

D3.6 Guidance to insurers

WP 3: Risk management workflows for deep geothermal energy

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Lead Beneficiary	
Type	<input checked="" type="checkbox"/> R - report, document etc. <input type="checkbox"/> OTHER - software, technical diagram etc. <input type="checkbox"/> DEM - demonstrator, pilot etc. <input type="checkbox"/> E - ethics <input type="checkbox"/> DEC - website, patent filing etc.
Status	<input type="checkbox"/> Draft <input checked="" type="checkbox"/> WP manager accepted <input checked="" type="checkbox"/> Project coordinator accepted
Dissemination level	<input checked="" type="checkbox"/> PU – Public <input type="checkbox"/> CO - Confidential: only for members of the consortium
Contributors	<input type="checkbox"/> 1-GFZ <input type="checkbox"/> 5-GES <input type="checkbox"/> 9-GTL <input type="checkbox"/> 13-SNU <input type="checkbox"/> 2-ENB <input type="checkbox"/> 6-TNO <input type="checkbox"/> 10-UoS <input type="checkbox"/> 14-KIC <input checked="" type="checkbox"/> 3-ESG <input type="checkbox"/> 7-ETH <input type="checkbox"/> 11-TUD <input type="checkbox"/> 15-ECW <input type="checkbox"/> 4-UoG <input type="checkbox"/> 8-GTN <input type="checkbox"/> 12-NEX <input type="checkbox"/> 16-WES
Creation date	01/08/2019
Last change	28/11/2019
Version	Final
Due date	30.11.2019
Submission date	02.12.2019

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1 Introduction

In the framework of the work package 3 of the Destress Eu project, embracing **Risk Management Workflows for deep Geothermal Energy**, the Deliverable **D3.6** entitled “**Guidance to insurers**”, deals with how insurers could be guided for covering the potential impacts of operational EGS deep geothermal projects during exploitation mainly. This deliverable is closely related to the Destress Milestone **MS8** done by ESG (Peterschmitt et Genter, 2019) in which a dedicated questionnaire of about 20 questions was set up for insurers, sent to them and analyzed. This questionnaire was designed for obtaining the feedback from them in order to evaluate their level of perception of potential risks linked to deep geothermal energy. It is mainly based on the operational experience of the two geothermal plants operated by ESG in Northern Alsace (France) at Soultz-sous-Forêts and Rittershoffen. However, we noticed that it was quite challenging to get proper feedback from insurers. Only a few of them answered or contributed to the survey. First, because geothermal energy is not well-known among insurers and second, because of the lack of structural damages related to the operational geothermal EGS plants of Soultz-sous-Forêts and Rittershoffen. In other words, there is no concrete business with insurance related to geothermal exploitation (e.g. in France, deep geothermal energy does not have a specific insurance scheme). Originally, this deliverable aimed to provide guidance to insurers in terms of premiums and optimum arrangements for EGS plants. Based on concrete operational EGS projects, risks of damage should be covered by insurance policies of the project owner but not by individual insurance policies.

As the MS8 report was clearly designed for recovering feedback from insurers, this D3.6 report aims to propose guidance and recommendations to insurers, even no real specific scheme exists in France where two EGS plants are running. Thus, we decided to build a guide for insurers by explaining, from a pedagogic angle, how exploitation and maintenance of a deep geothermal site works and what are the risks linked to those operational phases for the environment and inhabitants living nearby the plants.

The work here presented is mainly focused on deep geothermal energy during the exploitation phase which represents in average at least two decades of continuous operations. Stimulation phases which represent in average only a few days of technical operation are also considered because occurrences of felt induced seismicity already happened (Charlety et al., 2006). Drilling phases and related potential nuisances are not considered in this deliverable D3.6.

