Report on GEOTHERMAL INNOVATION TRENDS IN EUROPE

Edition 2026

EGEC GEOTHERMAL

20 October 2026

Market Trends for geothermal technologies

Five themes are shaping the next generations of projects:

I. **Increasing plant capacity** also by diversifying and multi-purposes applications, e.g., in Combined Heat and Power projects and supply of minerals such as lithium, potassium etc., to increase economics;

II. **Adapting the depth** to be accessed, reducing risk and taking advantage of increased efficiency of production at lower temperature;

III. **Adopting right number of wells:** multiple wells, new drilling design with sub-horizontal wells, advancing from the concept of a single production well to a doublet (production and injection wells) and then to multiple wells, to improve the sustainability of the production system and resource performance;

IV. **Expanding Greenfields**, moving from the vicinity of known areas and expanding the geothermal asset with new exploration techniques;

V. **Innovative Business Models:** De-risking approaches in top of the topics highlighted above, which also contributes to de-risk geothermal projects, it must be noted the project portfolio approach to de risk development with several projects in a same area.

VI. **Growing cooling demand** creates additional market opportunities



Research trends

Research Trends for geothermal technologies

Low TRL	Utilisation of **Machine Learning and Artificial Intelligence Tools** in geothermal exploration and operation
Low TRL	**Digitization** and Digital Twins (real and virtual plants in connection)
Low TRL	**Advanced exploration tools** (Fiber Optics Sensors, -Forward modelling method…)
Low TRL	**Using a subsurface working fluid** other than water (e.g. CO2) for Advanced geothermal Systems or UTES
Low TRL	**Coupled** thermal, hydraulic, mechanical, chemical (THMC) and microbiological system models
Low TRL	**Smart monitoring and assessment techniques** for well integrity and pump lifetime
Low TRL	**Extraction technologies** for co-production of critical raw materials
Low TRL	**Crystalline rocks**: Laboratory experiments to obtain unique data and simulation
High TRL	**Novel drilling technologies**
High TRL	**Materials for Geothermal installations**
High TRL	**Full reinjection power plants**
High TRL	**Underground thermal energy storage**
High TRL	**Geothermal heat pump systems** (pipes, grouting, rigs, heat pump)

TRL	Description
1	Basic principles observed
2	Technology concept formulated
3	Experimental proof of concept
4	Technology validated in a lab
5	Technology validated in a relevant environment (industrially relevant environment in the case of key enabling technologies)
6	Technology demonstrated in a relevant environment (industrially relevant environment in the case of key enabling technologies)
7	System prototype demonstration in an operational environment
8	System completed and qualified

Other Readiness Levels

from Manufacturing to Commercial, Integration, Service, and even Policy levels

Technology and systems

Technology readiness level (TRL 1-9)
TRL 1–3 (basic principles → proof of concept)
TRL 4–6 (lab validation → relevant environment prototype)
TRL 7–9 (operational prototype → flight-proven system)

System readiness level (SRL)
SRL 1–3 (system concept → architecture defined)
SRL 4–6 (integration feasibility → subsystems integrated)
SRL 7–9 (prototype integrated → mission-proven system)

Integration readiness level (IRL 0–9)
IRL 0–2 (no integration → conceptual integration)
IRL 3–6 (interfaces defined → demo in relevant environment)
IRL 7–9 (prototype integrated → proven in mission)

Design readiness level (DRL 1–9)
DRL 1–3 (conceptual design → requirements defined)
DRL 4–6 (preliminary/detailed design reviews → design verified)
DRL 7–9 (design validated → frozen for production)

Science readiness (SR 1–9)
SRL 1–3 (hypothesis → concept model)
SRL 4–6 (data gathered → peer-reviewed findings)
SRL 7–9 (operational validation → mission-grade science)

Manufacturing and commercialization

Manufacturing readiness level (MRL 1–10)
MRL 1–3 (manufacturing implications → proof of concept)
MRL 4–7 (lab process validated → prototype production)
MRL 8–10 (pilot line proven → full-rate production)

Commercial readiness level (CRL 1–9)
CRL 1–3 (concept → business plan defined)
CRL 4–6 (value proposition validated → repeatable sales)
CRL 7–9 (competitive positioning → established market presence)

