

Overview

Duration	<ul style="list-style-type: none"> – 4 x 45 min. (two double lessons)
Prior knowledge	<ul style="list-style-type: none"> – Introductory module on the topic of earthquakes – Earthquake risk and hazard – Swiss climate and energy strategy (optional)
Learning objectives	<ul style="list-style-type: none"> – Students understand what induced earthquakes are. – Students are familiar with various natural and man-made causes that can trigger earthquakes. – Students can critically reflect on the risk of induced earthquakes in geothermal projects. – Students can contribute valid arguments from different perspectives to the public debate on geothermal energy.
Required materials	<ul style="list-style-type: none"> – Laptop or tablet – Internet connection
Further information	<ul style="list-style-type: none"> – Induced earthquakes: www.seismo.ethz.ch/en/knowledge/causes-of-earthquakes/induced – Geothermal energy in brief: www.seismo.ethz.ch/en/knowledge/geothermal-energy-earthquakes/geothermal-energy-in-a-nutshell – BedrettoLab: www.bedrettolab.ethz.ch – Geo-Energie Suisse – Swiss Competence Centre for Deep Geothermal Energy: www.geo-energie.ch – Switzerland's net zero target: www.bafu.admin.ch/bafu/en/home/topics/climate/klimapolitik/ziele-und-strategien/netto-null-ziel-2050.html – Collection of Raspberry Shake on induced seismicity (in English): https://shop.raspberrypi.org/category/induced-seismicity/?srsltid=AfmBOopT0fnpM1P5NP2KRWPo_VV_IOTeog-ahVp1BDgCjzx8Z-u2Q3NJ – German Geothermal Association – various learning materials on geothermal energy (in German): https://www.geothermie.de/bibliothek/downloads – TA-Suisse publication "Electricity from deep below" https://www.ta-swiss.ch/publikationen

Structure and content of the module

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1. Earthquakes – man-made?

Introductory questions: Can humans or other factors trigger earthquakes?

- Form a group of 3 or 4 people.
 - Discuss these questions and take notes of your ideas to present to the class later.
1. Do you believe that humans can trigger earthquakes? If so, how could they do this? If not, why not?
 2. Can you imagine other causes besides plate tectonics that might trigger earthquakes? If so, what could they be? How could such an earthquake occur?

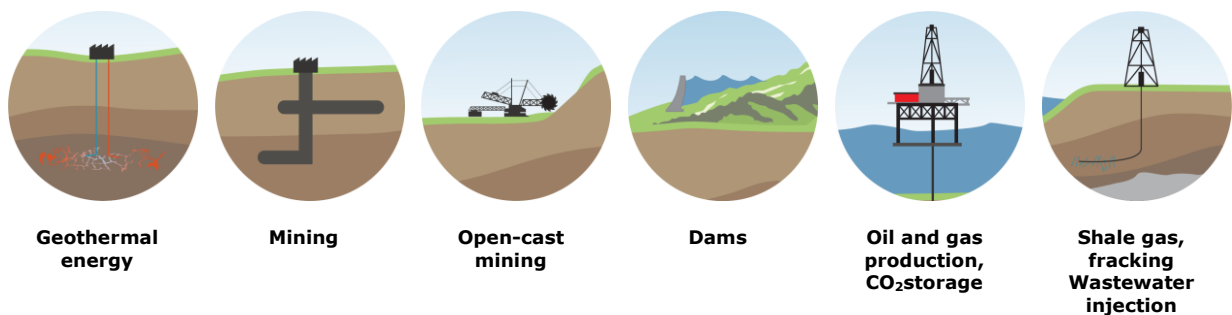


Figure 1. Symbolic image © Adobe Stock

2. What are induced earthquakes?

The Earth is constantly moving, and somewhere in the world there is always an earthquake. The US National Earthquake Information Center records around 20,000 earthquakes worldwide every year, which is about 55 per day. However, these are only the earthquakes detected by seismic measuring stations, many more go unnoticed. The main cause of earthquakes is plate tectonics, but some are triggered by human activity. In such cases, scientists refer to *induced earthquakes*, *induced seismicity* or *man-made earthquakes*.

Induced earthquakes are usually caused by major technical interventions in the subsurface that alter the stress in the Earth's crust. Examples include:



2.1 Induced vs. natural

Induced earthquakes are physically no different from natural earthquakes. They are also caused by a sudden release of stress along fractures in the Earth's crust. For this reason, induced earthquakes are almost indistinguishable from natural ones.

With few exceptions, induced earthquakes are very small and are either imperceptible or barely noticeable at the surface. Their exact location, strength and timing cannot be controlled.

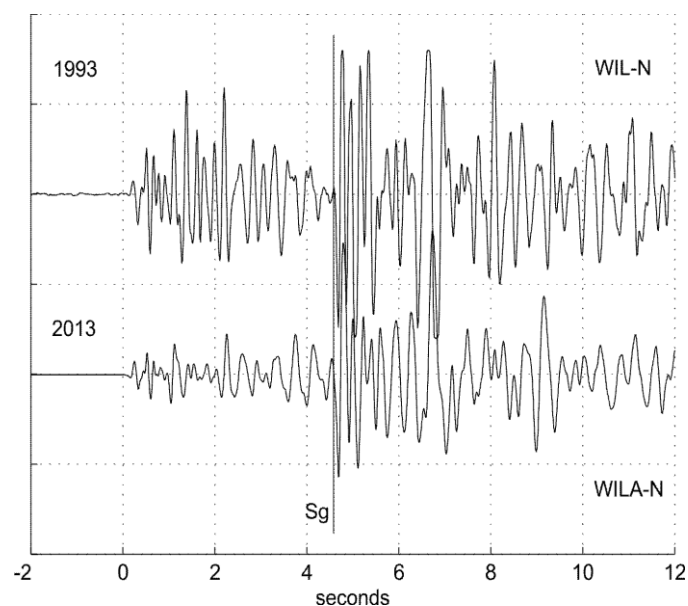


Figure 2 Seismogram of a natural earthquake (1993) and an induced earthquake (2013).

Task 1: Causes of induced earthquakes

- Open the following interactive infographic:
www.seismo.ethz.ch/de/static/interactive_images/eq_induced/manmade_eq_EN.html
- Answer the following three questions by clicking on the different circles in the graphic:

1. What is the cause of a possible induced earthquake at a **reservoir**?
2. Which human activities can lead to **volume changes**, and what exactly does this mean?
3. What can increase the **pressure in the pores of the rock**, and why can this trigger earthquakes?

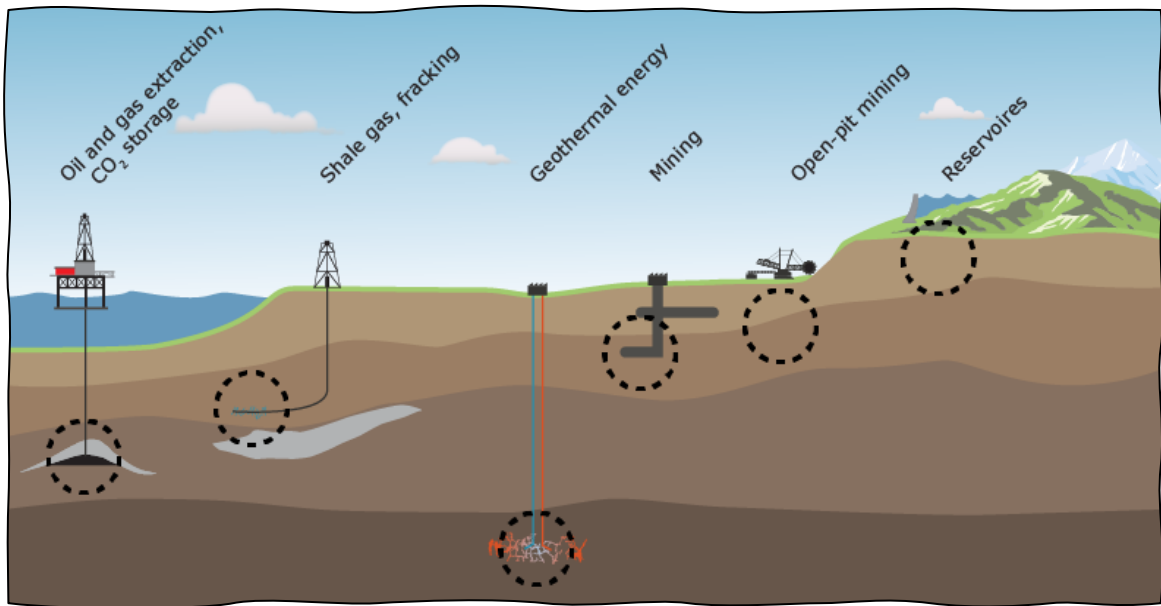


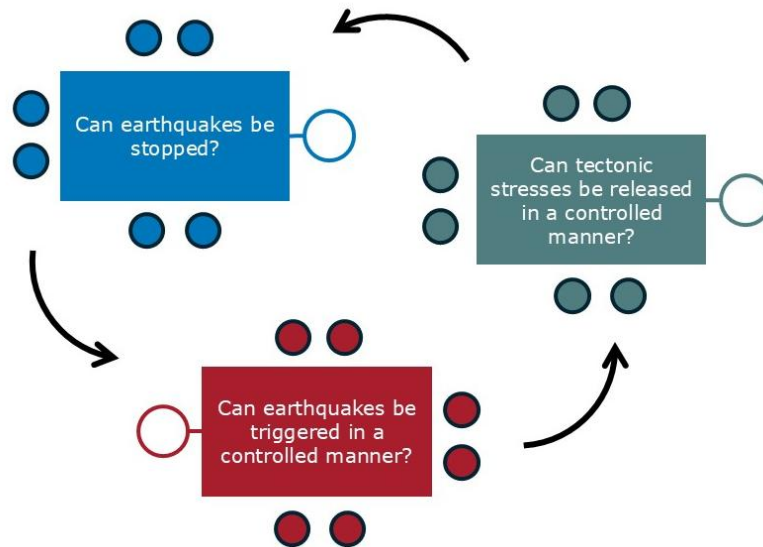
Figure 3. Overview of possible causes of induced earthquakes.