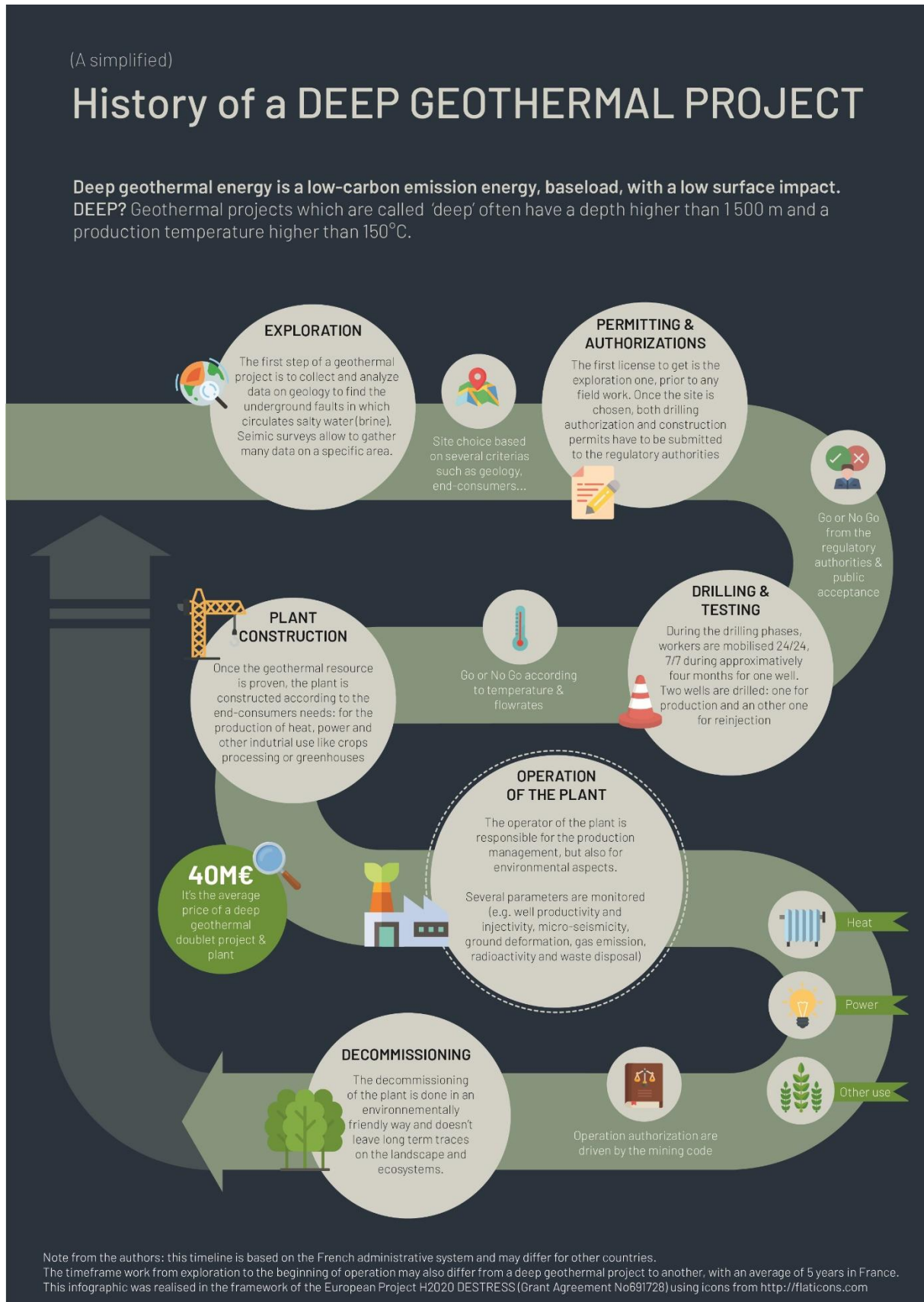


Figure 1 A generic history of a deep geothermal project in continental Europe

2 What is geothermal energy?

Among the various energies available in the renewable panel, geothermal energy is a low-carbon emission energy, baseload, with a low surface impact. Taking heat from underneath the Earth surface is not a new concept: in the Antiquity, hot springs were already used daily. The energy available underneath our feet come mainly from the natural radioactivity of the Earth: the radioactive decay of the elements creates heat that can be harvest with different methodology, dependent on the geology of the concerned area, but also the depth and capacity of the heat extraction unit at the surface. The term 'geothermal energy' refers to various techniques, as it is possible to heat (and cool) an individual house with a heat pump using the available temperature of 15°C at low depth, but also produce electricity or heating for thousands of housings using a temperature of more than 150°C at higher depth. The deeper, the higher the temperature will be and the extractive technique can be different from a project to another. However, the common thread is geothermal water, used as heat vector, from the deep underground to the surface. This is the reason why in the exploration phase of a geothermal project, the objective is to find available, hot water that can be pumped to the surface through deep wells (around 3000m). The main technical phases of a generic geothermal project designed in the French part of the Rhine Graben are presented on Figure 1.

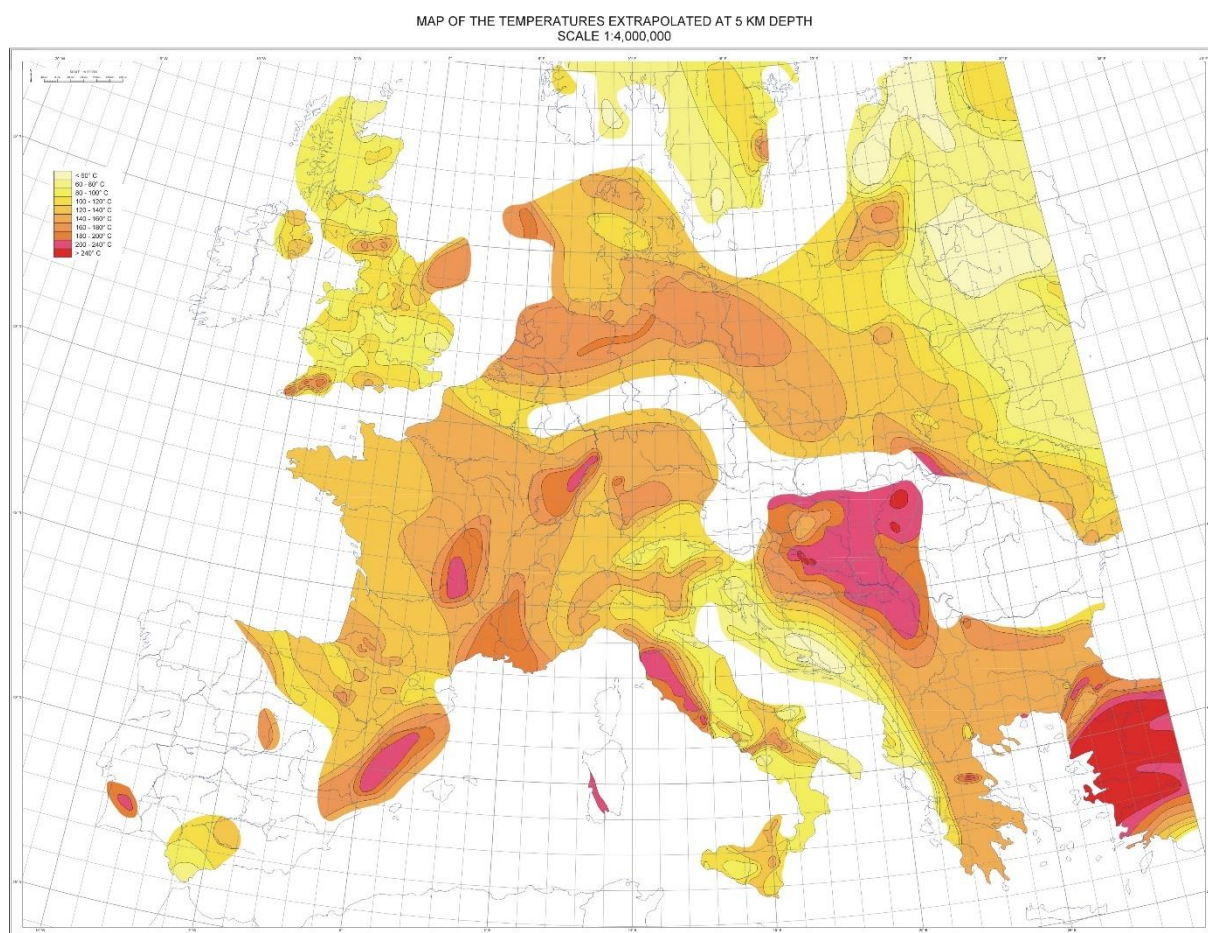


Figure 2 Extrapolated temperature map at 5km deep in Europe from Hurtig et al. 1992

In Europe, high temperatures at depth are well known from various deep drilling data (Figure 2). The red spots on the map correspond to the most promising zones where high temperatures could be reached at drillable depths. Deep geothermal projects or installations which are called 'deep' often have a depth higher than 1500 m and a production temperature higher than 150°C. A standard geothermal system is made of two wells: one well for producing hot water and one well for reinjecting

the colder water (Figure 3). Generally, a down-hole pump is used for extracting high flow rates and thus reaching economic threshold.

