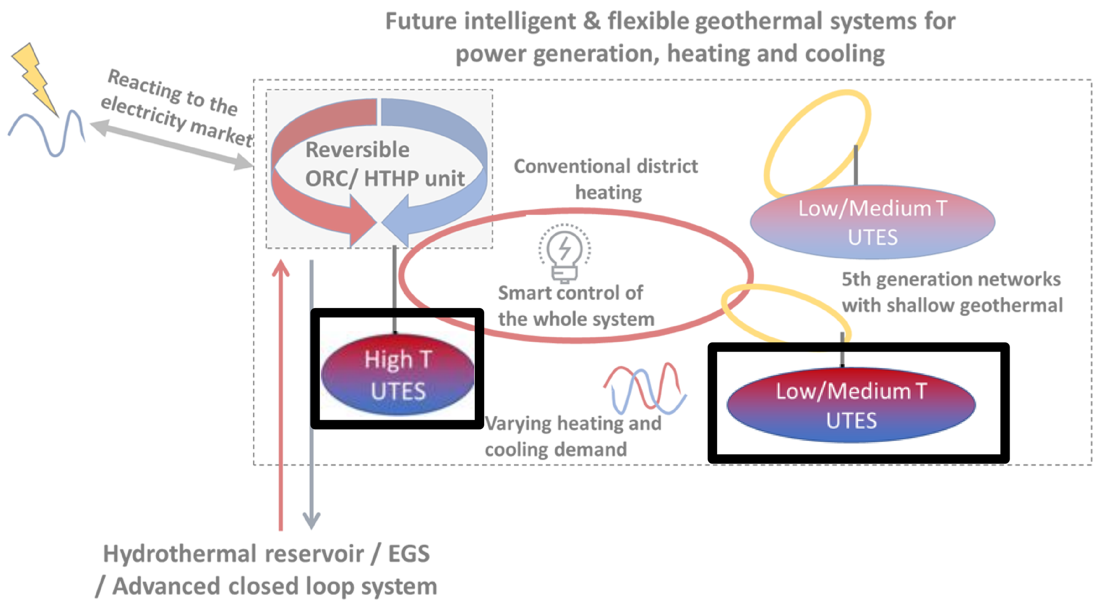
FlexGeo

Shaping the future of flexible geothermal energy

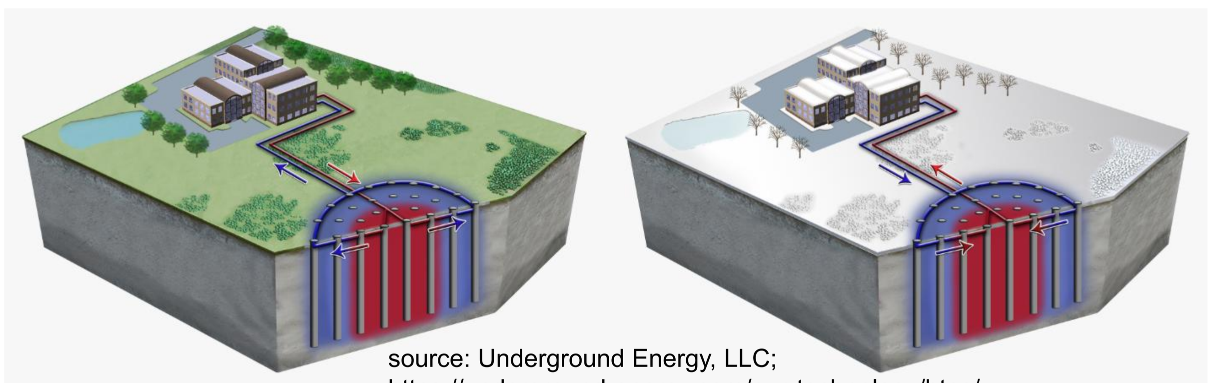
Project Partners

Future smart & flexible geothermal systems



- **Enhancing Renewable Energy Flexibility:** Underground Thermal Energy Storage (UTES), helps manage peak loads and fluctuating energy flows in district heating systems, supporting the full decarbonization of the heating sector.
- **Modeling for Optimization:** Conceptual UTES designs are transformed into calibrated numerical models, enabling performance prediction through sensitivity analyses and parameter variation across geological and operational scenarios.
- **Scalable Solutions Through Simulation:** Coupling UTES simulations with grid models allows for the development of regression models generating broadly applicable formulas to assess flexibility potential across various locations.
- Our study primarily focuses on **Borehole Thermal Energy Storage (BTES)** as a sustainable solution for seasonal thermal energy storage.

