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# First results from the exploration phase of the Haute-Sorne EGS project in Canton Jura, Switzerland

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## ABSTRACT

After 10 years of planning and permitting the multi-zonal stimulation EGS project in Haute-Sorne has started the exploration phase.

A field campaign with Ambient Noise Tomography was carried out in February 2024. This was followed by a 2D geophysical campaign in April 2024. The drilling site work started in fall 2023 was completed by April 2024. After the official approvals from the canton, the first exploration well was started on 21 May 2024 and drilled to a depth of 4000 m by mid-August with a 350 t rig. The drilling of the hard crystalline rocks with specially designed PDC bits benefited largely from the experience and the very successful learning curve from the Utah FORGE project.

This is the first borehole in the entire Jura Arc to reach the crystalline basement and provide information on the deep subsurface. The drilling went through all the sedimentary rocks of the Secondary Era. Significant thickness of rock salt of 150 m was crossed in the Triassic at a depth of 1200 m. The presence of older sediments from the Primary Era (Permocarboniferous) was uncertain before drilling. More than 700 m thick, including coal-bearing levels, were finally drilled.

The crystalline basement is made up, as expected, of gneiss and granite. Measurements in the borehole showed that these rocks are crisscrossed by numerous natural fractures. Preliminary temperature measurements at 4000 m show a normal temperature gradient for Switzerland. No induced seismicity was measured during drilling or cementing. At this stage of the work, the conditions are met for the continuation of the project.

A 3D geophysical campaign was conducted in January 2025 and a stimulation test is scheduled for summer 2025 incorporating all the experiences obtained to date from Utah FORGE. Thereafter, data analysis and integration, model updates and risk studies will be done in order to make a decision for the continuation of the project.

The next phases include the drilling of a second well with a horizontal section of up to 1500 m at a depth of about 5000 m. A reservoir will be created out of the horizontal section with the multi-stage stimulation concept similar to the ones tested at the Bedretto underground laboratory and recently utilized successfully in Utah and Nevada by the Utah FORGE project and FERVO Energy. At this time, the vertical first well will serve as monitoring well instrumented with a seismometer chain that was tested and qualified for high temperatures previously at the Utah FORGE project.

Thereafter, the first well will be deepened and drilled horizontally through the stimulated reservoir. Most likely, a second multi-stage stimulation will be necessary also in the second horizonal section for an optimal hydraulic connectivity between the two wells. Monitoring will then be done out of the second well.

After the creation of the reservoir a circulation test will be performed and an ORC power plant with a capacity of up to 5 MW will be constructed by 2029.

## 1. INTRODUCTION

After ten years of planning and permitting, the multi-zonal stimulation Enhanced Geothermal System (EGS) project in Haute-Sorne has entered its exploration phase. Developed by Geo-Energie Suisse AG, the multi-zonal stimulation concept was designed in response to lessons learned from the Basel EGS project in 2006 and has been patented for use in Switzerland since 2012. The same concept is now being successfully implemented in Utah, both by the U.S. Department of Energy's R&D project Utah FORGE

and by the private company FERVO Energy, which is currently building a 400 MW electric power plant.

Geo-Energie Suisse is a research partner in Utah FORGE and collaborates regularly with FERVO Energy, allowing the latest field knowledge to be integrated into the Haute-Sorne project.

The Haute-Sorne EGS project will be executed in three phases: (1) exploration including geophysical surveys, a 4000 m deep borehole, and a stimulation test; (2) drilling of a second deviated borehole, creation of the reservoir, and a circulation test; (3) construction of a geothermal power plant with an installed capacity of up to 5 MW.

This paper presents an overview of the state of the art of multistage EGS and preliminary results from the ongoing Phase 1.

## 2. OVERVIEW ON THE STATUS OF MULTI-STAGE EGS

The seismic risk observed during the EGS Basel project in 2006 delayed the development of deep geothermal energy in Switzerland for almost 20 years. The lessons learned from the Basel project indicated that controlling seismic risk could be achieved by limiting the radius of each stimulated fracture surface to a few hundred meters and using a multi-stage stimulation approach with ideally 30 or more stages created from horizontal borehole sections (Meier et al., 2015). Numerical modelling has predicted that 20 to 30 stages are necessary to achieve commercially viable flow rates of 40 to 100 l/s between two boreholes (Meier and Ollinger, 2016).