Once at the surface, the geothermal hot water can be used variously, depending on the temperature range of the produced fluid. The discharged geothermal fluid at high temperature will go through an exchanger with fresh water or an Organic Rankine Cycle fluid that will allow to take out the heat (calories), and the geothermal water will be reinjected in the reservoir underneath at lower temperature (Figure 5). The heat extracted will be used for heating (e.g. for the Paris basin area, where 150,000 housings are heated with geothermal plant), industrial processes (e.g. for the Rittersshoffen heat plant, Figure 4) or for the production of electricity using heat transfer fluid (e.g. Soultz-sous-Forêts power plant).

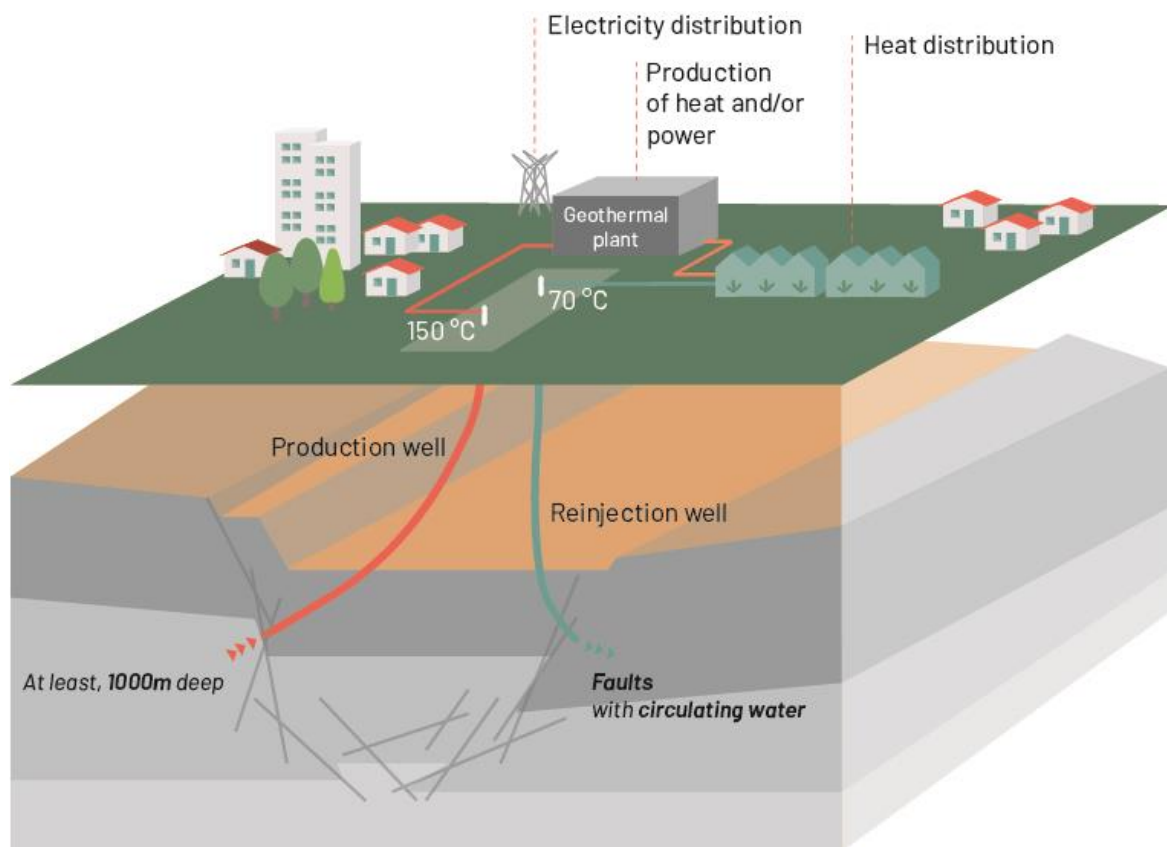


Figure 3 Sketch of a generic deep geothermal project in continental Europe showing a doublet pumping and reinjecting in a naturally permeable faulted reservoir

In some volcanic areas (e.g. in Italy, in the Tuscany region), the temperature of the geothermal water is so high (more than 300°C) that the water is available under the steam state, in that case, the steam pass directly through turbines to produce electricity (Figure 6).



Figure 4 The recent geothermal plant of Rittershoffen producing heat at high temperature ($>160^{\circ}\text{C}$ on surface) in the Upper Rhine Graben, source ES

