A MORE AFFORDABLE PATH TO GEOTHERMAL ENERGY

Geothermal energy has great potential, but drilling is expensive. That is why intensive research is being conducted into affordable drilling technologies. One such method is Directional Steel Shot Drilling (DSSD). A research team at ETH Zurich, together with international partners, has investigated this still-developing technology and assessed its potential for Switzerland.

Hagerbach test gallery in the Sarganserland region: DSSD drilling technology was trialled here by driving two 125-metre horizontal boreholes into the mountain, which here consists of limestone (Malm). Photo: ETH Zurich

A technical report about the results of a pilot and demonstration project in the field of geoenergy, which is financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine Aqua£&Gas (issue September 2025).

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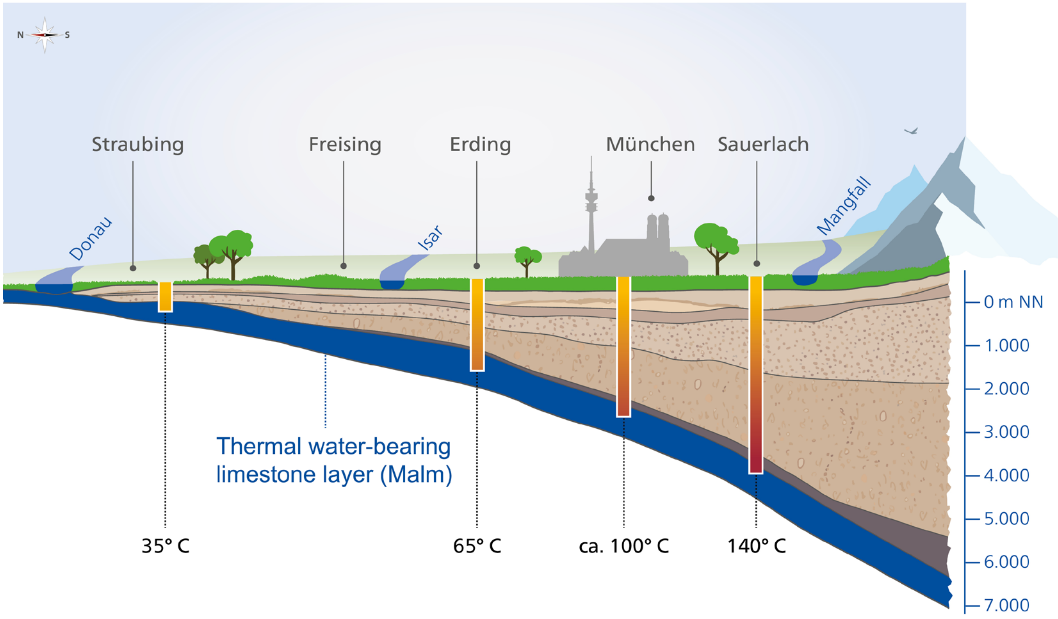


In the Munich area, geothermal heat is already being produced from the Malm formation. Graphic: Stadtwerke München

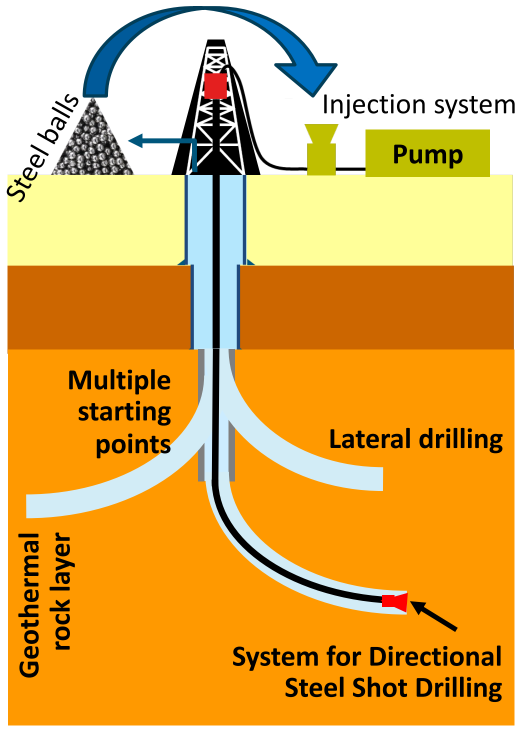
Lucky Munich! Around 2,000 to 3,500 metres beneath the Bavarian capital lies a limestone layer ('Malm') through which 70–130°C water circulates. Munich's public utility company operates six geothermal plants that use this resource to heat buildings via the district heating network, and also to generate electricity. By 2040, the aim is for more than 60 percent of Munich's heat demand to be met by district heating, largely from deep geothermal sources.