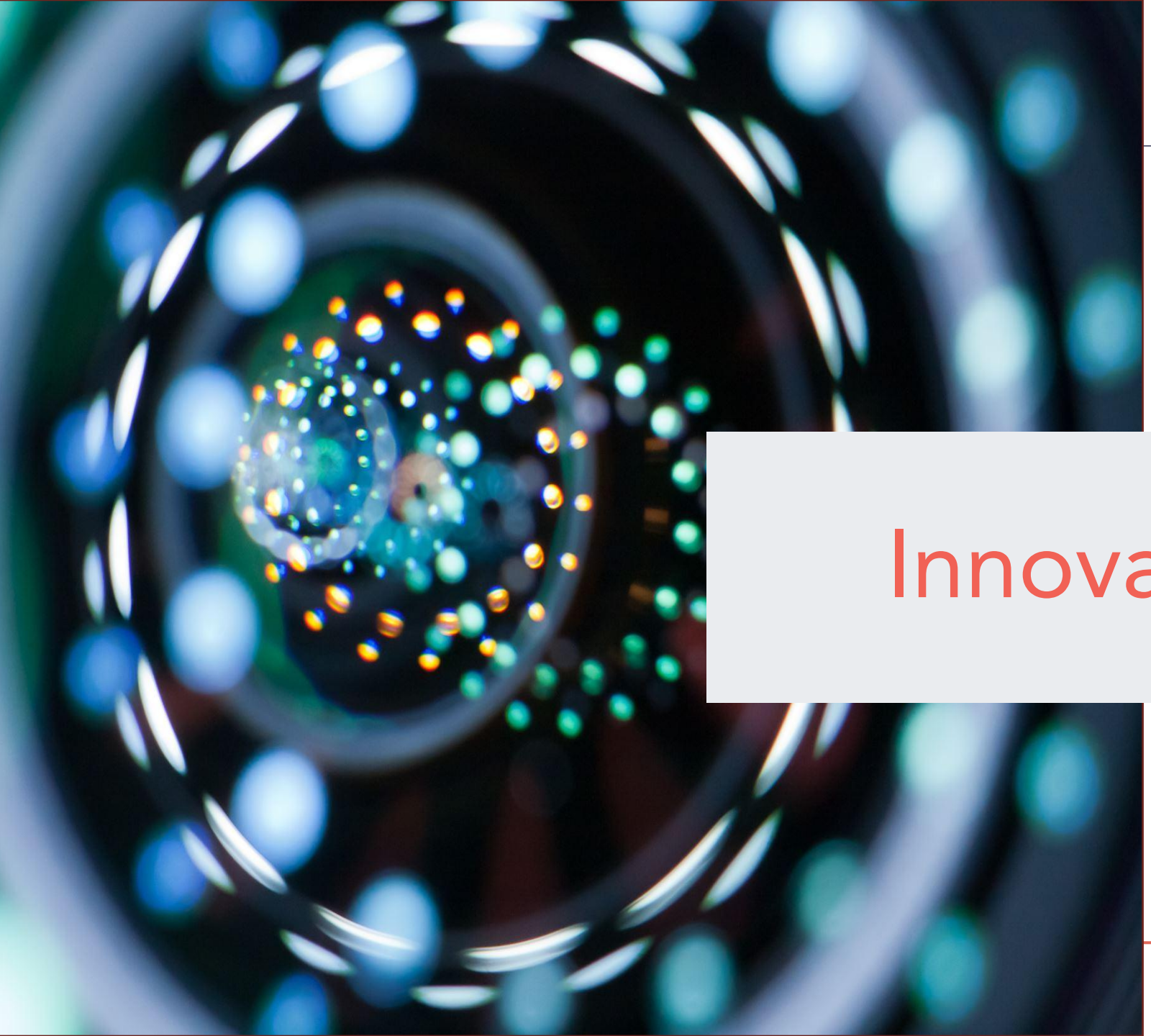
Market and technology readiness level (MTRL 1–9)
MTRL 1–3 (early tech concept + market need)
MTRL 4–6 (validated demand + scalable prototype)
MTRL 7–9 (mature technology with established market)

Operational readiness level (ORL 1–9)
ORL 1–3 (concept → use case defined
ORL 4–6 (processes, training, logistics validated)
ORL 7–9 (trials → sustained operations)

Specialised readiness framework

Data readiness level (DRL A1–C4)
A1–A4 (raw/unverified → structured)
B1–B4 (cleaned → labeled)
C1–C4 (validated → monitored in production)

Policy readiness level (PRL 1–9)
PRL 1–3 (problem defined → draft concept)
PRL 4–6 (pilot designed → evaluated with stakeholders)
PRL 7–9 (policy validated, governed, implemented)



Innovation trends

Innovation Trends for geothermal technologies

I. Market ready technology

- **Large and High Temperature Heat Pumps**
- **Large-scale geothermal HP** systems
- **Low temperature heating systems** (5th generation DH networks)
- **New drilling, well designs and equipment, and New casing materials**
- **Larger ORC turbine**
- **District cooling**

Market Ready Technologies (1/2)

These technologies are being commercialized



Larger ORC Turbine

GEMINI Turbine (Exergy)

Unveiled in 2025, a single high-capacity unit delivering up to 60 MWe.