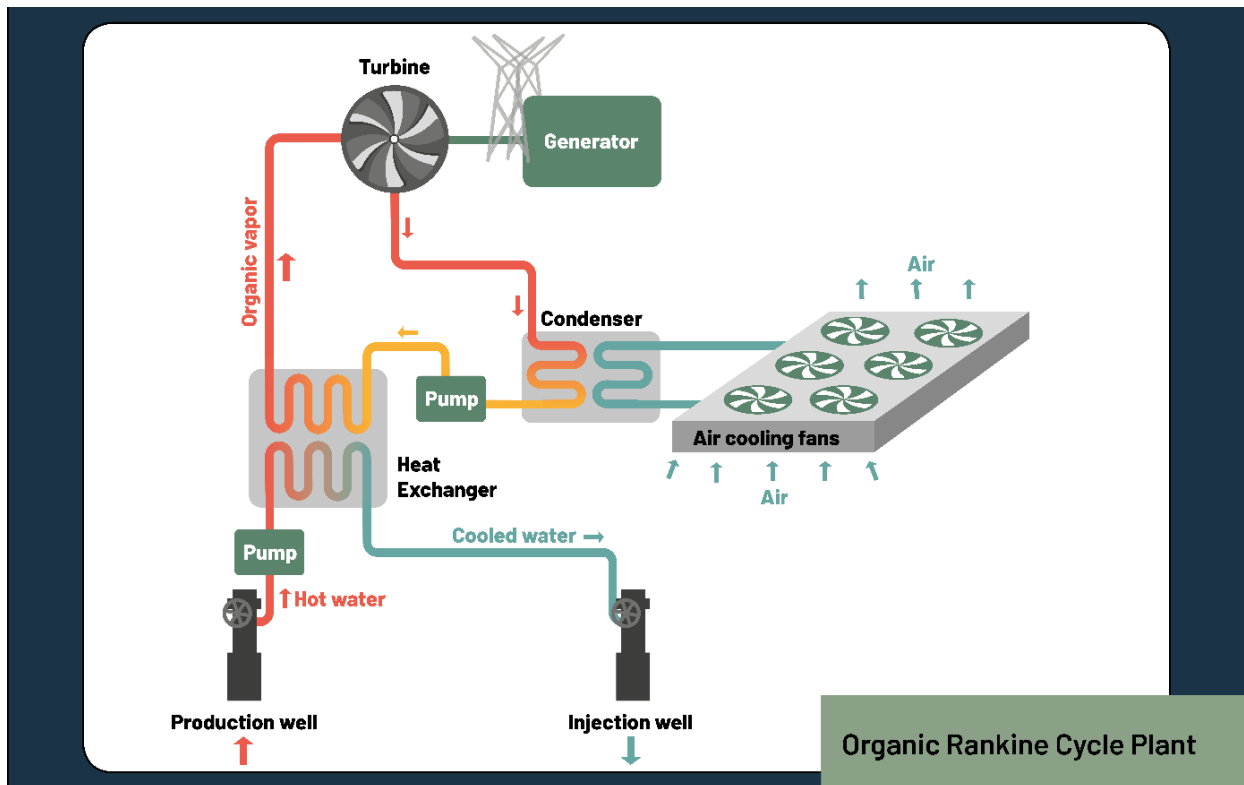


Figure 5 Geothermal plant technologies used in Europe. ORC plant like in the Upper Rhine Graben

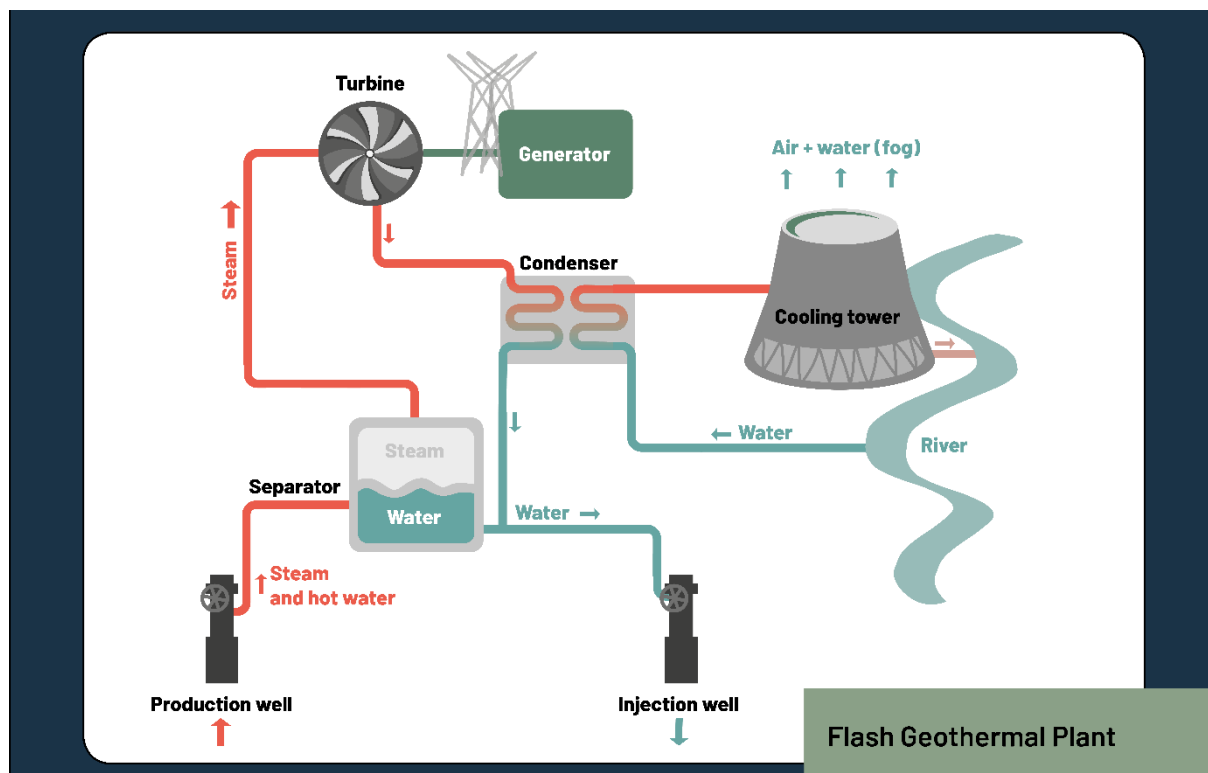


Figure 6 Geothermal plant technologies used in Europe. Flash plant like in Tuscany region, Italy

3 The insurance scheme of geothermal projects: state of the art

In France, deep geothermal does not have a specific insurance scheme. As for now, two EGS plants are running in Northern Alsace: Soultz-sous-Forêts, to produce electricity and Rittershoffen to produce heat for industrial uses, while two others are under construction and more under development.

The insurance framework for Soultz and Rittershoffen geothermal plants is organised according to the following structure (Figure 7):

- The plant (considered as a 'building') is covered by an insurance contract, that includes many 'classical' items such as fire, intrusion... but also the seismological risk: If the geothermal activities induce an earthquake strong enough to provoke damages, the insurance of the plant will take in charge the cost of reparations. Thus, quotes and assessments will be done and discussed between the insurers of the plant owner and the representative of the housing insurance (Figure 7).
- The operator of the plant is covered by an insurance contract with a status of 'civil liability', for the technical operations taken on the plant itself. This could cover unexpected operation like productivity decrease due to human error.
- As the environmental issues coverage is very specific from an installation to another in the field of industry, a specific insurance contract on the financial coverage of environmental potential damages is contracted.

In 1972, the OCDE rose the *polluter pays* principle in which all the cost resulting from preventive measures, pollution reduction or tackle measures have to be supported by the polluter. In France, this principle is described in a dedicated article of the *code de l'environnement* (Environmental law).

It is important to notice that the risks related to fracking are not included in the contract neither between the operator and the insurance company, nor between the owner of the plant and the insurance company. In France, fracking is forbidden for O&G industries and geothermal developers are authorized to inject with a maximum well-head overpressure of 100 bars.

Therefore, the insurance premium of the housings surrounding a geothermal plant are not impacted by the localisation of the plant, as any potential damages are covered by the (owning or operating) company insurance contract.