"From Switzerland we look almost enviously at this showcase example of deep geothermal energy," says Martin Saar, Professor of Geothermal Energy and Geofluids at ETH Zurich. "However, Switzerland's geology is not as favourable as Munich's." While parts of the Swiss subsurface do contain Malm, in Switzerland it is often found at greater depths, is compact and largely impermeable. Sufficiently permeable zones ('reservoirs') occur only sporadically, where the rock contains pores and, above all, fractures that have not been closed by the great pressure of the overlying rock.

Reducing drilling costs

A special drilling concept could help locate water-bearing layers in Switzerland. First, a deep vertical borehole is drilled, followed by several horizontal boreholes extending several hundred metres in different directions. This network of horizontal bores increases the chances of hitting permeable zones. Horizontal drilling is complex and costly, so more affordable drilling methods are crucial.

One such technique is Directional Steel Shot Drilling (DSSD), which uses tiny steel balls (see textbox p. 3). This method, currently under development by the Dutch company Cano-



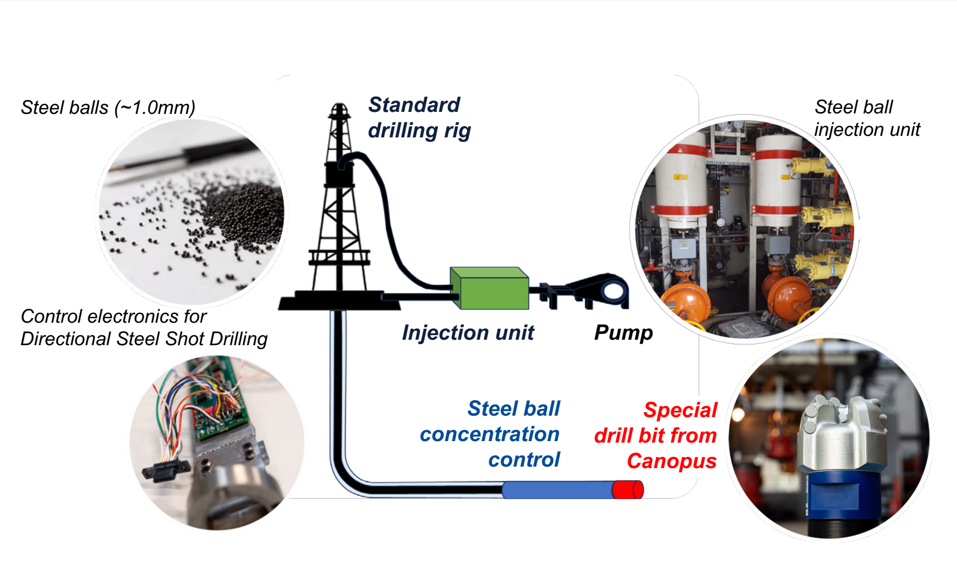
In steel-shot drilling, the drilling fluid is enriched with steel beads that shatter or weaken the rock so that the drill bit can remove it more easily. The graphic shows the horizontal boreholes (300 to 1,000 metres in practical applications) that help to access permeable fracture systems in the limestone layer (e.g. Malm). Graphic: ETH Zurich pus Drilling Solutions B.V., was the focus of the 'DEPLOI the HEAT' research project, led by Canopus with international partners. The Swiss contribution was carried out by ETH Zurich and funded by the Swiss Federal Office of Energy (SFOE) under its Pilot & Demonstration Programme. The project is part of GEOTHERMICA, an EU research initiative addressing various aspects of geothermal energy use. As part of DEPLOI the HEAT, ETH researchers tested DSSD in the Hagerbach Test Gallery, southeast of Flums (SG).

