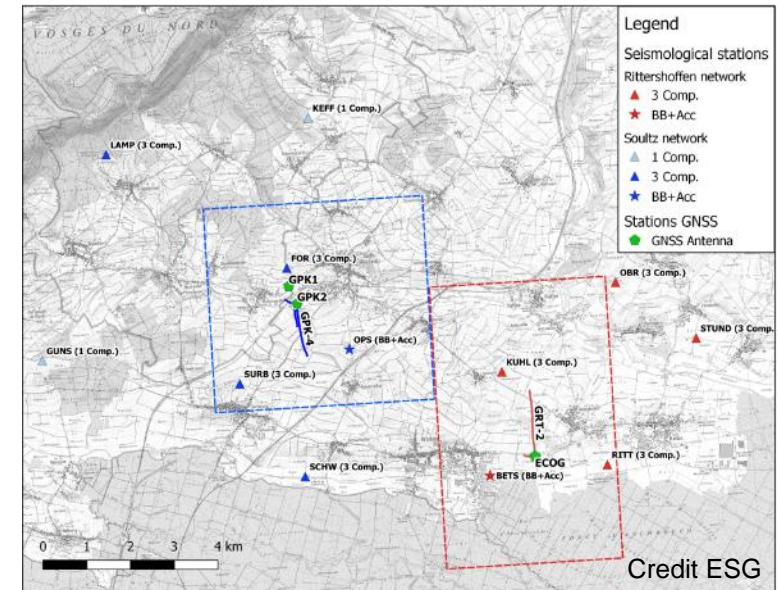
○ Regulation Framework

- No national regulation for induced seismicity
- Current regulation framework:
 - Drilling/exploitation permits
 - Regulation only in the Upper Rhine Graben (URG) at the moment
 - No risk in Paris or Aquitaine basins
- A young and evolutive framework:
 - First framework in 2011 for the Rittershoffen drilling permit
 - Permanent network and densification based on operator's decision
 - Based on magnitude threshold, limit at $2.0 M_L$
 - Operation must be stopped in case of anomalous event felt by the population

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○ First evolution of the regulation framework

- Evolution of drilling permits for Vendenheim and Illkirch project in 2015 (close to Strasbourg)
- Seismic and geodetic monitoring of geothermal plants in the French URG:
 - 4 real-time short-period stations in the vicinity of the plant
 - 1 real-time multi-sensor station (1 accelerometer and 1 broadband sensor, public data)
 - 1 GNSS antenna and 1 corner-coin (Interferometry) on drilling platform
 - Seismic monitoring must be operational 6 months before any operation
 - Must be in real-time and operational during the whole life of the project
 - 2 Thresholds: 1.5 ML (alertness) and 2.0 ML (stop operation)
 - Injection pressure limited to 100 bar



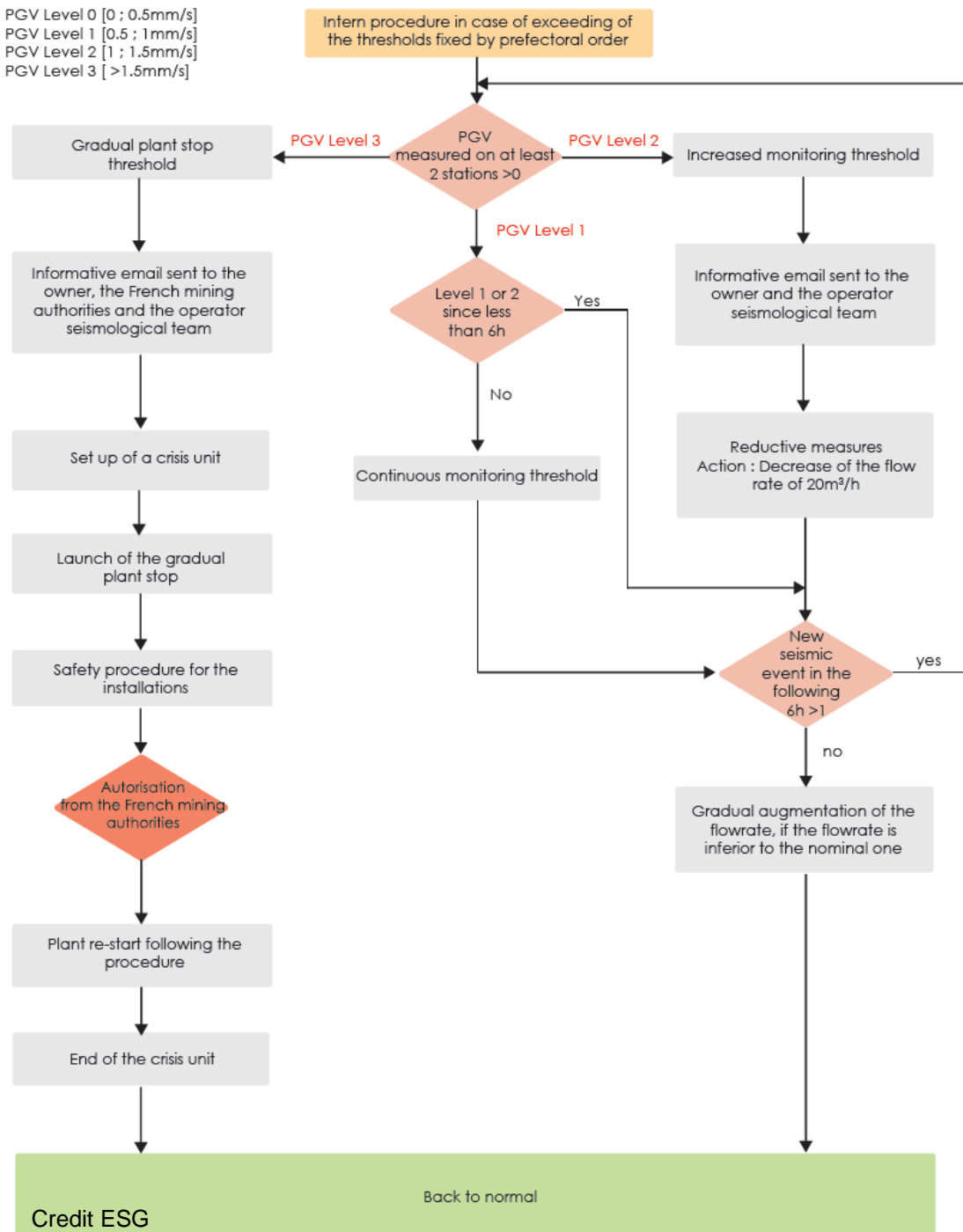
○ Second evolution of the regulation framework