Figure 7 Schematic relationship for insurance between geothermal plant owner, plant operator and housing

4 Potential disturbances and monitoring of geothermal projects

The main potential disturbances that can occur during the operation of geothermal projects are listed: induced seismicity, ground deformation, natural radioactivity, degassing, leaks, emissions, surface disturbances (as vibrations, noise, visual, dust, land occupation), wastes. Among them, the ones that can provoke structural damages are monitored daily. Also, activities are framed by the law (European and national - French) setting thresholds. Such legal framework is controlled by local mining authorities under the umbrella of the Prefecture (Local representative of the French government) which delivers a prefectural decree for operating during the concession, i.e. for 25 years.

All the potential disturbances described below are specific to a geothermal plant under operation. They correspond to:

- **explosion** when the working fluid is an Organic Rankine Cycle plant (Figure 8),
- **gas emission** in case of geothermal fluid releases in the atmosphere (Figure 9),
- **ground deformation** like subsidence in case of reservoir depletion (Figure 10),
- **leakage** of geothermal fluid in the environment due to a pipe failure (Figure 11),
- **vapor emission** related to temporary fluid discharge in the atmosphere (Figure 12),
- **induced seismicity** related to thermo-hydromechanical response of the reservoir during reinjection (Figure 13),
- **surface disturbance** like noise or vibrations generate by the plant (Figure 14),
- **waste** like scaling or fluids (Figure 15),
- **natural radioactivity** related to the composition of the scaling (Figure 16).



Explosion

The explosion potential risk is linked to the presence of organic rankine cycle fluids that are used on the ORC plants for the production of electricity. It is not particularly relevant for flash or geothermal heat plants, as for them, the heat transfer is made directly with water.

Nethertheless, the risks inherent to the presence of high pressure fluids are not to be left out. Those risks are not specific to geothermal installations, and are very common in various type of industrial installations.



How it is monitored?

The installations have to be checked regularly (annually) by the operator. Storages have very specific constraints, established by the law.




What does the law say?

The French law is quite strict on the specificities required for the use and storage of highly explosive fluids. Sites are classified according to the ICPE* criterias, and and relative recommandations are set on concerned site zones.

*Installations classified for the protection of the environment


Figure 8 Potential risk related to ORC plant like explosion



Gas emission


During the operation of the plant, the natural gas stored in the underground goes up to the surface and have to be taken in account when assessing the environmental impacts of geothermal activity.

The amount of released gas in the atmosphere is related to the geology of the geothermal site. The most frequent gas are CO₂, CH₄, NO_x, H₂S, N₂, Rn. The following ones CO₂, CH₄ are classified as Green House Gases and can participate to global warming, while the other ones may be toxic to the humans and environment. This is the reason why they have to be monitored.



How it is monitored?


At Soultz and Rittershoffen plants, the Radon Rn emission is monitored annually. Other gases emission is not monitored as those installations are under pressure.



What does the law say?


In France, the emissions are regulated by the French environmental code, local health regulations and exploitation authorization.

Figure 9 Potential risk related to a geothermal plant like gas emission




Ground deformation

Ground deformation due to human activity can be either uplift or subsidence. It is not an new observation for mining activity, but it is not usual for deep geothermal sites. A few incidents (e.g. Landau geothermal site, Germany) were observed, and since then, the monitoring of ground deformation for deep geothermal site is mandatory in France.



How it is monitored?


GPS are installed on the geothermal platform and a monitoring is made thanks to the use of satellites.



What does the law say?

One GPS for monitoring the ground deformation in mandatory of each site according to the local French mining authorities.

Figure 10 Potential risk related to a geothermal plant like ground deformation




Leakage

Geothermal water generally contains a high amount of salts (NaCl, KCl). This high concentration can provoke chemical damages, in the case of leakage in the environment.

Geothermal water is also very hot. In case of leakage, the heat can provoke damages, but also mechanical risks linked to overheated water.


The corrosion inhibitors are adapted and specific coats are chosen for the plant tubes, to avoid leakages.



How it is monitored?

Visual controls are regularly made on the installations.


Flow meters and pressure sensors are also installed on the plant for continuous monitoring.



What does the law say?

In France, the environmental code sets strict rules on the quality of the water released in the environment. Brines can not in any case be leaked out in the surroundings of the plant.


Figure 11 Potential risk related to a geothermal plant like leakage



Vapor emission

For ORC plants, vapor emission occurs during transitory phases or short-term tests. It can also happen in the case of involuntary stop of the plant.


For Flash plants, vapor is continuously released in the atmosphere. This can be a potential nuisance if this vapor is rich in heavy metals. In such case, the installation of filters is necessary.



How it is monitored?

For ORC plants, installed equipments are underpressure and minimize the occurrence of vapor emissions.


For Flash plants, a regular chemical analysis of the vapor is necessary



What does the law say?


In France, there is no known law or rules regulating the emission of vapor. In general, emissions to the environment are regulated by the environment and health codes.

Figure 12 Potential risk related to a geothermal plant like vapor emission




Seismicity

Induced microseismicity can occur in the close area near the injection well of the geothermal plant, due to the injection of the water: for hydraulic reasons, but also because of thermal effect. Indeed, cold water reinjected amid hot rocks can create microseismicity.



How it is monitored?


Four mandatory seismological stations are installed in the surrounding of the geothermal plant. The seismic events are measured in PGV (Peak Ground Velocity) which is also used for structural damages reglementation. Thresholds are set, and a traffic light system is settled.



What does the law say?


In France, the local mining authority sets the rules in the operation permits. The operator have to give the monthly monitoring data to the authorities.
Some specific constraints are also set for the wellhead reinjection pressure: it can not be higher than 100 bars

Figure 13 Potential risk related to a geothermal plant like induced seismicity




Surface disturbance

Geothermal activity can produce surface disturbance that can have a limited but still noticeable impact on the surroundings.
Among them, noise might be the most important one. All types of plants are concerned.
Vibrations can also be a noticeable disturbance, as for almost every industrial process. This is an well-known issue, and the installations are built to minimize it.
The visual impact question can also be raised, even if it has to be think of since the very beginning of each project.



How it is monitored?


Noise is regularly measured on the geothermal plant to verify if it is not higher than the thresholds set by regulation



What does the law say?


In France, noise emission thresholds are set depending on the initial measured level of noise: If the plant is located in an urban area, the threshold for noise emission will be higher than for a rural one because of a high initial level of human activity

Figure 14 Potential risk related to a geothermal plant like surface disturbance




Waste disposal

As for every industrial activity, geothermal plants produce wastes. In the operation phase of a geothermal site, this amount is quite low compared to the drilling one: the drilling mud has to be treated.