Tests in the Hagerbach Test Gallery

In the test location, two horizontal boreholes, each 125 metres long, were drilled into limestone using the technology. "With these test bores we demonstrated that DSSD can be integrated into conventional drilling operations without incident," says Andreas Reinicke, who led the ETH project and now works at the Dutch research institute TNO. The tests also yielded new insights into how to maintain stable and optimal circulation of the steel balls during drilling. Using DSSD, drilling speeds improved by a factor of three to four, penetrating hard rock (e.g., limestone or possibly granite) at 20 m/h compared to 5 m/h for conventional methods.

The DSSD system is now commercially available for shallow drilling up to about 500 m. For deep drilling, further improvements are needed. In the test tunnel, drilling fluid containing 0.5% by volume of steel balls was used. Increasing this to 2% could further boost drilling speed and improve performance in very hard rock. The special steel shot system can also steer the drill bit, a capability demonstrated in Hagerbach, where a deflection of up to 20 degrees per 100 metres was achieved; in future, 45 degrees may be possible.

DRILLING WITH STEEL SHOT



Graphic: Canopus

When drilling into the ground, one typically uses a drill bit that removes the rock and a drilling fluid (water plus additives) that carries away the crushed rock. The same principle applies to 'Directional Steel Shot Drilling' (DSSD). In DSSD, small steel beads of about 1 mm in diameter are added to the drilling fluid, conveyed to the drill bit, and brought back to the surface along with the drill cuttings. Inside the drill bit, the beads impact the rock at high velocity, shattering or weakening it so that the drill bit can then remove it more easily. The beads account for 0.5 to 2% by volume of the drilling fluid. At a flow rate of 400 l/min and a concentration of 1% by volume, this corresponds to roughly six million beads per minute. The drilling fluid circulates in a closed loop and there are only minor losses of steel beads.

The first experiments with steel-shot drilling were conducted back in the 1970s, aiming to penetrate very hard rock. The method was subsequently further developed by the energy company Shell to create small-diameter boreholes (4 to 8 inches, i.e. 10 to 20 cm). About six years ago, the Dutch company Canopus took up the technology to enable cost-effective directional geothermal drilling with small (4 to 6 inches) to medium diameters (8 to 10 inches). Innovations in the Canopus approach include not only the use of steel beads but also a novel sensor-based directional control of the drill bit (‹directional control›). Here, the concentration of steel beads is modulated in relation to the rotation of the drill bit; the borehole is removed more on one side than the other, guiding the bit towards the side of greater removal. This system is highly effective and allows rapid changes in direction. A measurement system controls and monitors the drilling direction.

Parameters were also optimised during testing to ensure sufficient borehole cleaning (removing cuttings and steel balls).

Modelling quantifies the benefits

A sub-study of DEPLOI the HEAT estimated how much DSSD could increase geothermal yields. Researcher Paromita Deb, then with the ETH Zurich Geothermal Energy and Geofluids group, developed a numerical modelling method using geological data from Geneva and Lausanne to create about 1,000 virtual models of fractured limestone formations. She simulated how horizontal DSSD drilling would affect flow rates, thermal output and economic feasibility under these various scenarios.