Borehole Thermal Energy Storage (BTES)



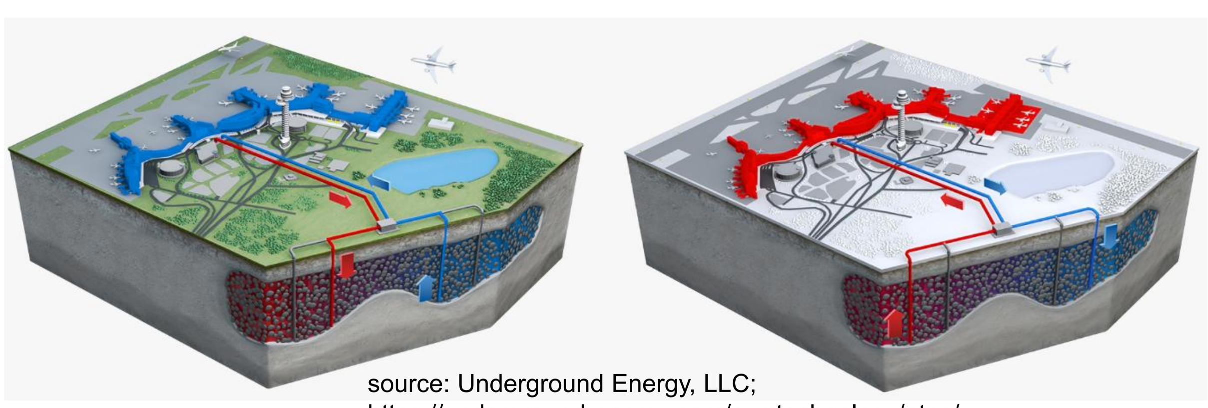
source: Underground Energy, LLC; https://underground-energy.com/our-technology/btes/

- **Closed-Loop Heat Storage:** A BTES system uses borehole heat exchangers (BHE) to circulate fluid underground, heating or cooling the subsurface in a sealed, insulated loop to minimize thermal losses.
- **Flexible Temperature Ranges:** Depending on geological conditions, BTES systems can operate as low, medium, or high-temperature storages, making them adaptable to different energy needs.
- **Seasonal Energy Management:** BTES stores excess heat from renewable sources or industrial processes during low-demand periods and supplies it during peak demand, enhancing energy efficiency.

Integration of BTES systems in DH networks

- **Promising Integration Potential:** Multiple studies highlight BTES systems (depths until 400 m) as effective solutions for seasonal thermal energy storage, especially in urban DH networks, with potential to reduce greenhouse gas emissions significantly.
- **Model-Based Performance Analysis:** Researchers use advanced modeling tools (e.g., Matlab, FEFLOW, Modelica) and real-world data to simulate BTES efficiency under varying environmental and geological conditions.
- **Design and Optimization Tools:** Innovative simulation tools like TEGSim and optimization methods (e.g., mixed-integer bilinear programming) support the integration of BTES with ULTDH systems, analyzing factors like temperature swing, system capacity, and heat pump efficiency.

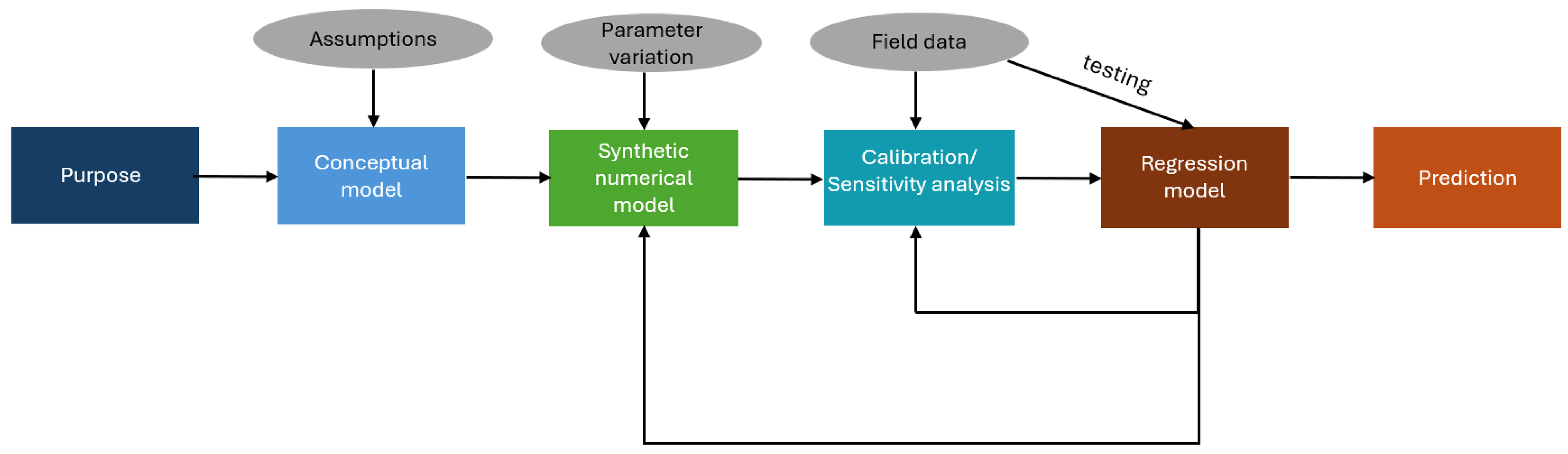
Aquifer thermal Energy Storage (ATES)



source: Underground Energy, LLC; https://underground-energy.com/our-technology/ates/

- **Thermal Energy Storage in Groundwater:** ATES is a system that stores and retrieves thermal energy by injecting and extracting warm or cold water from underground aquifers, typically in deep geological formations for storage purpose .
- **Efficient but Geologically Dependent:** ATES offers high energy efficiency and cost-effectiveness but depends on suitable hydrogeological conditions, as groundwater flow, thermal losses, and geochemical interactions can impact performance.

