

# Report on **GEOHERMAL** INNOVATION TRENDS IN EUROPE

Edition 2025



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Five themes are shaping the next generations of projects:

- I. **Increasing 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, 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 three or more 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. **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.



# Research trends

## I. Low TRL

- Utilisation of Machine Learning and Artificial Intelligence Tools in geothermal exploration and operation
- Digitization and Digital Twins (real and virtual plants in connection)
- Advanced exploration tools (Fiber Optics Sensors, -Forward modelling method...)
- Using a subsurface working fluid other than water (e.g. CO2) for Advanced geothermal Systems or UTES
- Coupled thermal, hydraulic, mechanical, chemical (THMC) and microbiological system models
- Smart monitoring and assessment techniques for well integrity and pump lifetime
- Extraction technologies for co-production of critical raw materials
- Crystalline rocks: Laboratory experiments to obtain unique data and simulation

## II. High TRL

- Novel drilling technologies
- Materials for Geothermal installations
- Full reinjection power plants
- Underground thermal energy storage
- Geothermal heat pump systems (pipes, grouting, rigs, heat pump)

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

## other Readiness Levels: from Manufacturing to Commercial, Integration, Service, and even Policy levels.

| Technology and systems  | Manufacturing and commercialization   | Specialised readiness framework   |
|---|---|---|
| <p><b>Technology readiness level (TRL 1-9)</b><br/> <b>Scale</b><br/>           TRL 1-3 (basic principles → proof of concept), TRL 4-6 (lab validation → relevant environment prototype), TRL 7-9 (operational prototype → flight-proven system).</p> | <p><b>Manufacturing readiness level (MRL 1-10)</b><br/>           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).</p> | <p><b>Data readiness level (DRL A1-C4)</b><br/>           A1-A4 (raw/unverified → structured), B1-B4 (cleaned → labeled), C1-C4 (validated → monitored in production).</p>  |
| <p><b>System readiness level (SRL)</b><br/>           SRL 1-3 (system concept → architecture defined), SRL 4-6 (integration feasibility → subsystems integrated), SRL 7-9 (prototype integrated → mission-proven system).</p>                         | <p><b>Commercial readiness level (CRL 1-9)</b><br/>           CRL 1-3 (concept → business plan defined), CRL 4-6 (value proposition validated → repeatable sales), CRL 7-9 (competitive positioning → established market presence).</p>     | <p><b>Policy readiness level (PRL 1-9)</b><br/>           PRL 1-3 (problem defined → draft concept), PRL 4-6 (pilot designed → evaluated with stakeholders), PRL 7-9 (policy validated, governed, implemented).</p> |
| <p><b>Integration readiness level (IRL 0-9)</b><br/>           IRL 0-2 (no integration → conceptual integration), IRL 3-6 (interfaces defined → demo in relevant environment), IRL 7-9 (prototype integrated → proven in mission).</p>                | <p><b>Market and technology readiness level (MTRL 1-9)</b><br/>           MTRL 1-3 (early tech concept + market need), MTRL 4-6 (validated demand + scalable prototype), MTRL 7-9 (mature technology with established market).</p>          |   |
| <p><b>Design readiness level (DRL 1-9)</b><br/>           DRL 1-3 (conceptual design → requirements defined), DRL 4-6 (preliminary/detailed design reviews → design verified), DRL 7-9 (design validated → frozen for production).</p>                | <p><b>Operational readiness level (ORL 1-9)</b><br/>           ORL 1-3 (concept → use case defined), ORL 4-6 (processes, training, logistics validated), ORL 7-9 (trials → sustained operations).</p>                                       |   |
| <p><b>Science readiness (SR 1-9)</b><br/>           SRL 1-3 (hypothesis → concept model), SRL 4-6 (data gathered → peer-reviewed findings), SRL 7-9 (operational validation → mission-grade science).</p>   | <p><b>KTH innovation readiness (multi-axis radar)</b><br/>           Technology, market, team, IP, funding, customer. Each axis scored 1-9 to show gaps and progress.</p>   |   |