 **How it is monitored?**

Waste is not particularly monitored. It can happen that in the framework of an operator ISO14001 certification (environmental management), waste is monitored and reduced.

 **What does the law say?**


In France, the industrial activity is responsible for its production and management of waste.

Figure 15 Potential risk related to a geothermal plant like waste disposal




Radioactivity

Deposits and scalings created by the geothermal activity can be radioactive, provoked by an accumulation of natural radioactivity. Thus, this low dose rate of radioactivity is related to deposits, but also equipments used to clean the installation, plant components (e.g. filters).

 **How it is monitored?**

A radioprotection campaign is regularly organized. Specific zones are set on the plant site, and dosimeters are used by employees.

 **What does the law say?**

In France, even if there is no rules specific to the accumulated natural radioactivity, the geothermal sector has to follow the recommendation of the French Nuclear Safety Authority

Figure 16 Potential risk related to a geothermal plant like natural radioactivity

5 Case studies related to geothermal activities

5.1 For hydraulic stimulation activities

In order to illustrate how some activities generated by geothermal site like hydraulic stimulation could impact their environment, three examples of sites are presented. The first one is quite old and corresponds to hydraulic stimulation done at Soultz in 2003 where an induced seismic event was felt related to a magnitude of 2.9 (Figure 17, Charlety et al., 2006). In that specific case, insurance experts from the site owners and the local population were mobilized but nobody could prove any concrete structural damages on the housing.

The second one is the Basel case study where a induced seismic event of a magnitude 3.4 was felt on 2006 following a hydraulic stimulation in a deep geothermal well (Figure 18, Häring et al., 2008). This event generated structural damages and stopped definitively this project (Trutnevyte et Azevedo, 2018).

The last striking example corresponds to a recent bad story of structural damages that took place in 2017 in South Korea (Ge et al., 2019). Hydraulic stimulations of the Pohang geothermal drilling site provoked a seismic event of magnitude 5.5 (Figure 19). The insurance scheme for this site is not known, but the amount of structural damages is very high and ranges around 75 million US dollar.



Figure 17 The Soultz-sous-Forêts case study



Figure 18 The Basel case study



Figure 19 The Pohang case study

5.2 During geothermal exploitation

In order to illustrate how exploitation of a geothermal plant could impact their environment, three examples of sites are presented below (Figure 21). The Rittershoffen geothermal plant is a real success story because a geothermal plant is operating and producing 24MWth of heat continuously from 2016 with an availability higher than 90% (Baujard et al., 2017). Moreover, no disturbances have been observed with this site (). For example, at Soultz and at Rittershoffen, no induced seismic event was felt after more than 3 years of exploitation (Cuenot and Genter, 2015, Baujard et al., 2018). Same observations could be done for the geothermal power plant of Insheim in Germany (Kuperkoch et al., 2018). The Landau geothermal plant had a technical problem with the injection well inducing an uplift of the geothermal platform (Figure 21, Heimlich et al., 2015). Thus, some potential damages have been observed.

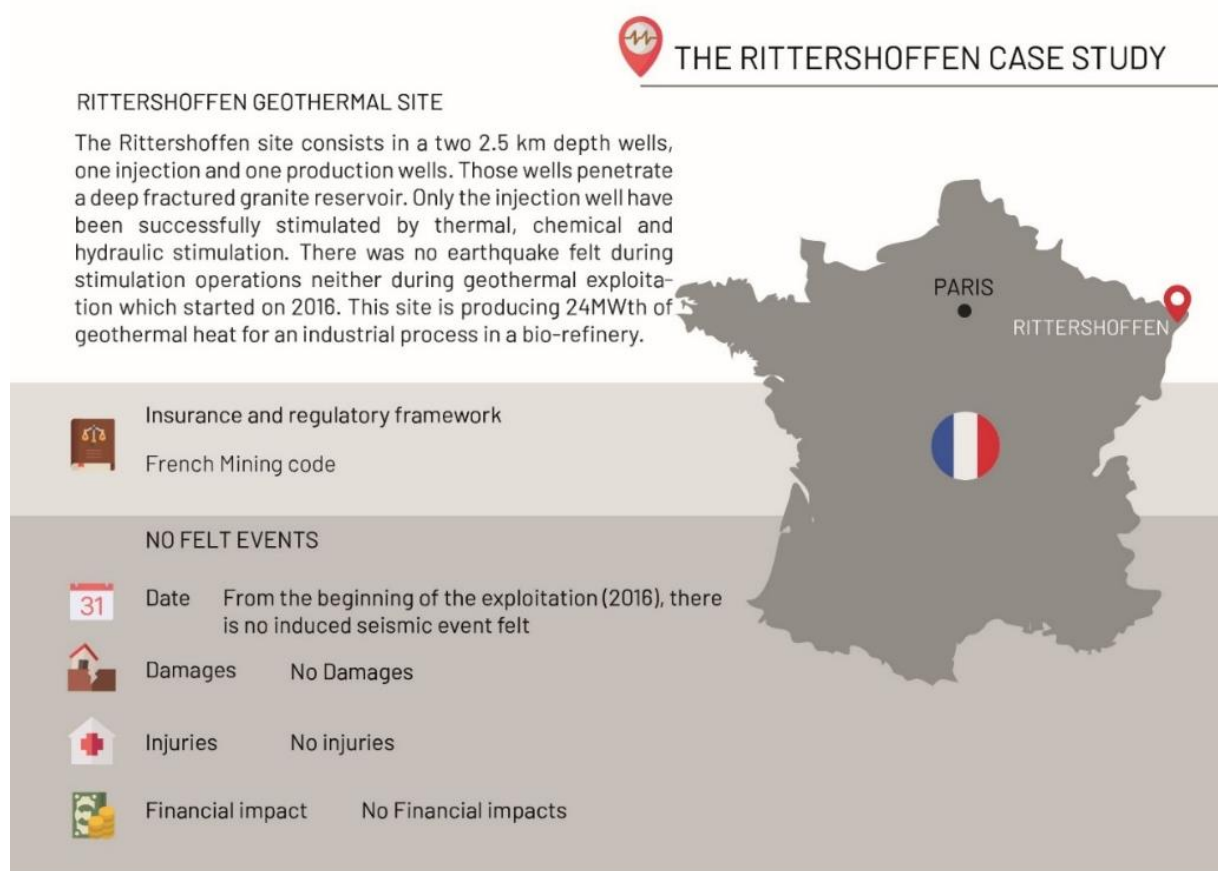


Figure 20 The Rittershoffen case study



Figure 21 The Landau case study

6 Felt events near an on-going geothermal project

Mid-November 2019, two seismic events occurred relatively closed to a geothermal project in the surroundings of Strasbourg city, France. The first one, of a magnitude of 3.1, occurred at 14h38 the 12nd of November 2019 at about 5km of the geothermal site. Felt by the local population, the seismic event was immediately flagged by the French National seismological survey (RENASS) as an 'induced' event. In the local press, the event was thus considered as induced by the geothermal activity near-by. In a press release, the developer of the geothermal project immediately declared that the activity on site was out of responsibility, as the injections were stopped in the wells since a few days (Figure 23)