Solution task 1: Causes of induced earthquakes

1. **Load change:** The weight of the dam and the impounded water alter the stresses in the underlying subsurface, which can trigger earthquakes.
2. In **oil and gas extraction, CO₂ storage, shale gas production, fracking and geothermal energy**, liquid or gas is pumped into the ground (injected) or extracted from it. This changes the space (i.e. volume) in the pores of the rock. Such changes can affect the stress conditions: new fractures may form, or existing fractures may be reactivated.
3. **Water** is often naturally present in rock. In geothermal energy, oil and gas extraction, shale gas production and fracking, additional water is pumped into the subsurface, increasing the pore pressure. This reduces friction along faults, allowing rock layers to shift abruptly against one another.

Task 2: Thought experiments

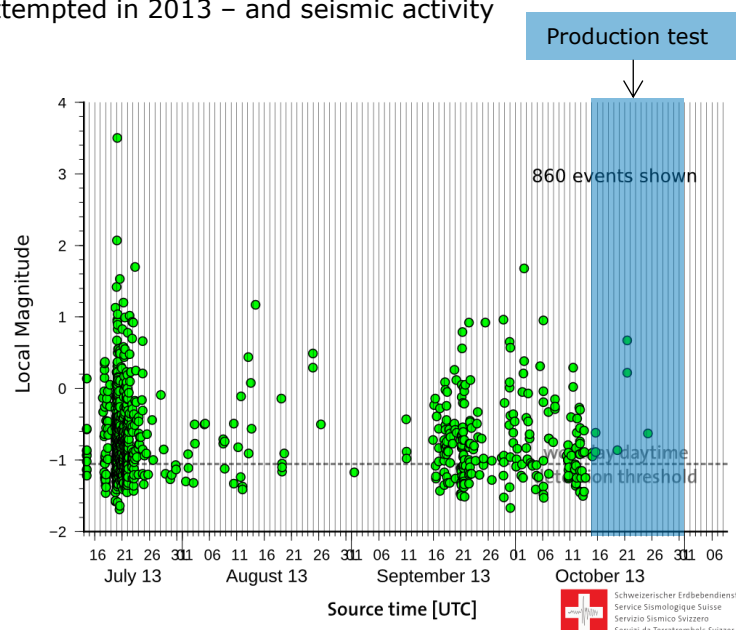
1. There are three thought experiments, each with its own discussion table.
2. Select a moderator for each table. This person will lead the discussion and supervise the respective thought experiment. The moderators remain at the same table throughout.
3. Divide the class into three groups.
4. Each group has 15 minutes to discuss the questions at its respective table.
5. The moderator records the most important points on paper (or digitally).
6. After 15 minutes, each group changes tables (the moderators stay).
7. Finally, each moderator presents to the class what was discussed at their table.



Thought experiment 1: Can earthquakes be stopped?

Let's imagine it was possible to reduce the pore pressure along a fault line by pumping water out of the rock. In theory, this should lower the likelihood of further earthquakes. In St. Gallen, such an intervention was actually attempted in 2013 – and seismic activity decreased significantly.

Discussion question:
 Could this be used to deliberately reduce the probability of earthquakes?



Solution task 2: Thought experiments

Basically, all answers are individual, but here are a few facts about Thought Experiments 1 and 2:

Thought experiment 1: Can earthquakes be stopped?

The engine of earthquakes, plate tectonics, runs continuously, building up tension all the time. In the best-case scenario, you buy yourself a reprieve at the cost of a future quake that could release even more energy. It would be extremely expensive (requiring a great many boreholes) and probably also dangerous, because our knowledge of where critically pre-stressed areas are located is too imprecise.

Bad idea.

Thought experiment 2: Can tectonic stresses be reduced in a controlled manner?

Earthquake, magnitude 7: Fracture length of about 50 km, roughly the distance between Zurich and Lucerne, with an offset of several metres.

Earthquake, magnitude 1: Approximately 10 m fracture length with an offset in the millimetre range.

So how many earthquakes would it take?

Magnitude 7: 2×10^{15} joules = 2 petajoules (PJ)

Magnitude 1: 2×10^6 joules = 2 megajoules (MJ)

This means that 1,000,000,000 magnitude 1 earthquakes would be needed to dissipate the energy of a single magnitude 7 earthquake, which would require regular drilling every 1–2 kilometres.

Bad idea.

Thought experiment 3: Can earthquakes be triggered in a controlled manner?

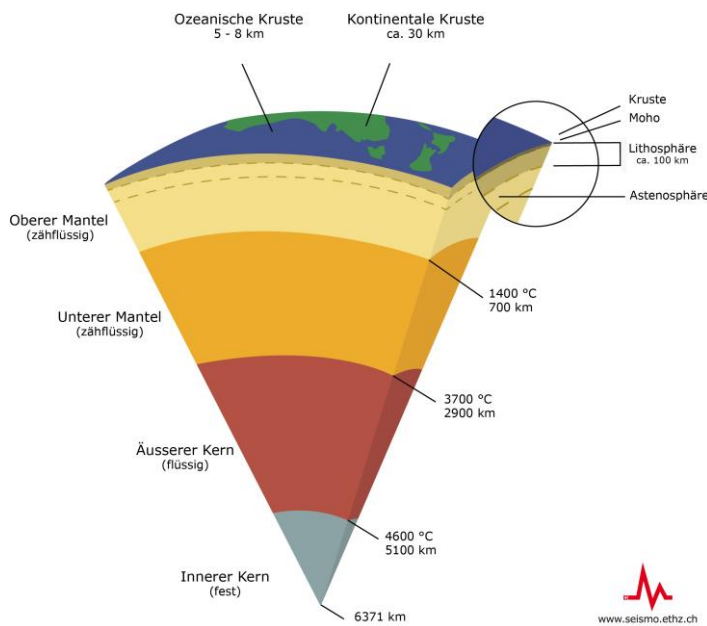
Individual solutions.

3. Geothermal energy

Geothermal energy, or “earth heat”, refers to the thermal energy present beneath the Earth’s surface. Alongside other renewable energies, it is a promising resource for electricity and heat production, harnessing the enormous heat found deep underground.

Unlike renewable energies such as wind and solar, which depend on weather conditions, geothermal energy is a stable and constant source of power. Geothermal energy can be used for various purposes, including electricity generation and heating and cooling buildings.

3.1 Energy source: hot earth



The Earth is a huge heat reservoir. The deeper you go into its interior, the warmer it gets. In the lithosphere, temperature rises by about **3 °C per 100 m** of depth. In the Earth’s interior, temperatures reach around **5,000 to 6,000 °C**, comparable to those on the surface of the Sun.

The various “temperature layers” are not uniform in depth. In some regions, it gets very hot just a few hundred metres below the surface – these are known as **heat anomalies**. Nature even helps in these areas: hot water can rise through cracks and crevices in the rock.

Figure 4. Structure of the Earth

This occurs in countries such as Iceland, Italy, Indonesia and New Zealand, where volcanoes, geysers and hot thermal springs allow heat from the interior to reach the surface. Thermal springs can also be found in Switzerland, for example in Zurzach (AG), Schinznach (AG), Lavey-les-Bains (VD) and Leukerbad (VS).



Figure 5. Strokkur geyser in Iceland © Adobe Stock



Figure 6. Geldingadalir volcano in Iceland © Adobe Stock



Figure 7. Pamukkale calcareous thermal spring in Turkey © Adobe Stock

3.2 Deep geothermal energy

Depending on the depth and the heat utilised, there are two types of geothermal energy:

- **Near-surface geothermal energy** (< 400 metres): Includes geothermal probes and probe fields, groundwater heat utilisation, energy piles¹ and geostructures. Induced earthquakes are unlikely.
- **Deep geothermal energy** (> 400 metres): Can potentially lead to induced earthquakes.

As this module focuses on induced earthquakes, we will concentrate on deep geothermal energy in the following chapters.

Deep geothermal energy accesses rock structures that lie at least 400 metres below the Earth’s surface. Depending on the underground temperatures, different applications are possible.



Aquifers (water-bearing layers) located at depths of **400 to 2,000 metres** have temperatures ranging from **20 to 70 °C**. The thermal water they contain is very well suited for **heat extraction**.



At a depth of **4,000 metres**, temperatures in Switzerland range from **150 to 200 °C**. Geothermal projects that access these rock layers typically use part of the energy extracted directly for **electricity generation**, while the remainder can be fed into a **district heating network**.