Large Geo HP Systems

MBH Bank (Budapest)

235 wells at 130 m deep deliver 1680.25 kWth heating and 1527.5 kWth cooling.



Geo District Cooling

Saint-Denis Olympic Village

Original 2024 project expanding in 2025-2027 to include 189 new residential buildings.



Large and High temperature HP

Municipality of Aarhus

Aalborg CSP's 10 MW electric HP increasing brine temp to 95°C using hydrocarbon refrigerant (isobutane + propane).

Market Ready Technologies (2/2)

These technologies are being commercialized





Low-temperature Heating Systems (5th-generation DH networks)

Nice Méridia smart grid project

Expansion of existing 5 km network (12 open wells at 50 m depth, delivering heat at 63°C and cold at 8°C) to 12 Km AI-operated smart grid. Network will include 2030 Olympics' ice-skating rink.

New Drilling, Well Designs & Well Equipment

HALLIBURTON TrueSync 738 series hybrid PMM: New electric submersible pump (ESP) for internal operating temps up to 204 °C

ISOR: Flexible Couplings in production casing

CORIANCE: Replacing steel with fiberglass in well materials

ARVERNE: Improving cementation quality (shallow geothermal)

Case studies 2025/2026 to illustrate these innovation trends

- Exploration
- Drilling technologies
- Production & injection pumps

Highlights of an Innovation Trend: Exploration Campaigns

- 3D Seismic campaigns are entering a new era

- Aerial geophysical surveys, aka “Geophysical flight”