- Main evolution: 3 thresholds based on PGV (Peak Ground Velocity)
- Application to plant in operation (Soulz and Rittershoffen in 2016)
- $PGV > 0.5$ mm/s on at least 2 stations
 - Threshold of vigilance
 - Operator must continuously monitor the evolution of seismicity
- $PGV > 1.0$ mm/s on at least 2 stations
 - Threshold of increased vigilance
 - Operator will take the necessary measures to return below the previous threshold
 - All seismic data of the last 7 days must be provided to a designated agency
- $PGV > 1.5$ mm/s on at least 2 stations
 - Threshold of progressive and obligatory stop of the plant
 - Operator will trigger the progressive shutdown of the facilities
 - All seismic data of the last 7 days must be provided to a designated agency

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PGV Level 0 [0 ; 0.5mm/s]
PGV Level 1 [0.5 ; 1mm/s]
PGV Level 2 [1 ; 1.5mm/s]
PGV Level 3 [>1.5mm/s]



○ Ongoing project under exploration and drilling

- 04.12.2020: Event of 3.6 M_L induced by the deep geothermal project at Vendenheim
- All ongoing geothermal projects under exploration and drilling in the French URG suspended and handed to conclusion of the mining authorities
- New framework expected in 2021 (max pressure, depth, seismic monitoring, seismic risk assessment...)
- However, no anomalous/felt seismicity induced by
 - Geothermal plants in operation at Rittershoffen and Soultz
 - Drilling and testing at Illkirch
 - In Paris Basin since the 70s (50 plants in operation)
 - In the Aquitaine Basin (15 plants in operation)
 - At Bouillante, in Guadeloupe Island (in operation since the 80s)

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Situation regarding GEOENVI's recommendations



Mandatory:

- Seismic hazard and risk analysis: Done in the Environmental Impact Assessment, but no guideline to handle clearly this analyze (all deep geothermal project)

Mandatory in the French URG:

- Seismic baseline monitoring
- Definition of Thresholds
- Open access of the data above certain threshold
- Evaluation of seismic activity

Not Mandatory:

- Seismic velocity model: Done by operators, but no validation by mining authorities, update not mandatory after drilling
- Predictive modeling
- Stress-strain analyses
- Traffic Light System

Differences between France and Germany

| Country: | France | Germany/Palatinate |
|---|---|--|
| Seismic network technical requirement: | <ul style="list-style-type: none"> – 1 real-time data monitoring with 4 short period velocimeters and 1 “multi-sensor” station (broad-band seismometer, an accelerometer, a GNSS receiver and a corner-coin reflector) | <ul style="list-style-type: none"> – 1 network designed with 4 velocimeters according to the DIN 4150 (on buildings) – 1 real-time network coordinated with the mining authority, that could use both accelerometers or velocimeters; number (generally 4 stations) |
| Seismic network installation: | 6 months before starting drilling | 3 months before or at least if drilling starts |
| Public data: | All data from the “multisensor” station | All data from the velocimeters used to monitor the DIN 4150 |
| Thresholds base on: | PGV | PGV |
| Number of thresholds: | 3 thresholds (measured on 2 stations): <ul style="list-style-type: none"> – 0.5 mm/s, close monitoring – 1.0 mm/s, short term reduction in flow – 1.5 mm/s, stop operation | 5 thresholds (measured on 1 station only): <ul style="list-style-type: none"> – 0.2 mm/s daily reporting – 0.5 mm/s short term reduction in flow – 1 mm/s long term reduction in flow – 5 mm/s operate at minimum flow – 10 mm/s stop operation |
| Reporting: to the mining authority | Before drilling: Report on natural seismicity Drilling: Monthly Testing: Daily Operation: Monthly | Before drilling: Report on natural seismicity and a seismic hazard analysis Testing: Daily Operation: Monthly |

○ Thank you for your attention

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