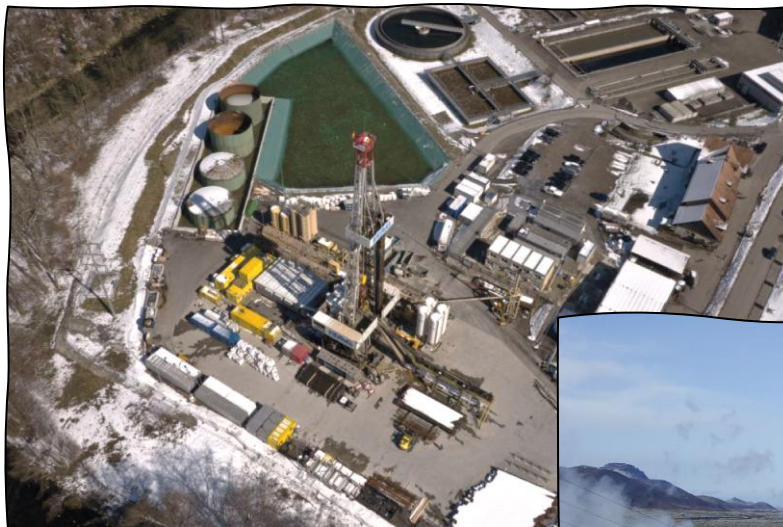


Figure 8. The geothermal project in St. Gallen in 2013 planned to use naturally circulating water in existing aquifers at a depth of over 4,000 metres for electricity production. © City of St. Gallen / St. Gallen Public Utilities



Figure 9. The Hellisheiði power plant in Iceland generates electricity and hot water using 50 boreholes that reach depths of up to 2,200 metres. (© ThinkGeoEnergy, CC BY 2.0, <https://commons.wikimedia.org/w/index.php?curid=10907139>)

¹ What are energy piles? “Heat from the ground” (TU Delft TV): <https://www.youtube.com/watch?v=j4d1AvWkNSg> (25-09-2025)

There are two distinct systems for generating energy at great depths:

Petrothermal system

In this method, water is pumped at high pressure into the warm subsurface – usually into hard, crystalline rock – over several days. This rock often contains natural cracks (known as fissures) through which the water can circulate and heat up.

The pressure of the injected water creates additional small cracks in the rock, which can trigger small earthquakes (microquakes) near the injection well. However, these microquakes are not an unwanted side effect but an important tool. The aim is to alter the rock so that water can flow through it more easily. This creates a network of fractures (fracture system) that is ideal for utilising geothermal energy.

Most of these earthquakes are so weak that they cannot be felt by humans. The induced seismicity is strictly monitored, and the injection process is adjusted if necessary to keep it as low as possible.

Later, a second borehole (*production well*) is drilled to create an artificial cycle: cold water is pumped down, heated underground, and returns to the surface as hot liquid. This heat can then be used, while the cooled water is pumped back down into the ground.

The challenge with this method is to create a sufficiently large fracture system. Water should flow as evenly as possible through a large volume of rock without taking a “shortcut.” This occurs when water flows too quickly from one borehole to another without heating sufficiently. At the same time, care must be taken to ensure that no strong earthquakes are triggered that could cause damage.

Other terms for petrothermal geothermal energy are *hot dry rock*, *deep heat mining*, or *enhanced geothermal system* (EGS).

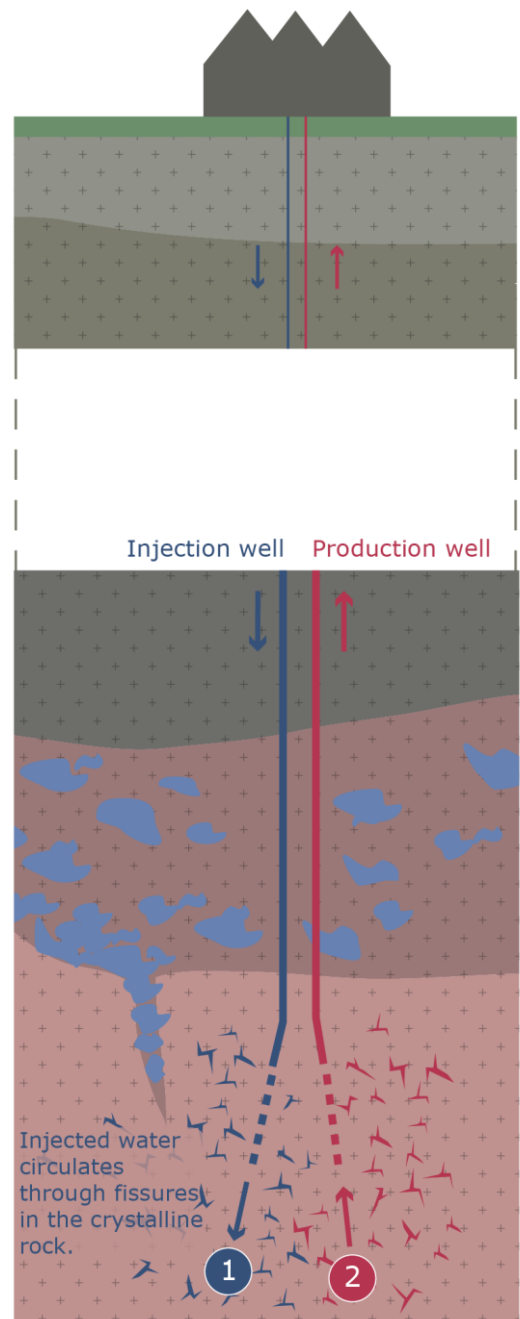


Figure 10. How the petrothermal system works.

Hydrothermal system

A hydrothermal system uses hot water that occurs naturally in water-bearing rock layers (aquifers) deep within the Earth.

Hydrothermal systems only work where there are aquifers with sufficiently hot water – typically above 100 °C – and a well-permeable fracture system.

This means they can only be implemented at certain locations. Extensive preliminary seismic exploration is therefore often a prerequisite for identifying a suitable site.

At least two boreholes are required for hydrothermal systems:

- **Production well (1)**: The first borehole pumps hot water from the rock to the surface to utilise the heat.
- **Injection well (2)**: The cooled water is then returned to the subsurface via a second well.

If there is already sufficient water flowing at depth, the rock hardly needs to be artificially altered. This is why hydrothermal systems usually experience few or no microearthquakes. Nevertheless, **induced seismicity** can also occur here. This is because the injection of water under high pressure can alter the stresses in the rock.

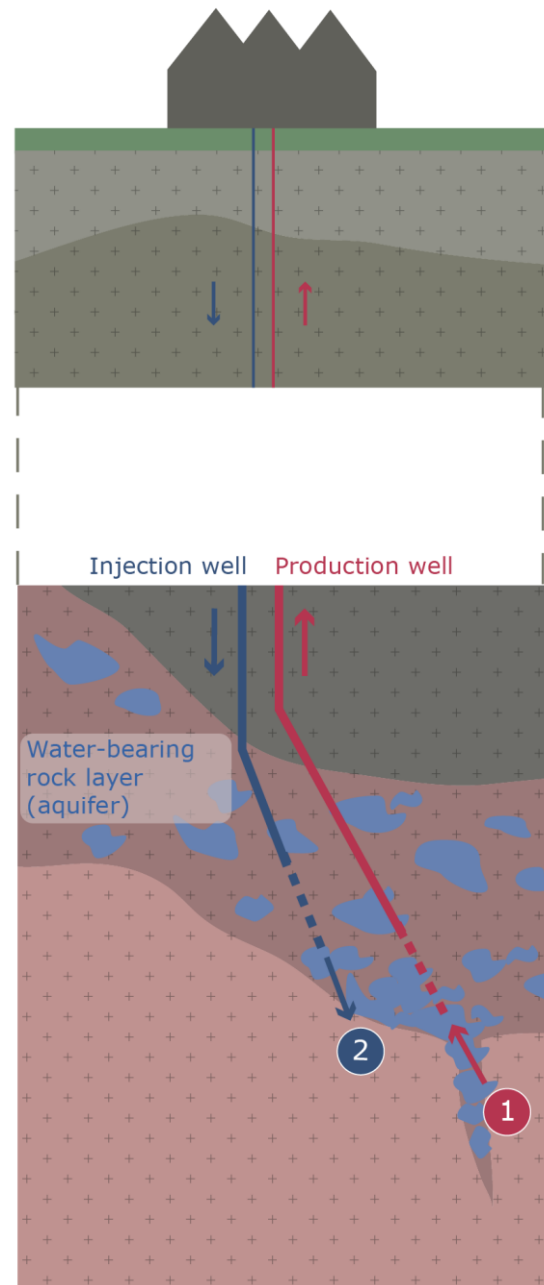


Figure 11. How the hydrothermal system works.

Important: In practice, a geothermal field usually comprises several production wells and a significantly larger number of injection wells. For example, the Hellisheiði geothermal power plant in Iceland has around 50 wells reaching depths of up to 2,200 metres (Figure 9).



Task 4: Types of geothermal energy

Label the infographic with the correct terms. Please note there are more terms than gaps!