On the 14th of November 2019, another earthquake of magnitude 2.6 occurs at 23h40, also felt by the local population. This time, the press spread the question of the responsibility of the geothermal project at a national level. The local mining authorities decided to stop operations on the geothermal site and launched a study to determine if the operator's responsibility was engaged in those felt events.

For now, the question is still unsolved: were those events natural or man-made? Some damages were linked to the occurrence of the two earthquakes, and the potential responsibility of the operator might be engaged. If so, the insurer of the project might need to take in charge the financial aspects of the reparation costs. As for now the situation is still unclear and under investigation between the regulatory authorities, the developer and the university in charge of the national seismological monitoring. This situation is a good example of how the question of induced seismicity can be managed between insurers in case of felt events near a geothermal project, that made minor structural damages.

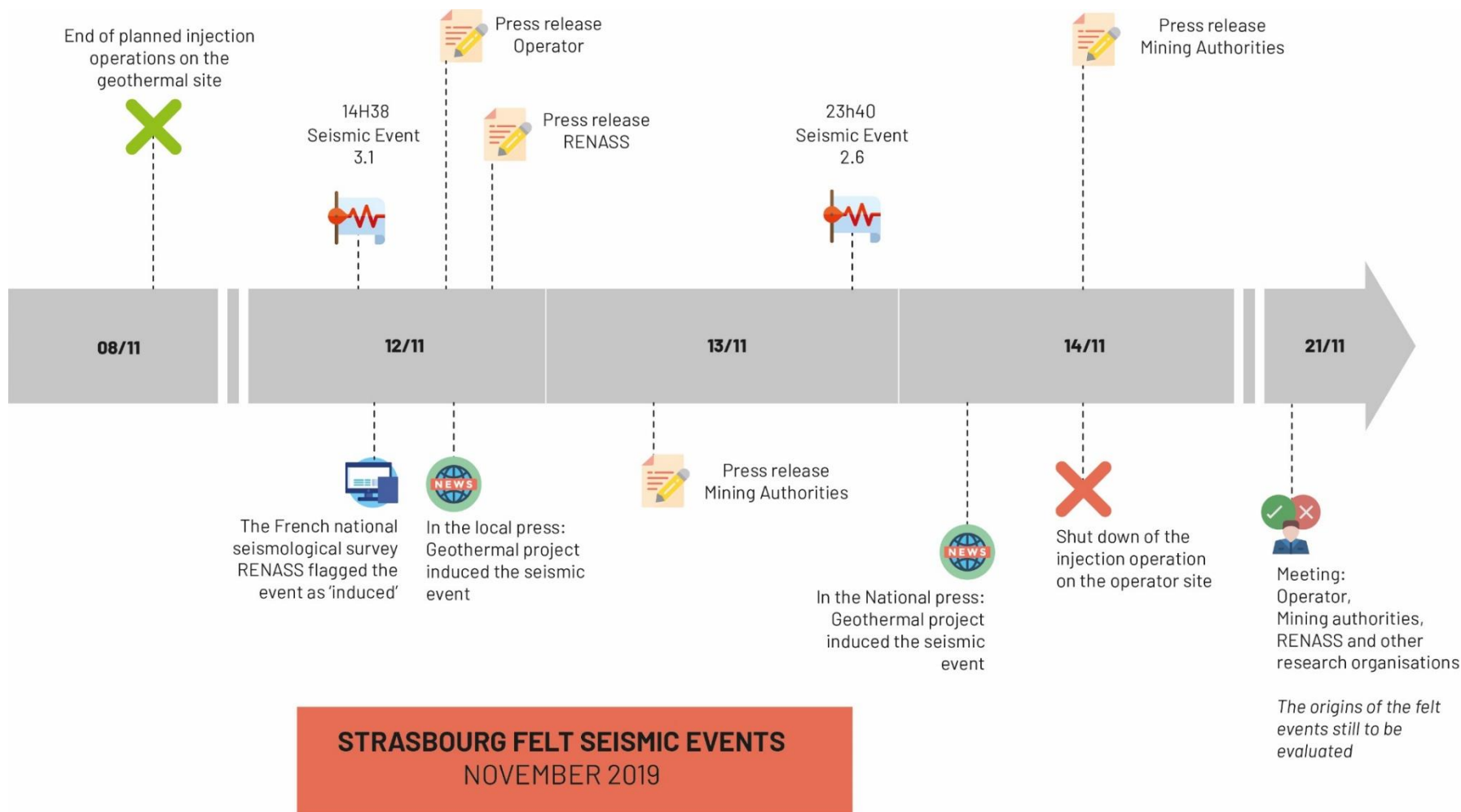


Figure 22 Time chart of a recent earthquake felt in Strasbourg

DNA RÉGION MERCREDI 13 NOVEMBRE 2019 13

UN SÉISME DE MAGNITUDE 3,1 SUR L'ÉCHELLE DE RICHTER

Un léger tremblement de terre a secoué Strasbourg à 14 h 38

Un séisme de magnitude 3,1 sur l'échelle ouverte de Richter s'est produit mardi en début d'après-midi près de Strasbourg. La secousse, qui a été ressentie dans une grande partie de l'Eurométropole, n'a fait ni blessés, ni dégâts importants.

Une déflagration sourde, suivie d'un tremblement, a agité Strasbourg et les communes environnantes mardi en début d'après-midi. À 14 h 38 précisément, les stations du Réseau national de surveillance sismique (ReNaSS) ont enregistré une secousse d'une magnitude de 3,1 sur l'échelle ouverte de Richter.