Following a decade of planning and permitting, the multi-zonal stimulation EGS project in Haute-Sorne commenced its exploration phase in 2024. The extended waiting period allowed for the development and testing of innovative tools, as well as incorporating advances made in the Western US.

Testing of a multi-stage stimulated reservoir in the Bedretto underground research rock laboratory demonstrated the suitability of available zonal isolation technologies and confirmed the feasibility of the flow rates required for industrial projects (Giardini et al., 2022). Technologies were also tested and improved for monitoring micro-seismicity and mitigating seismic risks in further R&D projects supporting the Haute-Sorne technical development (Alcolea et al., 2025a).

Significant progress for multi-stage EGS technology has been made recently in the Western US. In Nevada, FERVO Energy connected a multi-stage EGS project to the electrical grid, achieving approximately 3 MW, and has successfully operated it for over a year (Norbeck and Latimer, 2023; Norbeck et al., 2023). In Utah, FERVO Energy is scaling up the technology to target 400 MW of electrical power with a reservoir created and exploited using about 100 wells. Since 2023, they have drilled and stimulated approximately 30 horizontal wells, each with a total length of 4500 m (Dadi et al. 2024). The Utah FORGE project of the US Department of Energy, located on adjacent land, has drilled and stimulated two wells deviated to 65° from vertical, as well as several monitoring wells (Moore et al. 2023). Both Utah projects successfully demonstrated the concept through circulation tests in August 2024. The results are in good agreement with the predictions by Meier and Ollinger (2016).

Geo-Energie Suisse is involved as a research partner in the Utah FORGE project for micro-seismic monitoring utilizing down-hole seismometer chains, enabling precise imaging of the created reservoirs. Additionally, high-temperature downhole monitoring technology has improved significantly using DAS fibre-optic cables installed either along the deviated borehole and or temporarily deployed in a vertical monitoring well (Karvounis et al., 2025). The main objectives include providing high-quality micro-seismic data for reservoir imaging and testing and qualifying instruments, data handling, and real-time evaluation procedures and codes for the Haute-Sorne project (Alcolea et al., 2025b). The equipment tested and qualified in Utah will be deployed for the hydraulic test stimulation in Haute-Sorne planned in summer 2025 and later for the main stimulation during phase 2 of the project.

## 3. FIRST RESULTS OF THE EXPLORATION PHASE OF THE HAUTE-SORNE PROJECT AND NEXT STEPS

In February 2024, a field campaign using Ambient Noise Tomography was conducted, followed by a 2D geophysical campaign in April 2024. The drilling site civil construction work, which began in fall 2023, concluded in April 2024. After receiving official approvals from the canton, the first exploration well commenced on May 21, 2024, and reached a depth of 4000 m by mid-August, utilizing a 350-t rig. The drilling process, particularly through hard crystalline rocks with specially designed PDC bits (Garcia et al., 2025), benefited largely from the experience gained from the Utah FORGE project, and allowed to significantly reduce the rig time (Figure 1).

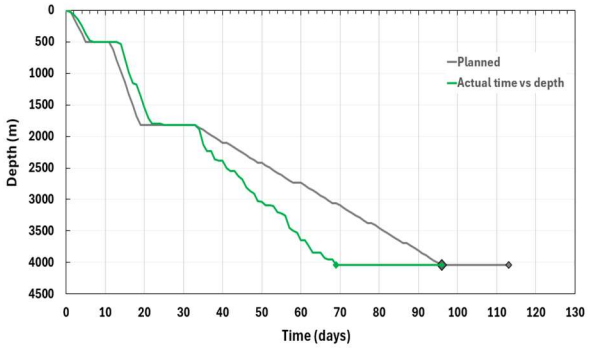


**Figure 1: GVL-1 well time vs. depth. The crystalline section from a depth of 2200 m to 4000 m was drilled with PDC bits improving drilling time by more than 20 days.**

This borehole is the first in the entire Swiss Jura Arc to reach the crystalline basement, providing valuable

information about the deep subsurface. The drilling passed through all sedimentary rocks of the Secondary Era, including a significant rock salt thickness of 150 m in the Triassic at a depth of 1200 m. The presence of older sediments from the Primary Era (Permocarboniferous) was confirmed, with more than 700 m drilled, including coal-bearing levels. Please note that Ambient Noise Tomography was able to predict most lithological changes (Figure 2).