Modelling workflow



FEFLOW as modelling software

Saturated Flow (Darcy's Law)

$$\nabla \cdot (\mathbf{K}\nabla h) = S_s \frac{\partial h}{\partial t} + q$$

$\mathbf{K}$ = hydraulic conductivity tensor S_s = specific storage

h = hydraulic head q = sources/sinks (wells, recharge, etc.)

Unsaturated Flow (Richard equation)

$$C(h)\frac{\partial h}{\partial t} = \nabla \cdot [K(h)\nabla h] + q$$

$C(h)$ = specific moisture capacity

$K(h)$ = unsaturated hydraulic conductivity

Heat Transport

$$\rho C_p \frac{\partial T}{\partial t} = \nabla \cdot (k\nabla T) - \rho C_p \mathbf{v} \cdot \nabla T + Q$$

T = temperature $\mathbf{v}$ = fluid velocity

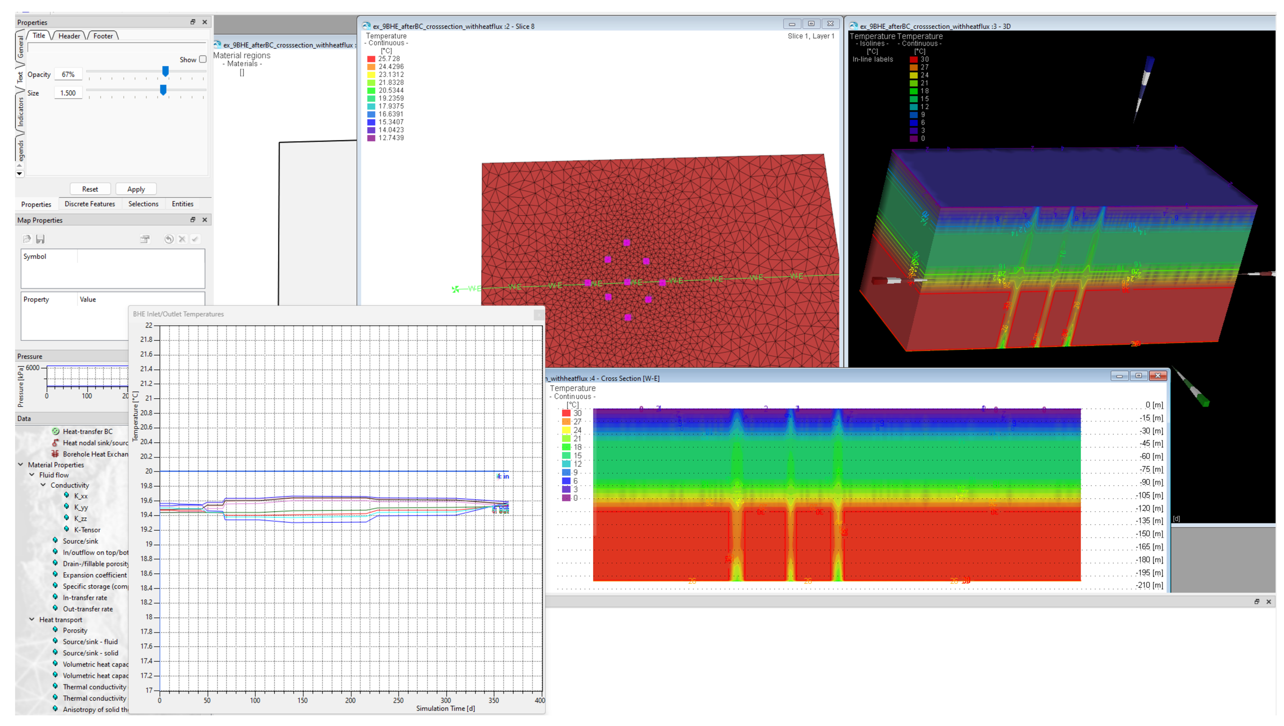
ρC_p = volumetric heat capacity Q = heat source/sink

k = thermal conductivity

source: FEFLOW 8.1 Documentation https://download.feflow.com/html/help81/feflow/01_Introduction/intro.html

Simulation outputs

- BTES system operating under various geological and technical conditions results to a matrix
- Regression model for flexible calculation of BTES performance
- Implementation of results into DHC grid modelling



Get actively involved & talk to us

- FlexGeo aims at a very active stakeholder interaction by establishing an observer board
- We are seeking several case-studies across Europe to assess the FlexGeo technologies and our modelling toolbox
- Potential travel reimbursement for external stakeholder to participate in project events and workshop
- In addition, several side-events at both the European Geothermal Congress 2025 and the ORC conferences 2025 and 2027 are planned

Register for the project newsletter

Project website

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