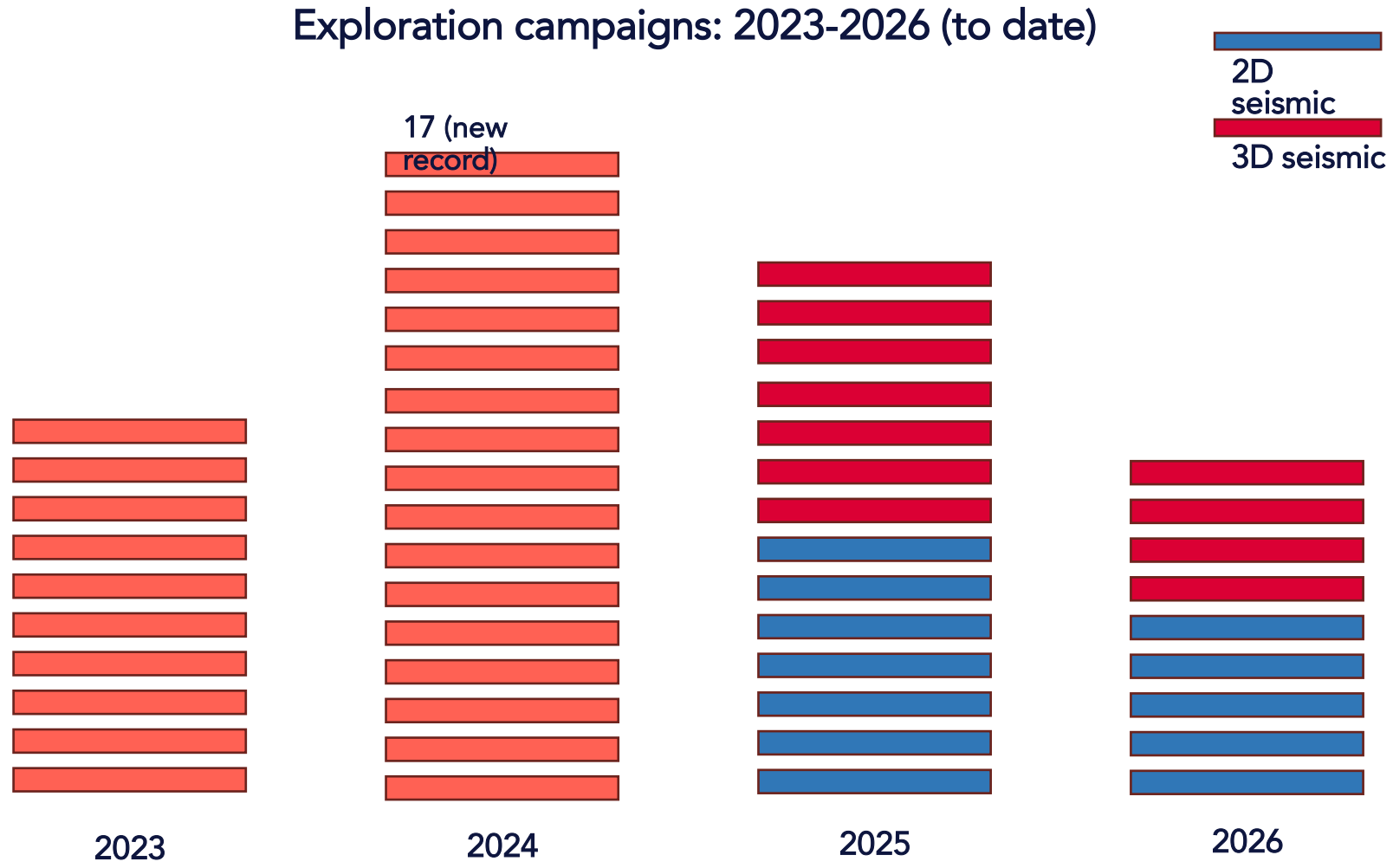


Project “GeoProH”

In 2025, Vulcan, OMV, Eavor Deutschland, the Stadt Frankfurt am Main, the Karlsruhe Institute of Technology (KIT) and the Hessisches Ministerium für Wirtschaft, Energie, Verkehr und Wohnen launched a collaborating for geophysical flights exploration campaign over parts of the central and northern Upper Rhine Graben.

Exploration campaigns

On the last 3 years, the geothermal sector has then invested in more than 500 million € in exploration.



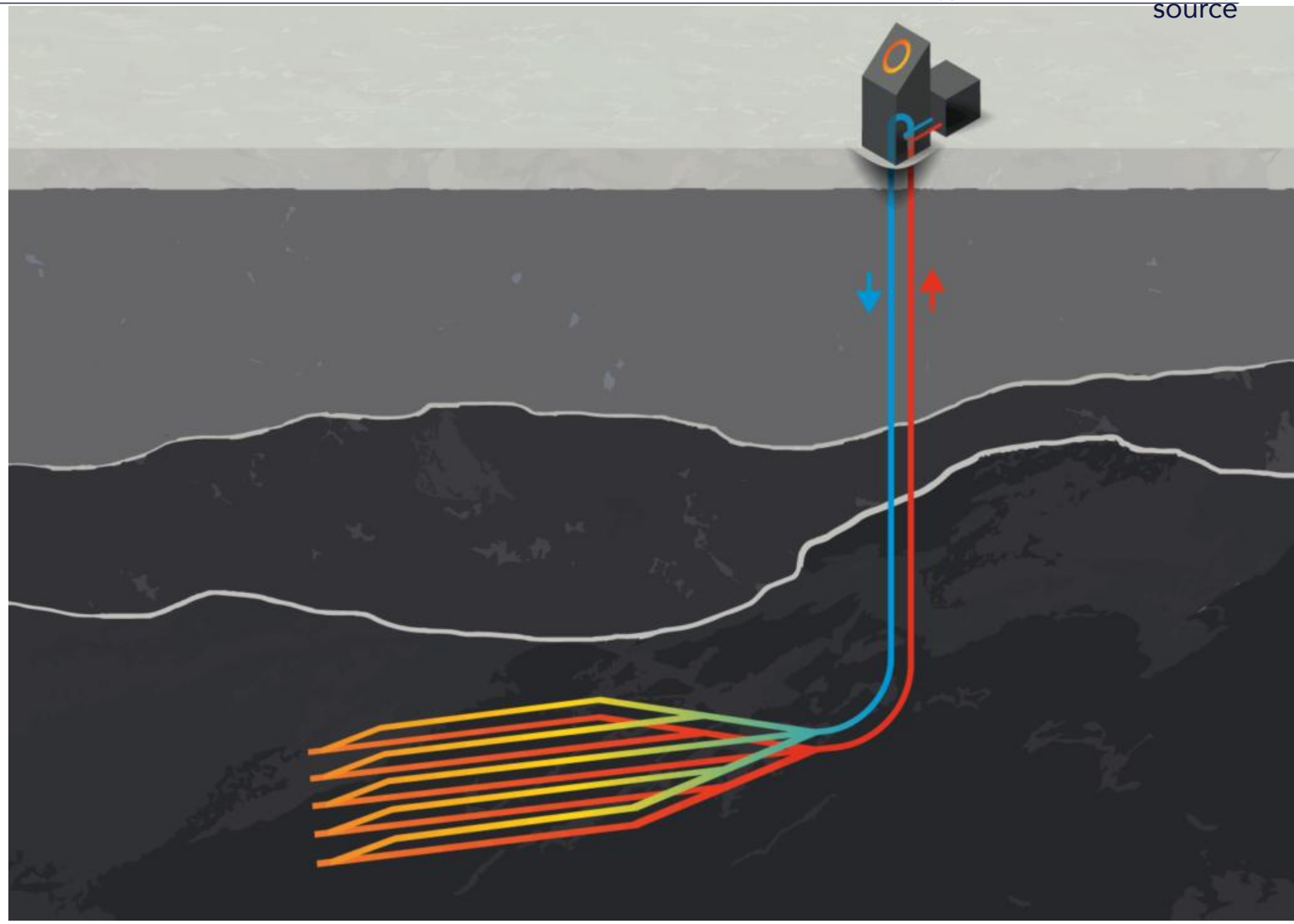
Improved Drilling Rates: EavorLoop (Gerestried)