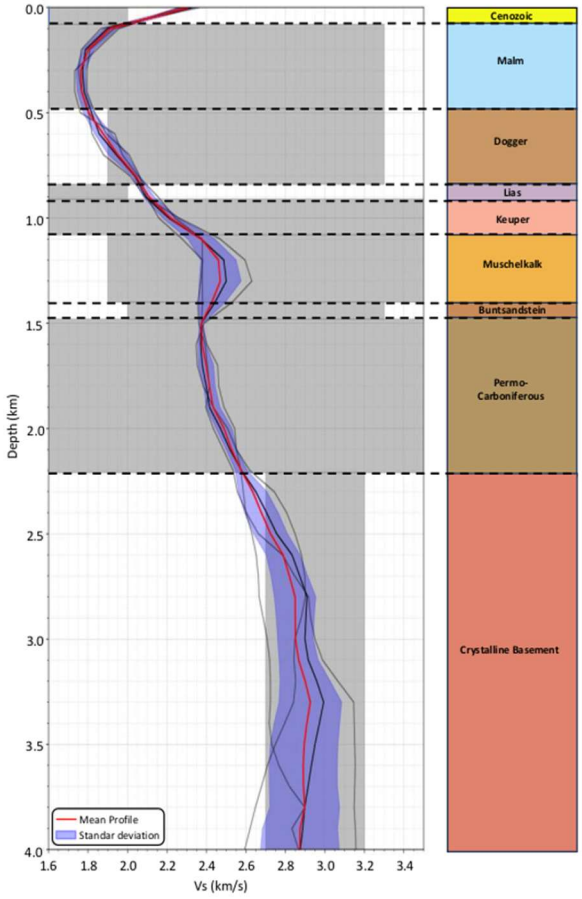


**Figure 2: Geology along the GLV-1 well (right). Shear wave velocities measured with Ambient Noise Tomography is capable to discern most lithological changes (left)**

The expected gneiss and granite comprised the crystalline basement. Borehole measurements indicated numerous natural fractures that can be hydraulically stimulated. Figure 3 shows the borehole interval "zone 5" that has been chosen for the stimulation test. Preliminary temperature readings at 4000 m showed a normal temperature gradient for Switzerland of about 30°C per km. No induced seismicity was detected during drilling or cementing activities. At this point, conditions are favourable for continuing the project.

A 3D geophysical campaign was conducted in January 2025 (Figures 4 and 5). The interpretation is still ongoing; however, geophysicists do not interpret any larger faults that would modify the current seismic risk model.

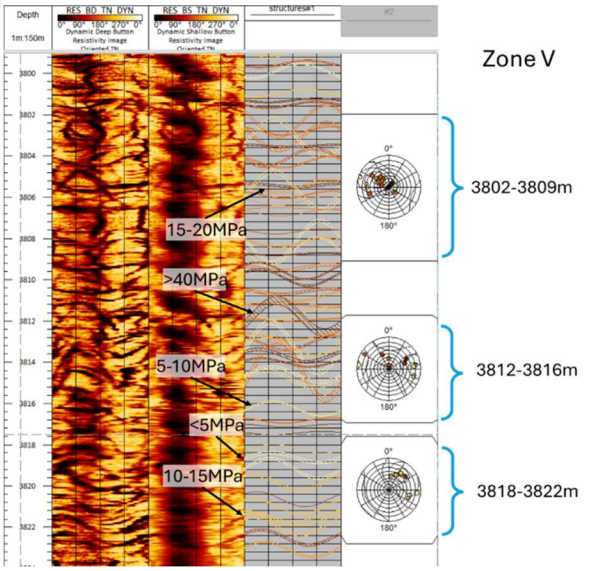


**Figure 3: Proposed zone V as the first option to perforate and stimulate. The color code on the fractures represents the minimum calculated shear pressures. Light yellow =< 5 MPa; Brown > 40 MPa. Three intervals inside this zone show high fracture frequency and orientations prone to be reactivated in shear. Interval 3800 - 3822 m seems the most promising.**