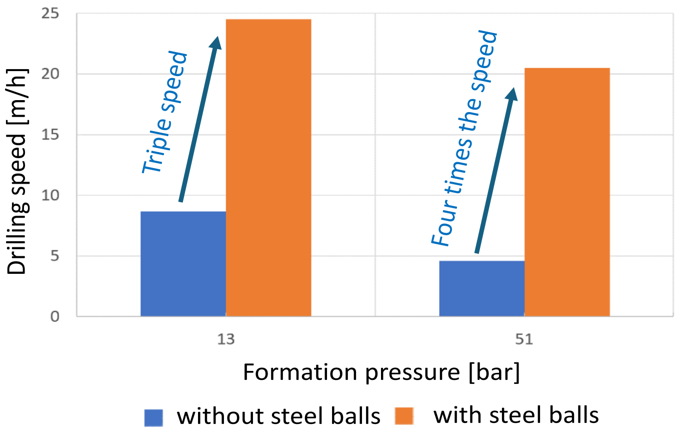
The modelling showed that configurations with up to three horizontal bores could significantly increase heat output (up to a doubling of yield). DSSD also reduces drilling costs compared to conventional methods, with savings increasing with the number of horizontal bores. However, beyond a certain point, the benefits no longer justify the costs. Overall, the results confirm DSSD's promise for enhancing both the performance and economic efficiency of geothermal drilling.

Use in Greater Geneva

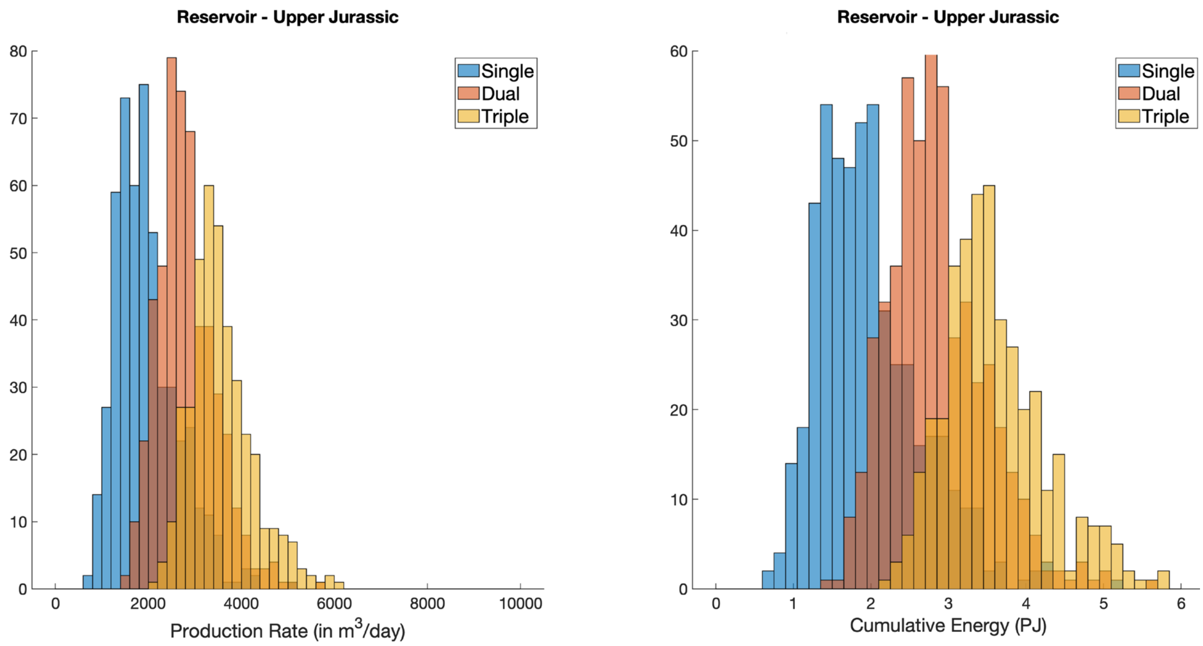
The ETH project received financial and data support from Services Industriels de Genève (SIG) and Services Industriels de Lausanne (SIL). "The project achieved significant progress, and we are confident we will be able to use DSSD within a few years," says Michel Meyer, SIG's head of heat solutions and geothermal energy.