Drill bits lifetime: x6 improvement

- Depths: 50 - 3500 m
- x3-x4 in the continuous distance drilled per bit run ("run length")
- cuts down non-productive time (e.g. tripping pipe)

Rate of penetration x2 improvement

- from 12 m to 25 m drilled per hour



ESP test on a four-stage heat pump installation in Hamburg

- Four-stage heat pumps with cascaded design, water supplied at 48°C then increased to 75-85°C for the heating network



II. First demonstration – close to market

- Medium temperature and High temperature UTES
- Single well
- Deep closed loops
- Robot drilling for shallow geothermal projects
- Electricity, Heating and Cooling for industrial purposes
- Co-production of critical raw materials

Technologies in Development (1/2)

These technologies are currently being piloted



Robot Drilling

Borobotics "Grabowski"

First completely automated geothermal drill. Targeting 20 m depth through new hammering design (2025). New development 2026



Med-High Temp UTES

Lounavoima (Salo, Finland)

6 deep coaxial heat wells function as heating and storage wells to waste incineration plant. Excess thermal heat stored underground.



Med-Deep Single Well

Eden Project

Heat supply from single well heat exchanger. Deviated well drilled to a vertical depth of 4,871 m. Signed new development with Baker Hughes.



"Cascade" HC Grids

Cascade Project (Austria)

Innovative heating and cooling grids for industrial, commercial and housing use. Powered with geo-based electricity generation, residual heat used in grids.

Technologies in Development (2/2)

These technologies are currently being piloted



Co-production of Critical Raw Materials (CRM)

EnBW "CASCADE" process (Bruchsal geothermal plant): 2nd reactor column with improved adsorbents for battery-grade Li.

Lithium de France: drilling started 11/2025.

Altamin, commercial-grade CRM research: Sulphate of Potash, lithium, and boron from geothermal brines in Lazio, Italy.

Cornish Lithium: Planning permits for two 2,000 m wells

United Downs DLE project: expansion of 2025 plant. Brine lithium concentration > 300 ppm. Low total dissolved solids (TDS).



Deep Closed Loops (Multilateral Well Systems)

Eavor-Loop™ (Geretsried, Germany): electricity generation projected Q4 2026. Electrical capacity 8.2 Mwe (est.) thermal capacity ~64 MWth. Closed-loop "radiator" design with 12 legs per vertical, 24 legs total, connected in pairs at 4,500 m deep.

Green Therma Heat4Ever™ (Aalborg): Demonstration capacity 2 MW (est.). DualVac technology. Operations projected for 2027. Drilling Q4 2026

Other technological innovations in development



Autonomous Drill Rig

FRASTE GT ROBOT

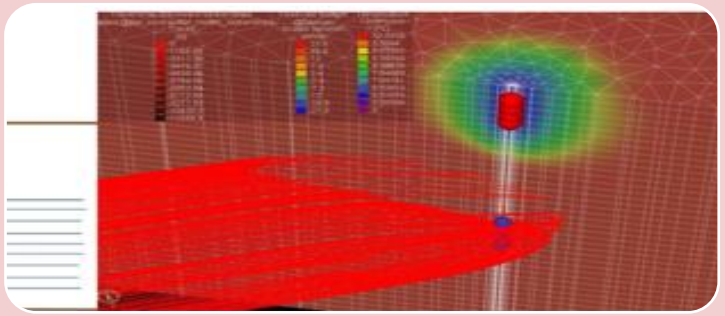
An automated drilling machine.