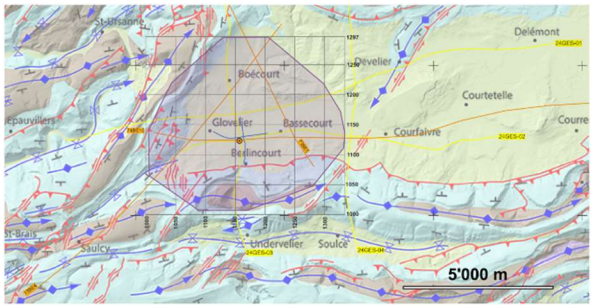


**Figure 4: Basemap for the Haute-Sorne geothermal project area. Vintage 2D seismic lines are shown in orange, the 23GES 2D seismic survey in blue and the 24GES 2D seismic survey in yellow. The 25GES 3D seismic survey is shown as a grid with inline (north to south) and crossline (east to west) labels. The shaded area with the grid corresponds to the area imaged by the 3D seismics. Also shown are the locations of inline 1165 and crossline 1110, both shown in Figure 4. The intersection of these two lines is situated over the location of the TD of GVL-1 and not the surface location (orange circle) as this closer to the test interval.**

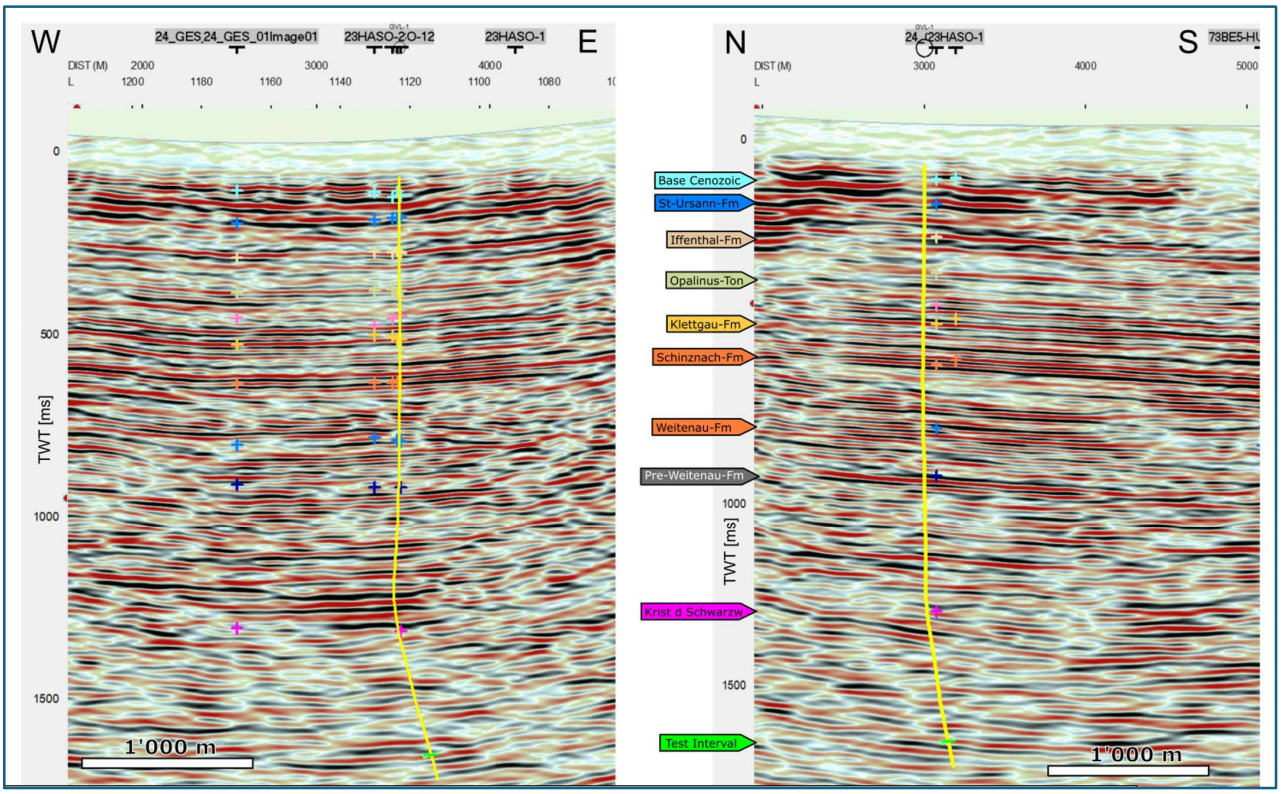


**Figure 5: Two (uninterpreted) seismic lines (W-E and N-S) extracted from the 3D volume and crossing at borehole GVL-1 (in yellow). The coloured crosses represent the seismic horizons interpreted on the 2D lines crossing this volume. The high continuity of the seismic reflectors indicates that the area is not affected by any major faults.**

## 4. STIMULATION TEST

After a detailed analysis of the logging and cuttings data the most adequate depth for the test stimulation in summer 2025 has been determined to be in the borehole interval from about 3800 to 3825 m (Figure 3).