Deep geothermal energy 400-5000 m

Hydrothermal

Near-surface geothermal energy 0-400 m

Petrothermal

400 m

Hydraulic

Reservoir

700 m

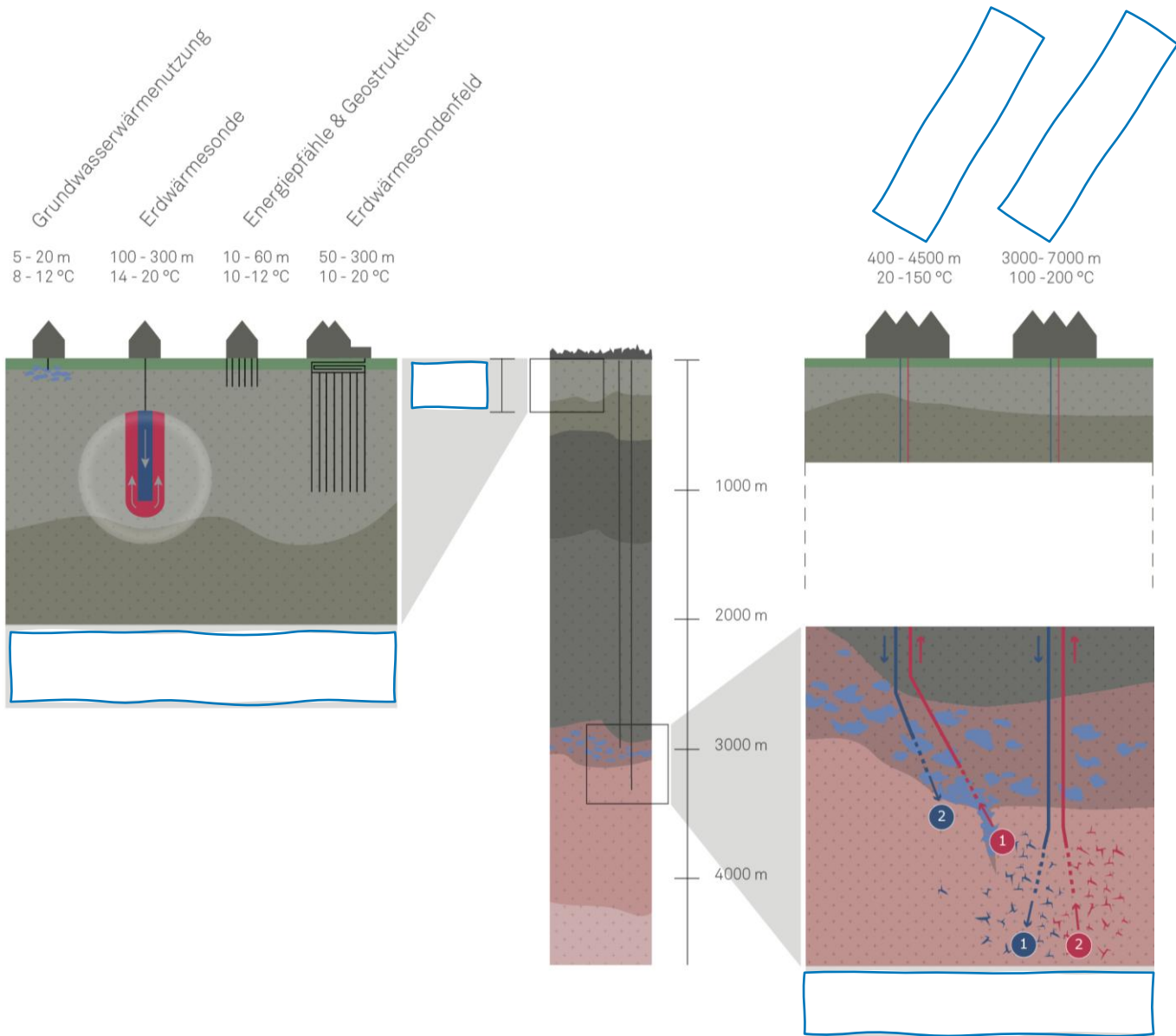
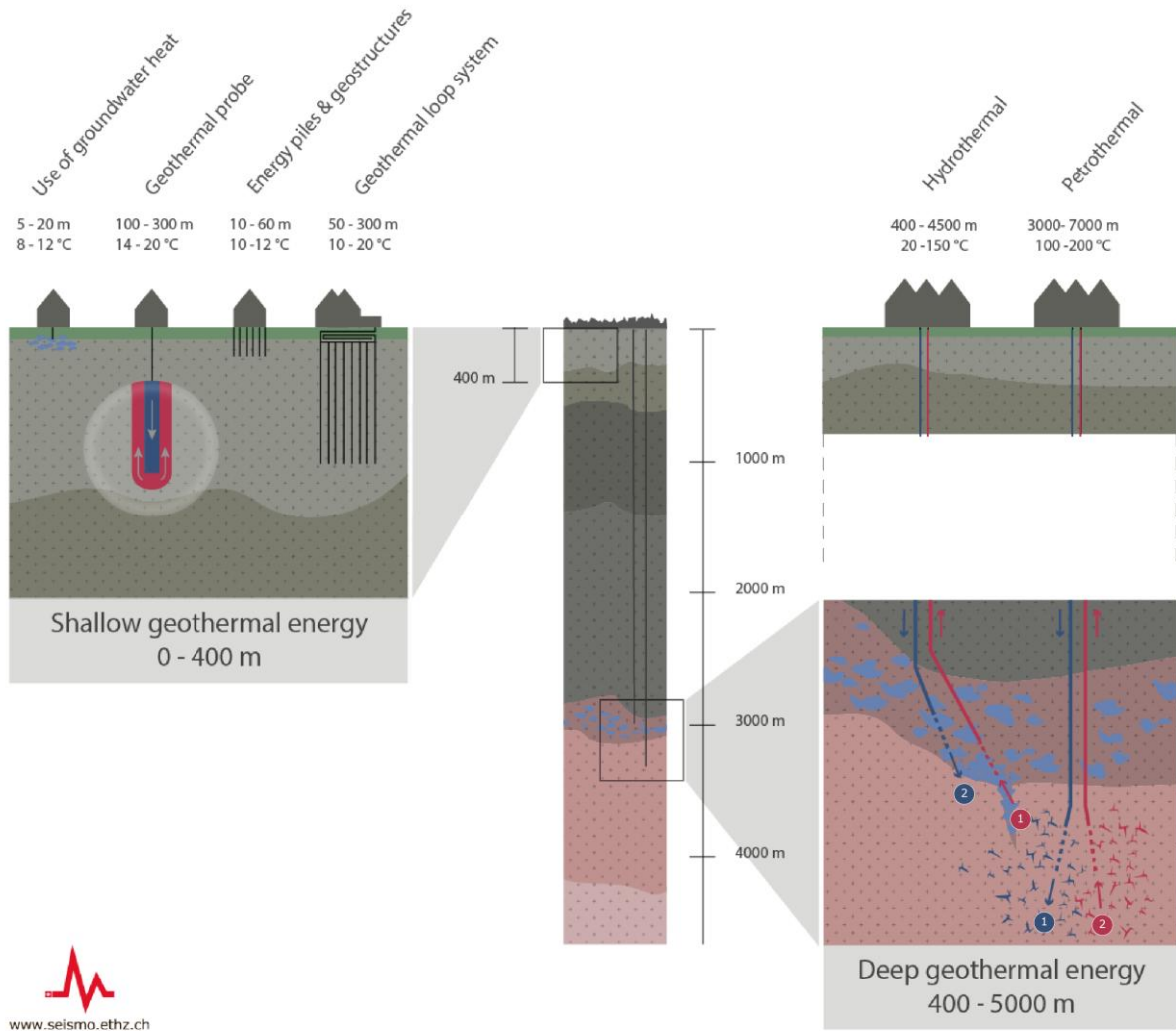


Figure 12. Types of geothermal energy

Solution task 4: Forms of geothermal energy



3.3 Hydraulic stimulation: the principle

The principle behind triggering earthquakes sounds quite simple in theory. This "recipe" works almost everywhere:

1. Drill into an active geological fault.
2. Inject water into the ground under high pressure.
3. This greatly accelerates natural tectonic processes.



Earthquakes play an important role, particularly in petrothermal projects. They help create a heat reservoir deep in the Earth. The aim is to prepare initially low-permeability rock so that water can flow through it, bringing heat to the surface.

For this to succeed, the rock underground must become hydraulically permeable. This is achieved by opening existing small cracks or creating new ones. To do this, water is injected into the rock under high pressure. The water increases the pressure within the rock (*pore fluid pressure*). When the stress becomes high enough, it is released in a sudden, jerky movement – an induced earthquake occurs.

The major challenge here is to generate earthquakes that are strong enough to change the rock, but weak enough that they cause no damage and are barely noticeable, if at all.

Some rock strata (e.g. aquifers) already contain large amounts of water. This natural pressure counteracts the existing tectonic stresses. If additional water is injected and the pore pressure increases further, the stress regime can become unstable. This can ultimately lead to an induced earthquake along a fault line (e.g. in hydrothermal systems).

3.4 Induced earthquakes in geothermal projects

Induced earthquakes were already observed **more than 100 years ago**, for example in connection with coal mining in Germany. With a few exceptions, these earthquakes are hardly noticeable, if at all. However, in some cases worldwide, induced earthquakes have caused considerable economic losses and even injuries.

In November 2017, a magnitude 5.5 earthquake shook the **South Korean** city of Pohang. The result: more than 100 people injured and damage amounting to 300 million dollars. Shortly afterwards, it was suspected that a nearby geothermal project could have triggered the earthquake. Subsequent studies and an international commission of experts confirmed this suspicion.