« Comme un gros bruit d'explosion, la sol et les vitres ont tremblé »

Les habitants se sont crûs sur les réseaux sociaux pour vérifier qu'ils n'avaient pas rêvé. « Hornheim : comme un gros bruit d'explosion, le sol et les vitres ont tremblé », décrit Stéphanie sur la page Facebook des DNA. « À l'Esplanade, comme un avion qui dépasse le mur du son avec des tremblements sur dix secondes », confirme Véro. À Schiltigheim, « deux gros boums ça secoue ». Quelques secondes avant, le chien a aboyé et s'est réfugié près du canapé », témoigne Olivier.

Plus tôt dans la journée, les appareils de mesure du ReNaSS avaient capté neuf imperceptibles tremblements de terre de magnitude 1,5 à 2,2 sur l'échelle de Richter (voir l'infographie ci-contre). Un phénomène relativement habituel dans les trente-trois communes de l'Eurométropole de Strasbourg, classées en « zone de sismicité 3 », c'est-à-dire présentant un risque « modéré ».

Selon la préfecture du Bas-Rhin, l'épicentre du séisme, resté inconnu par la population en début d'après-midi était localisé « dans le secteur Schiltigheim-Robertsau ». Les autorités allemandes du Land du Bade-Wurtemberg le placent, quant à elles, « à six kilomètres à l'est de Strasbourg et à deux kilomètres au nord de la ville frontalière allemande de Kehl, sur la rive opposée du Rhin ». Au nord de la capitale alsacienne, dans les deux

Seuil à partir duquel la secousse devient sensible pour la plupart des gens

Les séismes du 12 novembre 2019 (en magnitude sur l'échelle de Richter)

Source: ReNaSS Info: DNA, ReNaSS, avec Sophie Castel, Strasbourg, 13/11/19

Les regards se tournent vers la géothermie

Entre le jeudi 10 octobre et le mercredi 16 octobre, les DNA avaient relevé 35 microséismes mesurés par le ReNaSS à proximité de Strasbourg. Des « événements induits », liés à une activité humaine, le site de géothermie de Reichstett-Vendenheim, qui montait en puissance. Aucun de ces microséismes ne dépassait une magnitude de 1,9 sur l'échelle ouverte de Richter. Le directeur général de Fonroche, l'exploitant du site géothermique, expliquait alors que l'injection d'eau froide dans l'un des réservoirs créés dans le sol jusqu'à 5 300 mètres provoquait une « rétraction » de la roche capable d'induire des microséismes. Cette activité sismique était surveillée et il fallait vérifier à ce que les magnitudes engendrées n'excèdent pas 2. Est-ce que le séisme enregistré ce mardi est lié à cette activité ? Plusieurs observateurs, y compris des scientifiques, sont tentés de le croire.

La société Fonroche dément fermement. Au mois d'octobre, son directeur général expliquait qu'on n'était en aucun cas dans la configuration du site géothermique de Bâle le 8 décembre 2008, lorsque la pression était montée trop haut dans le réservoir, provoquant un séisme de 3,4 sur l'échelle de Richter (DNA d'hier).

Les forages géothermiques expérimentaux, menés à 4 600 mètres de profondeur à Vendenheim et Reichstett, ont aussitôt été pointés du doigt. « C'est la cause la plus probable. Celle vers laquelle on l'orienta », confirme Jérôme Van der Woerd. D'autant que chaque carottage réalisé sur le site de l'ancienne raffinerie provoque son lot de microséismes (lire ci-contre).

De son côté, Fonroche, l'exploitant du forage, se défend d'une quelconque responsabilité dans cette activité tectonique. « L'épisode sismique ressenti dans la région de Strasbourg n'a aucun lien avec le puits de géothermie situé au sein de l'écoparc rhénan de Vendenheim-Reichstett [...], celui-ci étant à l'arrêt depuis le 8 novembre au matin, conformément à la programmation normale des opérations en cours », affirme l'opérateur.

Des lézardes, et des bureaux évacués

La secousse n'a pas fait de blessés, ni de dégâts majeurs. Les pompiers du Service départemental d'incendie et de secours ont reçu une cinquantaine d'appels liés à l'événement.

À Schiltigheim, des lézardes se sont formées sur un immeuble de trois étages situé rue du Soleil. « Des petites fissures sont apparues et des fissures anciennes se

enregistrent dans l'agglomération strasbourgeoise. En cas de nouveau séisme, la préfecture du Bas-Rhin rappelle qu'il faut s'abriter près d'un mur porteur ou d'un meuble solide et s'éloigner des fenêtres pour éviter les bris de verre. À l'extérieur, il convient de s'arrêter le plus loin possible des constructions et de tout ce qui peut s'effondrer.

G. L.

Basé à Strasbourg, le Réseau national de surveillance sismique (ReNaSS) publie les activités enregistrées par ses stations, en temps réel, sur son site internet re.nass.unistra.fr

Le siège de Pôle Emploi au Wacken a été évacué par mesure de précaution.

Figure 23 Example of a press article published in a local newspaper on November 2019

7 Conclusion

The Deliverable **D3.6, *Guidance to insurers***, outlined how the potential nuisances of geothermal exploitation are monitored, based on the French operational plants located in Northern Alsace. For those running geothermal projects, the legal framework imposed by the French mining law as well as the existing insurance scheme already protect inhabitants of any proved damages.

Currently, in France, deep geothermal sites are protected by the insurances of the plant owner and of the plant operator, which take in charge any damages due to unexpected event related to geothermal activity. The individual insurance premiums of inhabitants should not be impacted by the vicinity of a geothermal site and its potential impacts linked to operational activities.

In the framework of the **Work Package 3 *Risk management workflow for deep geothermal energy***, the survey for insurers (Peterschmitt et Genter, 2019) did not provide conclusive results. Nevertheless, the outcomes on insurance for EGS projects is that the actual French insurance scheme is fully adapted to the compensation and responsibility shares in case of induced damages. Thus the French insurance scheme could be applied to other EU countries by taking into account their own legal framework for EGS projects.

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Imprint

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Project Website	www.destress-h2020.eu
Report Authorship	Peterschmitt A., Genter A. (2019). Deliverable D3.6 Guidance to insurers, public DESTRESS report, November 2019.
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DESTRESS is co-funded by

National Research Foundation of Korea (NRF)
Korea Institute for Advancement of Technology (KIAT)
Swiss State Secretariat for Education, Research and Innovation (SERI)