At that depth the casing will be perforated such that 8 seismic monitoring 3C receivers of a digital tool string or the two-level analog 3C receivers evaluated at the Utah FORGE site can be placed with a cable that includes fiber optic lines for DAS, 4 above and 4 below the perforations to partially avoid flow noise during injection (Figure 6).

The stimulation test design will be based on data from Basel, Bedretto and Utah FORGE. The injected volume will be in the order of 500 $m^3$. At such volumes we expect the moment magnitudes to attain values between the Basel (max. 1.8) and the Utah FORGE 2022 stimulations of stages 1 to 3 (max. 0.8) and the stimulated areas reaching an equivalent radius between 60 and 100 m.

The current state of planning is summarized in the following sequential main steps:

1) Pressure static recovery: After installation of the geophone chain the well is shut-in at surface and pressures are monitored.

2) Constant head injection test including recovery for evaluating transmissivity before the test stimulation.

3) First test stimulation cycle:

a. Stepwise increase of injection rates with 10, 20, 45, 60 l/min. The duration of the steps is two hours each. Thereafter a shut-in is planned to evaluate the closure pressure of the previously opened fracture. The injection is then continued with 60 l/min with the objective of estimating the b-values reliably from micro-seismicity. The flow rate may be adjusted in function of the tolerable noise on the geophones.

b. Observation of pressures to identify processes of shearing, jacking or fracturing.

c. Stop injection if pressures at the wellhead are close to the pressure of 32 MPa the well was previously tested in March 2025.

d. Stop injection and further actions e.g. backflow according to the Traffic Light System (TLS).

e. Stop injection at an injected volume of 500 $m^3$. Decide to continue with a second 500 $m^3$ cycle if not enough statistical relevant seismic data have been obtained for b-value estimation.

f. Backflow for 2 weeks to reduce seismic risk.

4) Constant head injection head test including recovery for evaluating transmissivity after the test stimulation.

5) Installation of a long-term seismic monitoring system at depth into GLV-1.

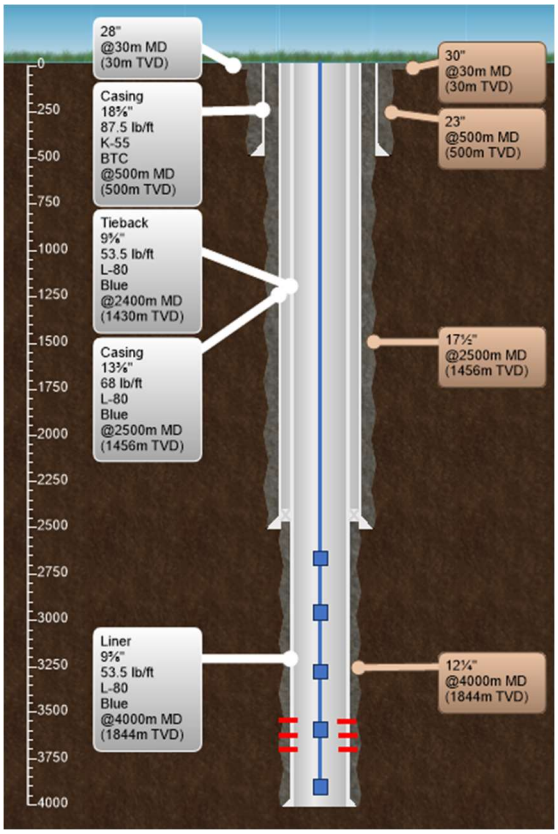


**Figure 6: Borehole information with schematic drawing of the perforations and the seismic receiver string for the stimulation test.**

## 5. ENVIRONMENTAL RISK MITIGATION

The Haute-Sorne project must be carried out to exemplary standards in every respect, which gives environmental protection and safety particularly high importance. To obtain official permits in 2015, extensive studies on seismic risks and environmental issues were conducted. These resulted in 136 requirements and conditions being included in the permit. Of these, 21 address induced seismicity. These conditions are particularly strict and demanding.