In **Switzerland**, man-made earthquakes are mainly associated with geothermal projects. In Basel, for instance, water injected into the ground under high pressure triggered an earthquake with a magnitude of 3.4 in 2006. On 20 July 2013, several tremors with magnitudes of up to 3.5 were recorded at a depth of 4,000 metres in the vicinity of St. Gallen.

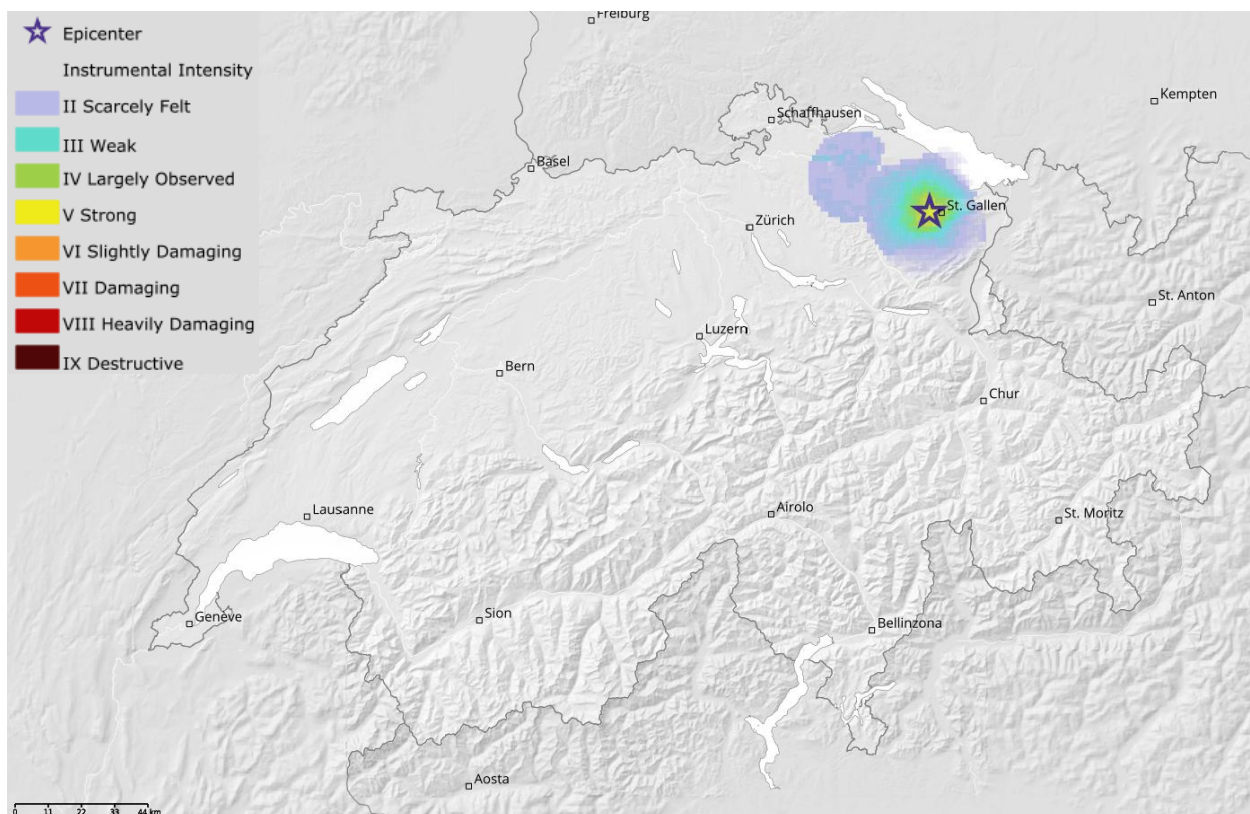


Figure 13. The induced earthquake with a magnitude of 3.5, which occurred in St. Gallen on 20 July 2013, was felt within a radius of approximately 15 km.

Task 3: Geothermal projects in Switzerland

1. Form groups of two.
2. Within each group, decide who will work on the Basel project and who on the St. Gallen project. Each of you should then create your own mind map based on your chosen project. Search the internet for information on the following points:

Possible sources:

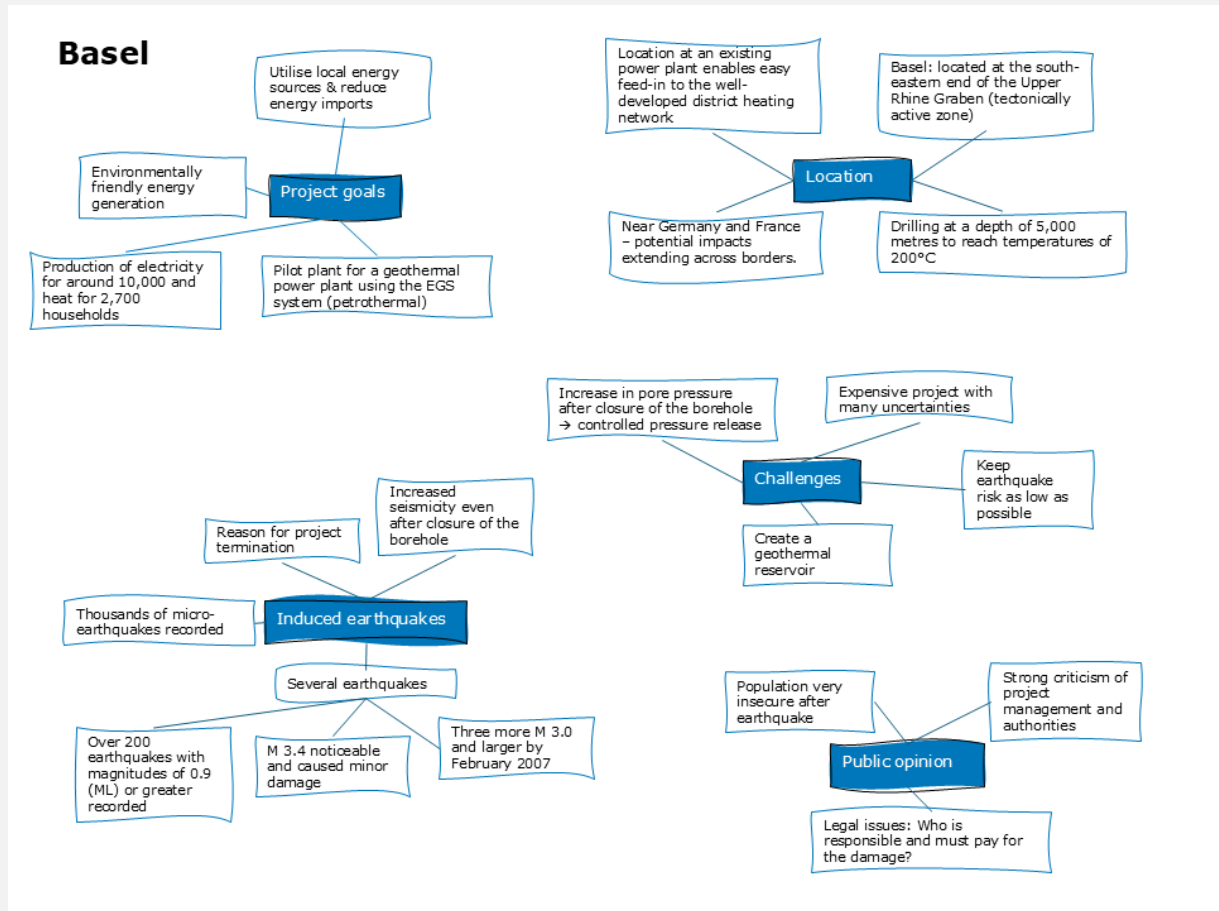
- St. Gallen geothermal project: www.seismo.ethz.ch/en/monitoring/special-networks/past-projects/geothermal-st-gallen/
- Basel geothermal energy project: www.seismo.ethz.ch/en/monitoring/special-networks/past-projects/geothermal-basel/