# Innovation trends

## I. Market ready technology

- **Large and High Temperature Heat Pumps** to increase the temperature of the geothermal brine for existing DH or industrial processes. Case of Aarhus: 10 MW electric heat pump, provided by Aalborg CSP, provide temperatures up to 95°C. The Natural refrigerant of the large HP is Hydrocarbon (isobutane and propane).
- **Large-scale geothermal HP** systems: case of MBH Bank in Budapest: 1680.25 kWth capacity for heating and 1527,5 kWth for cooling. 235 wells at 130 m deep.
- **Low temperature heating systems** (5th generation DH networks): case of Nice Méridia smart grid project, current geothermal system of 12 open wells drilled to 50 m depth, will be extended the network of 5 Km ( heat at 63°C and cold at 8°C) to a grid of 12 Km (incl. Olympic games 2030 ice skating rink), a smart grid operated by AI.
- **New drilling, well designs and equipment, and New casing materials:** case of 1) HALLIBURTON TrueSync 738 series hybrid PMM to develop new electric submersible pump (ESP) technology to operate at internal temperatures up to 204 °C, 2) ISOR Flexible Couplings in the production casing, 3) CORIANCE innovative use of fiberglass in the wells, replacing the traditional steel., 4) ARVERNE enhancing cementation quality for shallow geothermal installations.
- **Larger ORC turbine:** EXERGY, unveiling in 2025 its GEMINI turbine, a single high-capacity unit delivering up to 60 MWe.
- **District cooling:** case of iconic geothermal district cooling for the Olympic 2024 village in Saint-Denis is extending in 2025 to connect 189 new housings by 2027.

## II. First demonstration – close to market

- **Medium temperature and High temperature UTES:** 6 deep coaxial heat wells for Salo’s district heating, Heating and Storage Wells to Waste Burning Facility, storing excess thermal energy.
- **Single well,** at medium and deep depth: Eden project single well heat exchanger with deviated well drilled to a vertical depth of 4,871 metres, supply heat to Eden Project, signed new development with Baker Hugues .
- **Deep closed loops,** of multilateral well systems: 1) , the Eavor-Loop™ project in Geretsried (Germany) is expected to generate electricity this year. The built plant capacity of. 8.2 MWe and Thermal output at approx. 64 MWth. The closed loops form a radiator composed of 12 legs per vertical, 24 legs in total connected in pairs at 4.500 m deep, 2) Green Therma demonstration of the Heat4Ever™ solution in Aalborg, estimated capacity of around 2 MW, utilizing the patented DualVac technology, to be in operation in 2027. Drilling of the well is expected in autumn 2026.
- **Robot drilling for shallow geothermal projects:** Borobotics developed a robot drilling called Grabowski to become the first geothermal drill to be completely automated. In 2025, a new hammering design leading them to drill for reaching a first milestone of 20 meters of depth.
- **Electricity, Heating and Cooling for industrial purposes:** Austrian project CASCADE with geothermally powered cascade heating and cooling grids for industrial, commercial and housing use, an innovative method of gradual heat utilization.
- **Co-production of critical raw materials:** 1) CASCADE process by EnBW, use of a second reactor column with higher-performing adsorbents. To extraction of solid lithium salts with “battery grade” purity. at the Bruchsal geothermal plant, 2) Lithium de France started to drill in November 2025. 3) Altamin research on critical minerals from geothermal brine in Lazio region of Italy: producing commercial-grade Sulphate of Potash (SOP), lithium, and boron using geothermal energy. 4) Planning permission were granted in 2025 to Cornish Lithium for two 2,000-metre-deep wells, 5) The United Downs geothermal project with DLE – high lithium (> 300 ppm ) and low TDS. demonstrator online in 2025. Follow on full-scale expansion at United Downs from 2025 to 2027.

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# Highlights of a 2025 innovation trend: Exploration Campaigns

- 3D seismic campaigns
  - 10 in 2023. In 2024, a record of more than 17 seismic surveys.
  - Numerous have been done already in 2025.

- Geophysical flight

joint project "GeoProH", in which 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 are collaborating for geophysical flights exploration campaign in 2025 over parts of the central and northern Upper Rhine Graben.



# Market trends

## Market 2024

- 3 new plants in 2024 (1 in Austria, 2 in Türkiye) for an additional almost 40 MWe base load capacity.
- Capacity of each plant: 2, 11 and 24.5 Mwe.
- Turbine Manufacturers: Orcan, Open Mountain (Kaishan) and Exergy.