One of the permit requirements stipulates that the topic of seismic risk must be closely monitored by a five-member independent expert group that advises the authorities of the Canton of Jura. Another condition ensures that the latest developments in the field of induced seismicity are continuously integrated into the project. In response to this condition, Geo-Energie Suisse was asked to carry out a detailed analysis following the 2017 Pohang earthquake. It was demonstrated that, had the conditions of the 2015 Haute-Sorne permit been applied, a scenario like Pohang would not have occurred (Zingg and Meier, 2019).

A key requirement concerns the obligation to obtain environmental liability insurance that covers seismic risk. Based on a probabilistic risk study (Bethmann et al. 2025), Geo-Energie Suisse and Geo-Energie Jura were jointly able to secure an insurance policy with a coverage amount of CHF 100 million. In this context, another regulatory requirement involved comprehensive evidence preservation measures, which were carried out on more than 2,000 buildings.

In the following, we briefly outline the implementation of the most essential measures.

### 5.1 Risk mitigation of induced seismicity

A surface monitoring network with 11 stations (6 operated by Geo-Energie Suisse and 5 by the Swiss Seismological Service, SED) is in place. The SED maintains a dedicated website for the Haute-Sorne project that provides real-time seismograms from all surface stations: http://www.seismo.ethz.ch/de/monitoring/special-networks/geothermal-energy-haute-sorne/Real-Time-Seismograms/.
Additionally, SED provides automatic alerts if pre-defined threshold values are exceeded.

No seismicity was recorded during drilling. Nevertheless, procedures for handling seismic events during drilling were defined in advance as a precaution.

For the stimulation test, a comprehensive Traffic Light System (TLS) was established. This system is not only based on measured magnitudes but also considers the spatial extent of the stimulated volume and the potential activation of faults—an approach developed as a lesson learned from the 2017 Pohang earthquake (Zingg and Meier, 2019). Within the Utah FORGE project, Geo-Energie Suisse has developed and refined data analysis methods for seismic monitoring and has spent several years qualifying and calibrating instruments (Karvounis et al., 2025).

### 5.2 Risk mitigation groundwater

According to the environmental impact assessment of the Haute-Sorne project, potentially usable groundwater resources are limited to the Malm limestone formation. Formations below the Malm are considered saline and non-potable. The Malm formation is protected by an additional casing run to about 500 m (Figure 6). As no measurable drilling fluid losses or inflows of formation water were observed during drilling, the risk of groundwater contamination is considered low. Nevertheless, based on an additional requirement set by the canton, Geo-Energie Suisse has operated a network of spring and groundwater monitoring stations in the project area before the start of the project.

### 5.3 Noise

Noise disturbances are mainly relevant during drilling phases and the future operation of the ORC power plant. During the drilling phase, all legal noise limits were respected. Nonetheless, several noise complaints were received from residents, primarily due to low-frequency noise caused by the shale shakers on the

drilling rig. Measures are being prepared to improve the situation for upcoming drilling phases.

## 6. Communication

Communication has been a particular challenge for the project. During the lengthy objection and permitting procedures, the canton, the municipality, and the project operator were very cautious and refrained from proactive public outreach. Meanwhile, a relatively small group of opponents succeeded in spreading misleading and negative claims among a large part of the local population.

Since the project officially began in 2023, communication has taken place on several levels. The Canton of Jura established an information and stakeholder group involving all regional stakeholders (https://www.csi-hautesorne.ch/).

The Swiss Confederation supports the project through a federal patronage committee, which issued a positive report for the year 2024.

Geo-Energie Jura operates an information center at the project site (https://www.geo-energie-jura.ch/visites/), regularly publishes background articles in the regional press of Jura, and issues media releases on major project milestones.

## 7. CONCLUSIONS

The learning curve since the Basel 2006 EGS project has been long in time but important in know-how gain. The newest available technologies mainly from the Utah EGS projects have been evaluated and thoroughly tested in field situations to mitigate seismic risks and maximize chances of success of a new EGS project in Switzerland.

Apart from seismic risk mitigation, new drilling techniques for crystalline rocks developed by the Utah FORGE project have been successfully implemented at Haute-Sorne, demonstrating a promising path toward cost reductions in geothermal projects. Also, Ambient Noise Tomography shows promising results for cost reductions of geophysical measurements.

If the expected success with multi-stage stimulation in Utah can be realized in Haute-Sorne, Switzerland will get its first power producing geothermal plant by 2029 in Canton Jura.

This example shows also the important role of R&D collaboration at experimental field sites between international partners for the development and realization of new technologies.

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