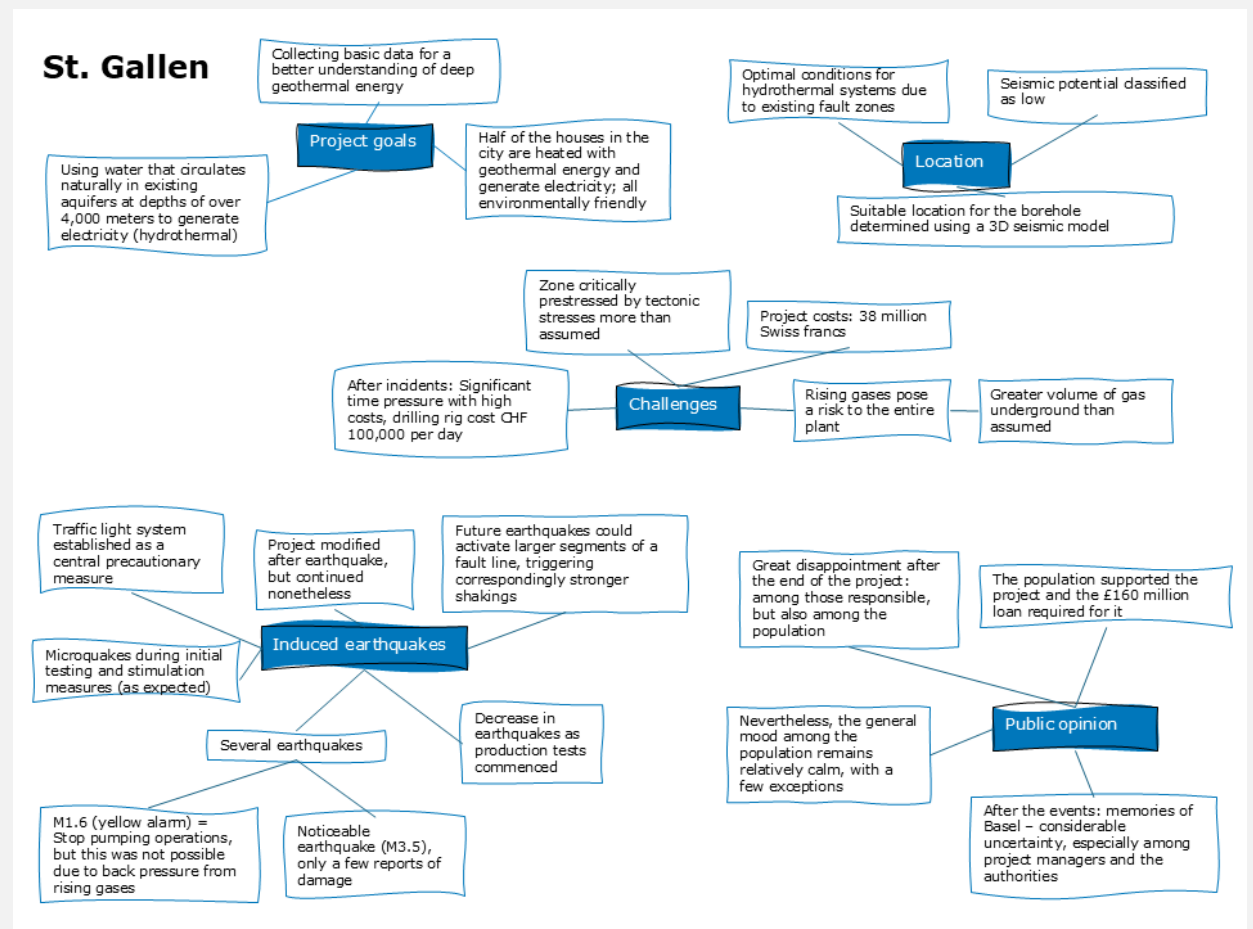
3. Present your mind maps to each other and explain what you have learned about the projects.

Solution task 3: Geothermal energy projects in Switzerland

Basel project (sample solution)



St. Gallen project (sample solution)



3.5 Geothermal energy in discourse: research, society and politics

Switzerland is committed to achieving the internationally agreed targets set out in the Paris Climate Agreement. This means that it is striving to limit global warming to well below 2 °C, and preferably to 1.5 °C, compared to pre-industrial levels. Global warming is caused by greenhouse gas emissions, with carbon dioxide (CO₂) accounting for the largest share. To achieve the global temperature target, emissions must be reduced to net zero by 2050. Net zero means that greenhouse gas emissions are reduced to zero as far as possible.

As part of this agreement, the Swiss energy strategy aims to generate 2 terawatt hours (TWh) of electricity from geothermal energy by 2050. Switzerland has considerable potential for deep geothermal projects. However, identifying suitable sites is time-consuming, and attempts are not always successful.

Task 5: Group puzzle

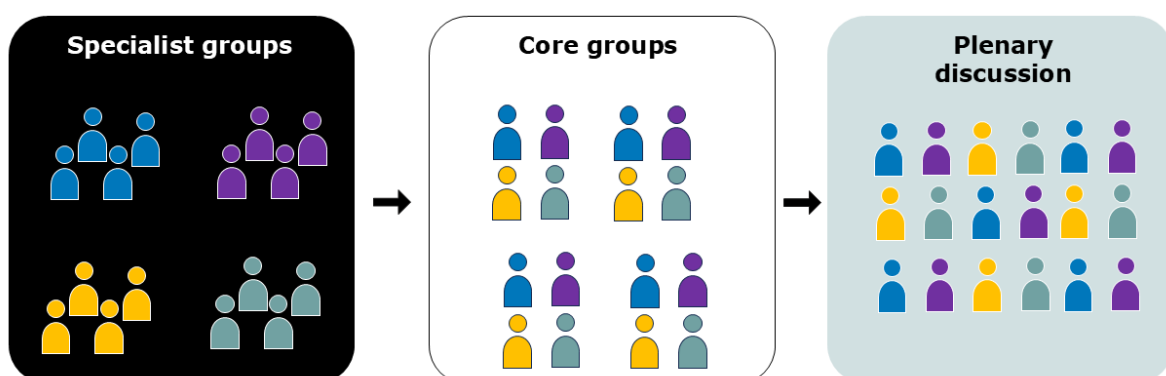
To better understand the social debate on geothermal energy, we will conduct a group puzzle.

First, you will work in **specialist groups**. Each group will focus on a specific perspective on geothermal energy (e.g. cantonal authorities, environmental organisations, operating company, residents). In doing so, you will acquire in-depth knowledge of your role.

Next, you will come together in **core groups**. Each role will be represented once in these new groups. You will discuss key issues and contribute your specific expertise. The aim is to gain insight into different perspectives and to think collectively about the opportunities and challenges of geothermal energy.

Finally, there will be a **plenary discussion** in which the most important findings and open questions from all groups will be compiled and reflected upon.

Duration: Depending on the desired level of depth, the group puzzle will take at least one lesson. Reading the role descriptions of the various specialist groups can also be assigned as homework in advance.



What it's about

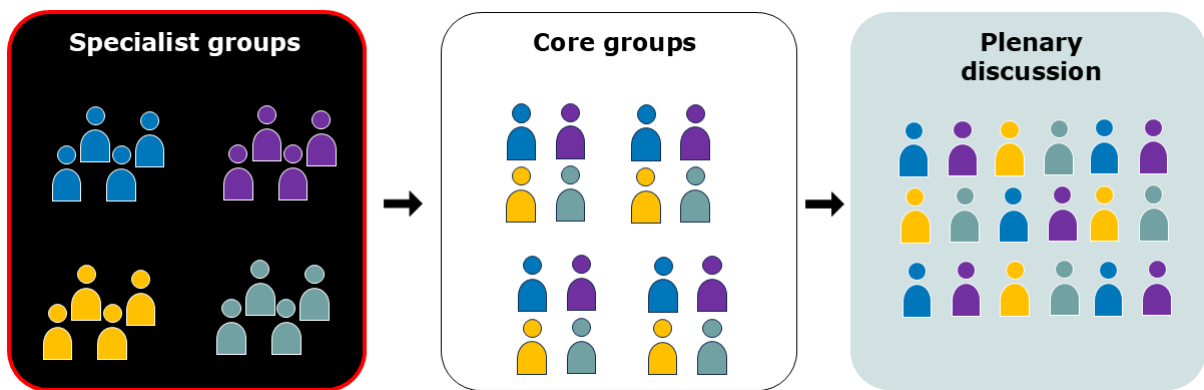
Geothermie AG is planning to build a geothermal power plant in the municipality of Schoolington. The technology to be used is the Enhanced Geothermal System (EGS), also known as a petrothermal system. Through a multi-stage process, the aim is to create a heat exchanger at a depth of approximately 4.5 km by increasing the hydraulic permeability of the crystalline bedrock.

You are invited to a round-table discussion organised by the municipality of Schoolington. At this event, representatives of the local population, the operating company, the cantonal authorities and an environmental organisation will discuss their respective interests, demands, opportunities and risks associated with such a geothermal plant.

Further reading

- Geothermal energy in brief: www.seismo.ethz.ch/en/knowledge/geothermal-energy-earthquakes/geothermal-energy-in-a-nutshell/
- Measures to mitigate induced seismicity: www.seismo.ethz.ch/en/knowledge/geothermal-energy-earthquakes/measures-to-control-induced-seismicity/
- Federal Office of Energy: www.bfe.admin.ch/bfe/en/home/supply/renewable-energy/geothermal-energy.html
- Swiss Geothermal Energy Association: <https://geothermie-schweiz.ch/>

Step 1: Specialist group



1. Read the information about your role and assigned topic on your own.
2. Spend 15 minutes searching for additional information on the Internet.
3. Take notes and then discuss the given discussion questions together.

Role profiles



Role profile 1: Energy company (=operating company)



Who are you?

You work for an energy company that plans to build a geothermal power plant. You are convinced that geothermal energy will play an important role in the future energy supply: clean, renewable, local and independent.

What do you want?

- To build and operate the geothermal plant in the long term
- To produce electricity or heat locally
- To achieve broad acceptance among the population
- To minimise risks while operating economically

What concerns you?

- You must invest large sums of money and bear significant financial risks
- There are uncertainties regarding induced earthquakes and potential public resistance
- You need to obtain permits and negotiate with many interest groups

Background information on the planned process

You – Geothermie AG – are planning to build a geothermal power plant in the municipality of Schoolington. The technology to be used is the Enhanced Geothermal System (EGS), also called a petrothermal system. Using a multi-stage process, the aim is to create a heat exchanger at a depth of about 4.5 km by increasing the hydraulic permeability of the crystalline bedrock.