Repurposing O&G Wells

CERAPHI

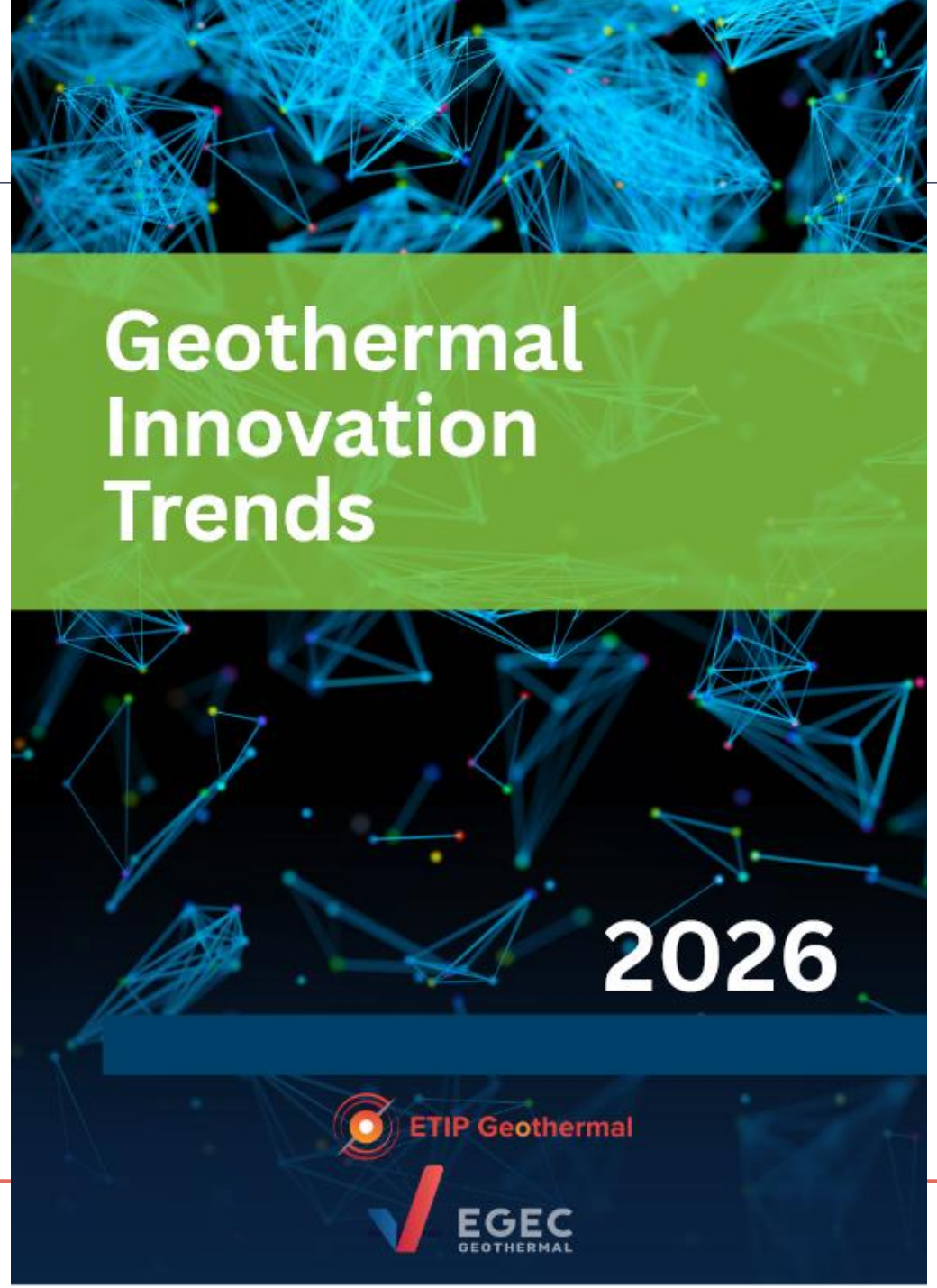
Repurposing of non-producing oil and gas wells for geothermal energy production.



Coaxial Geo HP Systems

(Various)

Coaxial design for geothermal heat pump systems in permeable aquifers.



Released mid-December 2026

Thank you for you attention!

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