OME T-01 geothermal power plant in Alasehir (source: JESDER) OME\_T-01



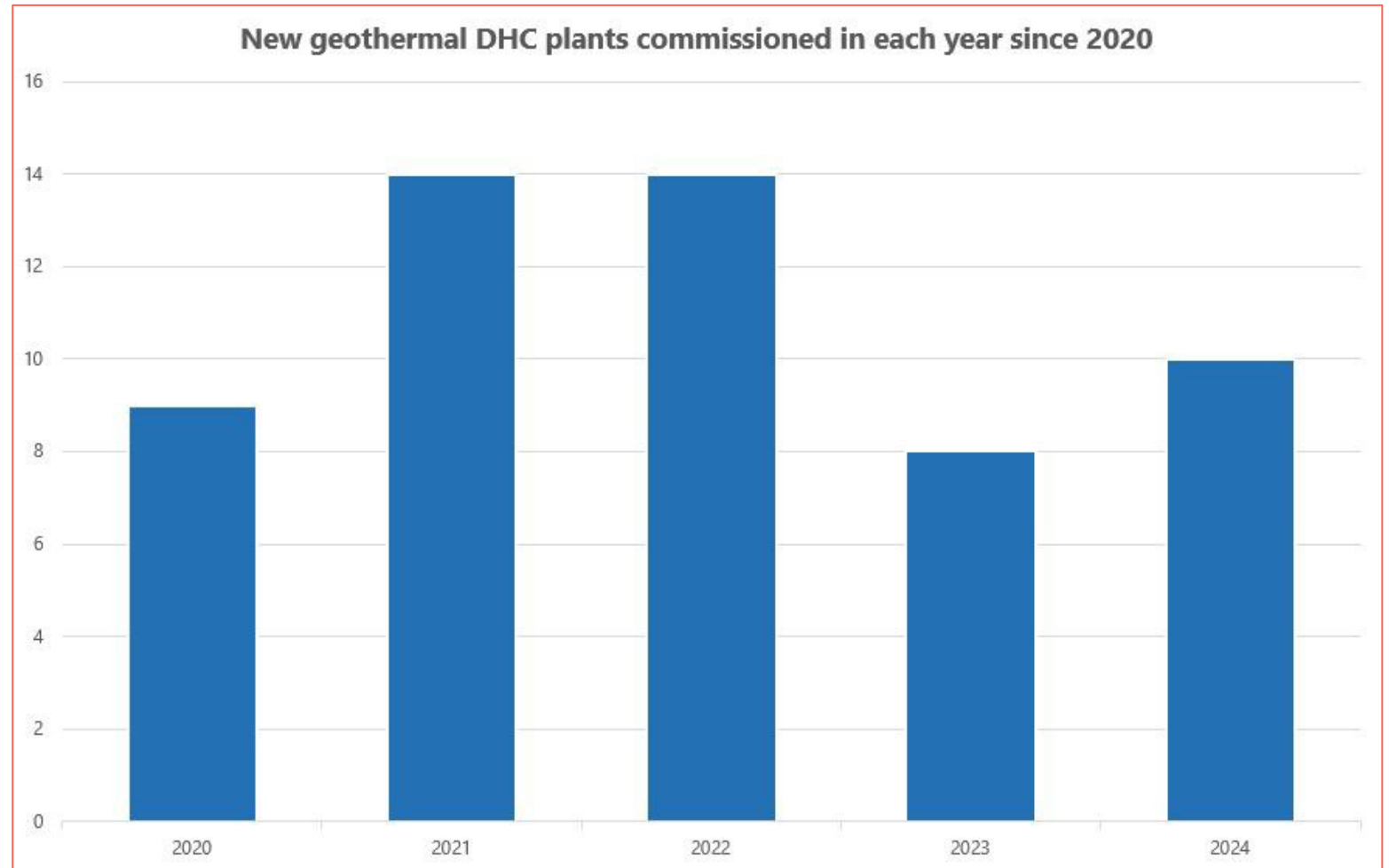
Greeneco Energy geothermal power plant in Sarayköy (source: EXERGY) GreenECO\_GPP-7.jpg

**10 new systems commissioned** in Europe: 1 in France, 1 in Greece, 3 in Poland, 1 in Romania, 1 in the Netherlands, 1 in Spain and 2 in the UK. **110 MWth** of capacity added.

**412 systems in operation**, 308 systems from EU Member States.

More than **500 projects** are under **development** at different stages.

## Number of new Plants commissioned in the last 5 years



111,000  
GHP sales  
in 2024

85 Twh  
Heat  
supplied

10,5  
million  
People  
supplied

2,43  
million  
installed  
units

37.6 GW  
installed  
capacity

29% decline from 2023 because:

1. Headwinds against heat pumps; Uncertainty relating to electrification.
2. Lack of European Geothermal Action Plan: Permitting issues and other technical barriers (taxation...)
3. Cost of living crisis impacting on capital availability;
4. Lack of equalization with the gas market.

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From our **survey about exploration campaigns** from 2023 to 2025, we listed 40 3D seismic campaigns in Europe.

**Around 120 wells to be drilled** from these exploration campaigns.

But **doubling the annual drilling rate** (about 30 wells drilled in 2024, so more than 60 wells/year in 2025 & 2026) will require:

- a more efficient permitting process to issue drilling approvals, along with
- improved project management within the geothermal industry to ensure rig and staff availability.

# Geothermal Innovation Trends

2025

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Thank you for your  
attention!



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