In contrast to hydrothermal geothermal energy, EGS does not rely – or relies only to a limited extent – on existing hydraulic permeability, such as that found in large tectonic fault zones or karst geological structures. EGS can therefore, in principle, be applied in numerous geological settings. It deliberately increases the hydraulic permeability of existing fracture networks in the subsurface, using many small earthquakes triggered by the injection of water under high pressure as a tool.

The rock is stimulated in several steps. This allows closer observation of how the subsurface reacts to the injection of water. The aim is to reduce the risk of triggering earthquakes on the one hand and, on the other hand, of failing to create usable fractures for heat transport. The process seeks to stimulate only a limited rock volume at a time and gradually create a sufficiently large geothermal reservoir in several separate stimulation phases. This method differs from the single-stage, large-scale stimulation strategies used, for example, in the EGS projects in Basel (2006) and Pohang (2017).

The multi-stage stimulation process is designed to improve control, making it both easier to manage and safer. It has already been successfully tested on a smaller scale at ETH Zurich's BedrettoLab.

Further reading

www.bedrettolab.ethz.ch | <https://geothermie-schweiz.ch/> | <https://vgks-zh.ch/>

Your notes:

Possible discussion questions

- How will you convince the public of the merits of the project?
- What safety measures will you implement?
- How will you respond to negative media coverage?

Role profile 2: Residents



Who are you?

You live near the planned site of the geothermal plant in Schoolington. You have heard of other projects that triggered earthquakes. You are generally open to new forms of energy, but you also have concerns.

What do you want?

- Safety and protection for your homes and neighbourhood
- Have a say and be well informed
- No noise or traffic pollution
- No loss in the value of your property

What concerns you?

- You are afraid of damage caused by earthquakes
- You don't feel sufficiently involved in the process
- You are unsure whether the promises made by the operating company (= energy company) are reliable

Background information

In Switzerland, there have been two pilot projects for deep geothermal energy that induced earthquakes: in Basel (2006) and in St. Gallen (2013). Both projects were discontinued after seismic events.

– Basel

In this petrothermal project, water was pumped into the ground over several days to create cracks in the rock. After an earthquake of magnitude 2.6 occurred, the injection was stopped. A few hours later, a stronger earthquake of magnitude 3.4 was felt in the city and caused minor building damage. In total, more than 200 earthquakes were recorded, several of which were felt. The damage amounted to around CHF 6 million. The project was terminated in 2009.

– St. Gallen

The geothermal project in St. Gallen in 2013 planned to use naturally circulating water in existing aquifers at a depth of over 4,000 metres for electricity production (hydrothermal project). Similar projects in southern Germany, which drill into the same rock layers, are being successfully operated. The project in St. Gallen was abandoned in 2014 due to safety concerns, earthquake risks and low water flow underground. Several earthquakes occurred, including a noticeable one with a magnitude of 3.6. Opinions on the project were divided: some praised the climate-friendly energy source, while others had confidence issues and concerns about possible risks.

In recent years, research into geothermal energy has provided many new insights into how to make it both more efficient and safer. Since 2019, ETH Zurich has been operating a research laboratory in the Bedretto Valley (TI), where technologies, methods, and instruments for deep geothermal energy are tested and developed under controlled conditions. Nevertheless, the risk of induced earthquakes remains a central concern: the subsurface is complex and difficult to characterise, and much of the critical data only becomes available as a project progresses. However, monitoring systems and control measures have been introduced to manage induced seismicity in deep geothermal projects as effectively as possible.

Further reading

- Measures to mitigate induced seismicity: www.seismo.ethz.ch/de/knowledge/geothermal-energy-earthquakes/measures-to-control-induced-seismicity/
- Energy perspectives 2050+: <https://www.bfe.admin.ch/bfe/de/home/politik/energieperspektiven-2050-plus.html>
- Overview and detailed information on various geothermal projects in Switzerland (current and past): www.seismo.ethz.ch/de/monitoring/special-networks/overview/

Your notes

Possible discussion questions

- What would need to happen for you to support the project?
- What kind of say or influence would you like to have?
- What does "risk" mean to you personally?
- Would you consider taking out insurance to financially protect your home or property?

Role profile 3: Environmental organisation



Who are you?

You are members of an environmental organisation. You support the expansion of renewable energies – but only if they do not harm the environment, nature, or people. You monitor such projects closely.

What do you want?

- Sustainable energy production, but not at any price
- Strict environmental assessments and transparent procedures
- Protection of groundwater, soil, and ecosystems
- A focus not only on reducing the carbon footprint, but also on the overall impact on nature and society

What concerns you?

- The subsurface is a sensitive system; every borehole has the potential to cause damage
- Protective measures are essential wherever risks cannot be ruled out
- There is often a lack of long-term studies on environmental risks
- You feel that economic interests frequently take precedence and that supervisory authorities are not fully independent

Background information

According to the report *Electricity from Underground*, deep geothermal energy requires fewer raw materials whose extraction harms the environment than most other renewable energy sources. The greatest environmental impacts stem from drilling activities, for example CO₂ emissions, particulate matter, water consumption, and the use of chemicals. Depending on the plant, emissions range from 8 to 46 g CO₂ equivalents per kilowatt hour. This is significantly lower than most other energy sources, with the exception of hydropower. Even when plant construction is taken into account, the overall environmental impact remains low.

The expected service life of a geothermal plant in Switzerland is around 30 years. After this, the underground reservoir must be left to rest for a longer period in order to regenerate. From the perspective of environmental organisations, it is essential that such natural resources are used sparingly and sustainably over the long term. By law, an environmental impact assessment is required for deep geothermal projects with a thermal output of more than 5 megawatts. The operating company must demonstrate compliance with environmental protection requirements concerning groundwater and noise. The question of how to manage the risk of earthquakes is also a central issue.

A large part of the ecological footprint arises from the stimulation of the rock: several million litres of water are injected underground under pressure. The exact amount of water required depends on the composition of the rock. During operation, however, the water circulates in a closed cycle, which significantly reduces consumption. Depending on the location, habitats may be disturbed, noise may be generated, or local recreation areas may be affected. It is therefore necessary to examine whether there are more appropriate alternatives – for example, solar energy or the use of waste heat.

Further reading

- TA-Suisse publication "Electricity from deep below": <https://www.ta-swiss.ch/publikationen>
- Federal Association for Geothermal Energy, Environmental and Climate Protection: www.geothermie.de/geothermie/einstieg-in-die-geothermie/umwelt-und-klimaschutz
- "Monitoring the environment around geothermal sites": <https://destress.ethz.ch/en/Best-Practices/Environment/index.html>

Your notes

Possible discussion questions

- How can geothermal energy projects be developed in an environmentally friendly way?
- Which aspects of deep geothermal projects should be regulated by law?
- Where should the line be drawn between benefits and risks?
- How can society be encouraged to stabilise or reduce its energy consumption – through awareness, incentives, or regulation?

Role profile 4: Cantonal authority



Who are you?

You work for a cantonal authority responsible for approving geothermal projects. You are neutral and want to examine the project carefully. You also must mediate between different interests and ensure that laws and safety standards are upheld.

What do you want?

- Legally compliant and transparent procedures
- Safety of the population and protection of the environment
- Safeguarding groundwater and ecosystem
- Support of renewable energy to contribute to government climate targets

What concerns you?

- You are under both political and public pressure
- You must evaluate technical reports, even though much remains uncertain
- You are tasked with building trust and resolving conflicts of interest between different stakeholders

Background information

Switzerland is heavily dependent on energy imports. At the same time, climate protection requires a significant reduction in CO₂ emissions. Deep geothermal energy could help address both challenges, as it provides renewable energy produced directly within the country. However, such projects are often technically demanding and involve risks. This is why clear rules, thorough planning, and careful oversight by the cantonal authorities are essential.

Cantonal authorities play a central role in deep geothermal projects. They are responsible for granting permits – in particular drilling permits – and for monitoring compliance with environmental and safety requirements. By law, an environmental impact assessment is required for plants with a thermal output of more than 5 megawatts. The operating company must demonstrate how it intends to mitigate risks such as earthquakes, noise, and groundwater pollution. Drilling may only begin once all legal requirements have been fulfilled.

Even after approval, the canton continues to monitor operations. It may impose conditions, for example regarding the maximum injection rate or requirements for real-time monitoring. It must also respond quickly to incidents such as micro-earthquakes or gas leaks. In addition, the cantonal authority informs the public and handles objections. Communicating the project in an understandable way and building trust are crucial tasks when managing a technically complex and potentially controversial issue.

The Swiss Seismological Service (SED) at ETH Zurich generally supports cantons free of charge with independent expertise. It helps to assess seismic risks, provides recommendations, and can take over seismic monitoring. This also includes informing the public.