MANY PATHS

Geothermal drilling in the Malm formation is one way to unlock the potential of geothermal heat in Switzerland. There are also other approaches with promising prospects for winning geothermal heat from other rock formations. Several geothermal plants are already in operation and are successfully producing heat today – an important contribution to a sustainable energy supply. Once DSSD technology is fully mature, it could be applied to rock types other than Malm as well.



Drilling rate of a conventional drill bit (blue) compared with steel-shot drilling (orange). The drilling rate depends on depth (formation pressure). Graphic: Final report "DEPLOI the HEAT" / Andreas Reinicke



Numerical modelling of DSSD boreholes in limestone shows that using one (single), two (double) or three (triple) horizontal boreholes per vertical borehole can significantly increase the recovery of geothermal heat. Graphic: Final report "DEPLOI the HEAT"

HEAT FROM GREAT DEPTHS

From a geological perspective, we live on a fireball: 99% of the Earth's volume is hotter than 1,000 °C. The Earth's surface is not nearly as hot: at a depth of 1,000 m the temperature is about 40 °C, at 2,000 m around 70 °C, and at 5,000 m roughly 150 °C. There are four main approaches to harnessing deep geothermal energy:
Hydrothermal geothermal energy: This targets hot, permeable rock layers ('reservoirs'). When such reservoirs are drilled and water is circulated through them, geothermal heat can be brought to the surface and used for heating, or (via a steam turbine and generator) for electricity generation. In future, DSSD drilling technology could be used to access these reservoirs. Key challenge: the deeper the well, the lower the probability of encountering reservoirs with sufficient permeability.
Petrothermal geothermal energy (enhanced geothermal systems, EGS): This targets very deep rock layers (up to 6 km) that are not permeable. Permeability is created by hydraulic stimulation (injecting water). The resulting fractures are then circulated with water, bringing geothermal heat to the surface. Key challenges: stimulation must not induce significant earthquakes; moreover, the artificially created fractures tend to clog due to mineral precipitation.
Deep closed loop (advanced geothermal systems, AGS): Like petrothermal systems, this approach targets impermeable rock but dispenses with hydraulic stimulation. Instead, several vertical boreholes at great depth (5,000 to 8,000 m) are connected by horizontal boreholes ('loops'). When these loops are circulated with water, the water absorbs the geothermal heat and transports it to the surface. Key challenge: very high drilling costs.

In the short term, SIG is sticking to conventional drilling, as DSSD is not yet ready for the complex geological conditions around Geneva, with highly fractured limestone, karst systems and strong artesian flows, says SIG expert Meyer. Medium term, however, DSSD has great potential in his opinion.

Nationwide interest

Former ETH researcher Paromita Deb now works at Swiss Geo Energy, a geothermal company founded in Payerne in 2019. She believes DSSD will soon be relevant across Switzerland: "Even though western Switzerland is currently the most active in geothermal energy, this technology has similar potential across the whole country, especially for heat supply solutions."

Representatives of the "DEPLOI the HEAT" research team and supporting partners. Photo: ETH Zurich

- The English-language **final report** on the project 'Demonstrate production enhancement through low cost directional steel shot drilling for district heating – CH' (DEPLOI the HEAT – CH) is available at: https://www.aramis.admin.ch/Texte/?ProjectID=51354.
- The DEPLOI project will be presented in several contributions at the **European Geothermal Congress** (EGC) in Zurich in early October 2025 – the first time this congress will be held in Switzerland: https://europeangeothermalcongress.eu/.
- Further **information** is available from Stefano Benato (stefano.benato@bfe.admin.ch), external head of the SFOE Geoenergy research programme.
- More **technical articles** on research, pilot, demonstration and flagship projects in geothermal energy can be found at www.bfe.admin.ch/ec-geothermie.
- Further **research projects** by the Geothermal Energy and Geofluids (GEG) group at ETH Zurich can be found at geg.ethz.ch.

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Version: September 2025