Further reading

- Measures to mitigate induced seismicity: www.seismo.ethz.ch/en/knowledge/geothermal-energy-earthquakes/measures-to-control-induced-seismicity/

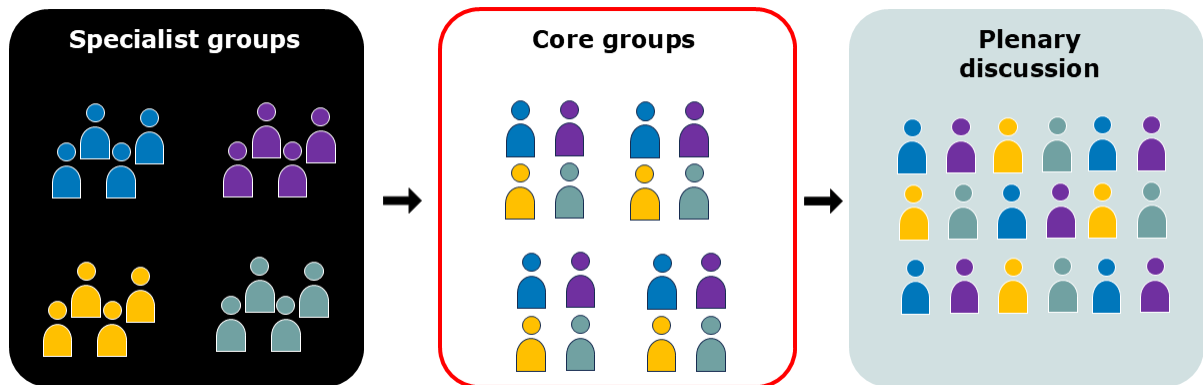
- Geothermal energy and the SED: www.seismo.ethz.ch/en/knowledge/geothermal-energy-earthquakes/geothermal-energy-and-the-sed/
- Promotion of geothermal energy: www.bfe.admin.ch/bfe/en/home/promotion/renewable-energy/promotion-geothermal-energy.html
- Net zero target Switzerland: www.bafu.admin.ch/bafu/en/home/topics/climate/klimapolitik/ziele-und-strategien/netto-null-ziel-2050.html
- Climate and Innovation Act (in German, French and Italian): www.bafu.admin.ch/bafu/de/home/themen/klima/dossiers/klimaschutzgesetz.html

Your notes

Possible discussion questions

- How would you weigh up the different interests of the population, environmental organisations and energy companies?
- What requirements would you set for approving the project? Consider the environment, safety, seismicity and public opinion.
- What risks are acceptable to you (e.g. micro-earthquakes, noise)?
- What steps could you take to reduce risks or stop the project?
- What if your team does not have the necessary knowledge to deal with these challenges?

Step 2: Discussion in core groups



Now sit down with one expert from each of the other interest groups. Select three of the questions below and discuss them in the group. Record your answers in keywords. One person from the group should also summarise the most important findings from your discussion. Allow 15–20 minutes for this.

Fundamental and decision-making questions

1. Should we support the geothermal project in Schoolington and thereby contribute to Switzerland's energy and climate strategy?
2. What conditions must be met for the project to be implemented successfully?

Risks, acceptance and role perspectives

3. How can potential risks be minimised and the chances of success for a geothermal project increased?
4. The "not in my back yard" (NIMBY) phenomenon: surveys show that people are generally more accepting of geothermal projects provided they are not located in their immediate vicinity. How can acceptance among the residents in Schoolington and among environmental organisations be promoted?
5. What role could research play in the Schoolington deep geothermal project, and how could this benefit both the project and society?
6. What interests does our group (e.g. environmental organisation / residents / cantonal authority / operating company) represent – and where might conflicts of interest with other stakeholders arise?

Step 2: Discussion in core groups | Food for thought

1. Should we support the geothermal project in Schoolington and thereby contribute to Switzerland's energy and climate strategy?
 - Weighing up the risks (e.g. induced earthquakes, contamination) and opportunities (e.g. reliable and constant energy source)
 - Induced seismicity: The risk of earthquakes can be minimised through careful site selection, modern technologies and continuous monitoring.
 - Compare with other renewable energies
 - By replacing fossil fuels, geothermal energy can make a significant contribution to reducing greenhouse gas emissions

2. What conditions must be met for the project to be implemented successfully?
 - Careful site selection and planning: geological surveys and risk assessment
 - Use of modern technology: advanced drilling techniques and real-time monitoring systems
 - Strict safety and environmental standards
 - Transparent communication and public involvement: actively informing the public and involving local communities in the planning process
 - Insurance and financial security

3. How can potential risks be minimised and the chances of success for a geothermal project increased?
 - Technology:
 - Gradual stimulation of the rock
 - Real-time monitoring and a traffic light system for monitoring
 - Careful site selection
 - Authorities:
 - Environmental impact assessment
 - Clear requirements (e.g. maximum injection rate)
 - Continuous monitoring and emergency plans
 - Society:
 - Transparent information and dialogue with residents
 - Involvement of environmental organisations
 - Fair compensation in case of damage

4. The "not in my back yard" (NIMBY) phenomenon: Surveys have shown that people are more accepting of geothermal projects as long as they are not located in their immediate vicinity. How can acceptance among the residents in Schoolington and environmental organisations be specifically promoted?
 - Addressing individual fears and concerns among the population
 - Solutions to increase acceptance: transparent communication, community involvement, safety standards, successful pilot projects, independent seismic monitoring (by the SED), adequate insurance

5. What role could research play in the Schoolington deep geothermal project, and how could this benefit both the project and society?
 - Technological development: improved injection methods (e.g. where, how and how fast)
 - Risk minimisation: seismic monitoring by the SED and environmental impact assessment
 - Efficiency improvement: heat transfer and reservoir management
 - Cost reduction: More cost-effective technologies and development of financing models
 - Social acceptance: Development of effective participation strategies and information products, development of a needs-based insurance system

- Interdisciplinary cooperation: integration of various relevant disciplines + international co-operation for knowledge exchange
 - Pilot projects and best practices for the future
6. What interests does our group (e.g. environmental organisation / residents / cantonal authority / operating company) represent – and where might conflicts of interest with other stakeholders arise?

Energy companies (=operating companies)

- Interests:
 - Successful project implementation (economically and technically)
 - Smooth approval process, planning security and clear framework conditions
 - Efficient cooperation with the various interest groups
 - Positive communication and public relations
- Conflict of interests:
 - Speed of implementation vs. thorough review procedures.
 - Economic efficiency vs. comprehensive safety requirements.
 - Trade secrets vs. the public's demand for transparency.

Residents

- Interests:
 - Safety and no impact on quality of life (no damage, no disruption)
 - Early information and consultation
 - Fair compensation for any damage
 - Better understanding of the uncertainties associated with the project
- Conflict of interests:
 - Support for climate targets vs. personal impact.
 - Trust in authorities vs. fear of loss of control.
 - Long-term benefits vs. short-term burdens.

Environmental protection organisation

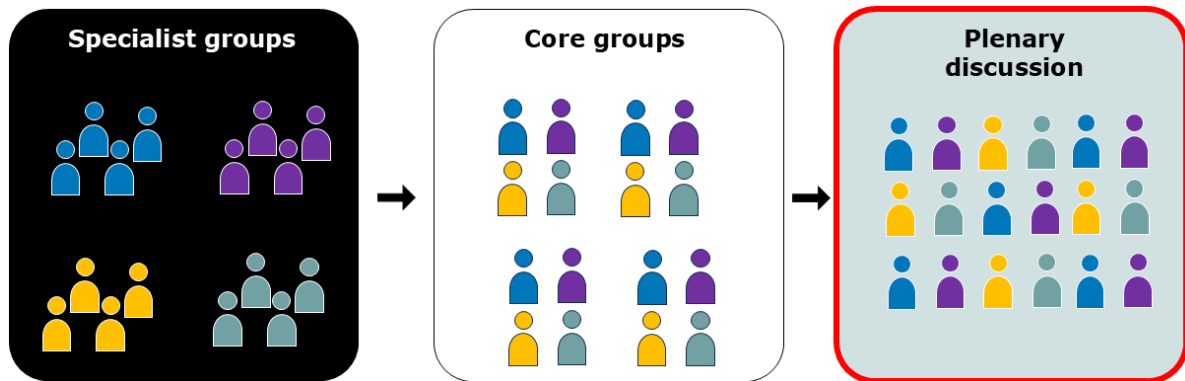
- Interests:
 - Planning protective measures in advance
 - Environmental protection before economic interests
 - Transparent environmental impact assessment
 - Site selection with minimal impact on sensitive ecosystems.
 - Involvement and transparent communication
- Conflict of interests:
 - Location near residential areas vs. ecological conservation areas.
 - Use of renewable energy vs. interference with nature and soil.

Cantonal authorities

- Interests:
 - Ensuring public safety
 - Cooperative collaboration with and complete documentation from the operating company
 - Promoting climate targets
- Conflict of interests:
 - Economic pressure from project developers vs. careful examination and requirements.
 - Promotion of innovation vs. precautionary principle.

Step 3: Plenary discussion

1. One person from each core group presents the main findings from their discussion in 3 minutes.
2. Closing round / summary by the teacher

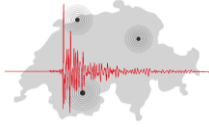


Note on step 3: Plenary session

As the teacher, conclude by emphasising that this is a very challenging topic. In a project like this, there are many different opinions from various interest groups and multiple aspects that need to be considered. Experts from all relevant fields are therefore extremely important.

Further teaching material

Want to learn more about earthquakes? Explore additional information here:



Earthquakes introductory module – basics and key concepts
[Download](#)



Misinformation and media literacy
[Download](#)



Earthquake hazard and risk in Switzerland
[Download](#)



Earthquake monitoring and Raspberry Shake
[Download](#)

Further information on earthquakes can be found on the website of the Swiss Seismological Service at ETH Zurich at www.seismo.ethz.ch.

We welcome your questions or suggestions regarding the teaching modules, or any other topics related to earthquake education in schools.

E-mail us: seismo_at_school@sed.ethz.ch

