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Flexibility options of an ATES regarding uncertain and dynamic energy demand

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University Campus CAU Kiel

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New Construction & Retrofitting of Buildings on the University Campus (by 2050)

- new data center: Year-round excess heat, significant cooling demand
- laboratories: Excess heat in summer, heat demand in winter
- offices, student dorms, cafeteria: Heat demand in winter

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- Stepwise integration in local heating/cooling network
- UTES for seasonal load balancing

Key Challenges

- variable and uncertain load requirements due to
  - changing timelines in development of building stock
  - uncertain total energy demand and temperature levels
  - seasonal and climate related fluctuations
- geological uncertainty affects UTES operation

→ Does ATES represent a suitable solution for these challenges?

→ How robust and flexible is an ATES layout to cope with these uncertainties?

Numerical Site Model

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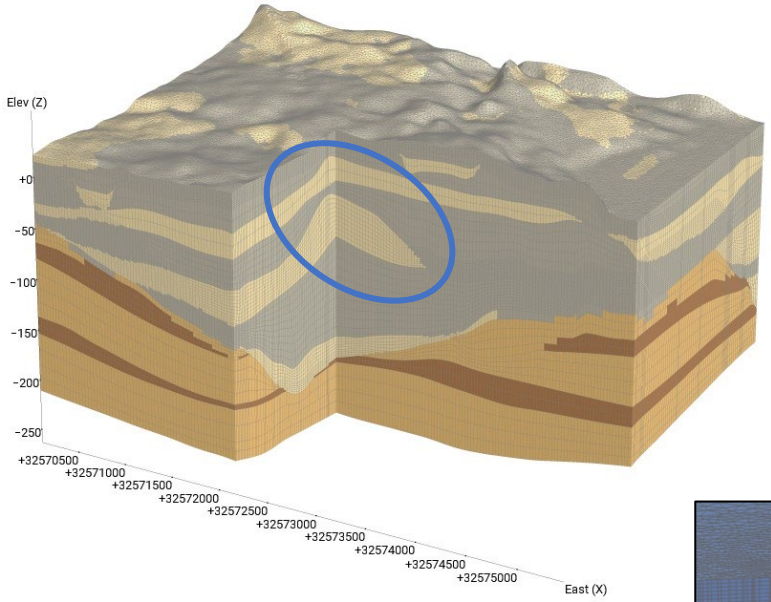
Geological Model (LfU SH)

- Glacial sand and till layers (Quarternary & Tertiary)
- K_f (sieve analyses & permeameter tests): ~ 10^{-4} - 10^{-5} m/s
- uncertain thickness (~ 20 - 40 m)

→ Pumping rates limited by maximum allowable head change

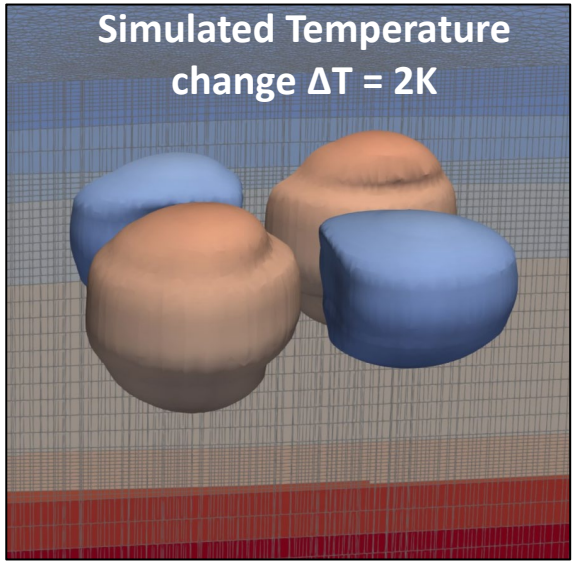


OpenGeoSys
OPEN-SOURCE MULTI-PHYSICS

Numerical Model

- OpenGeoSys (OGS) FE grid based on the geological model
- ATES well field dimensioned for each scenario to ensure peak load

→ TH-simulations of long-term ATES storage over 30 years



Simulation Results

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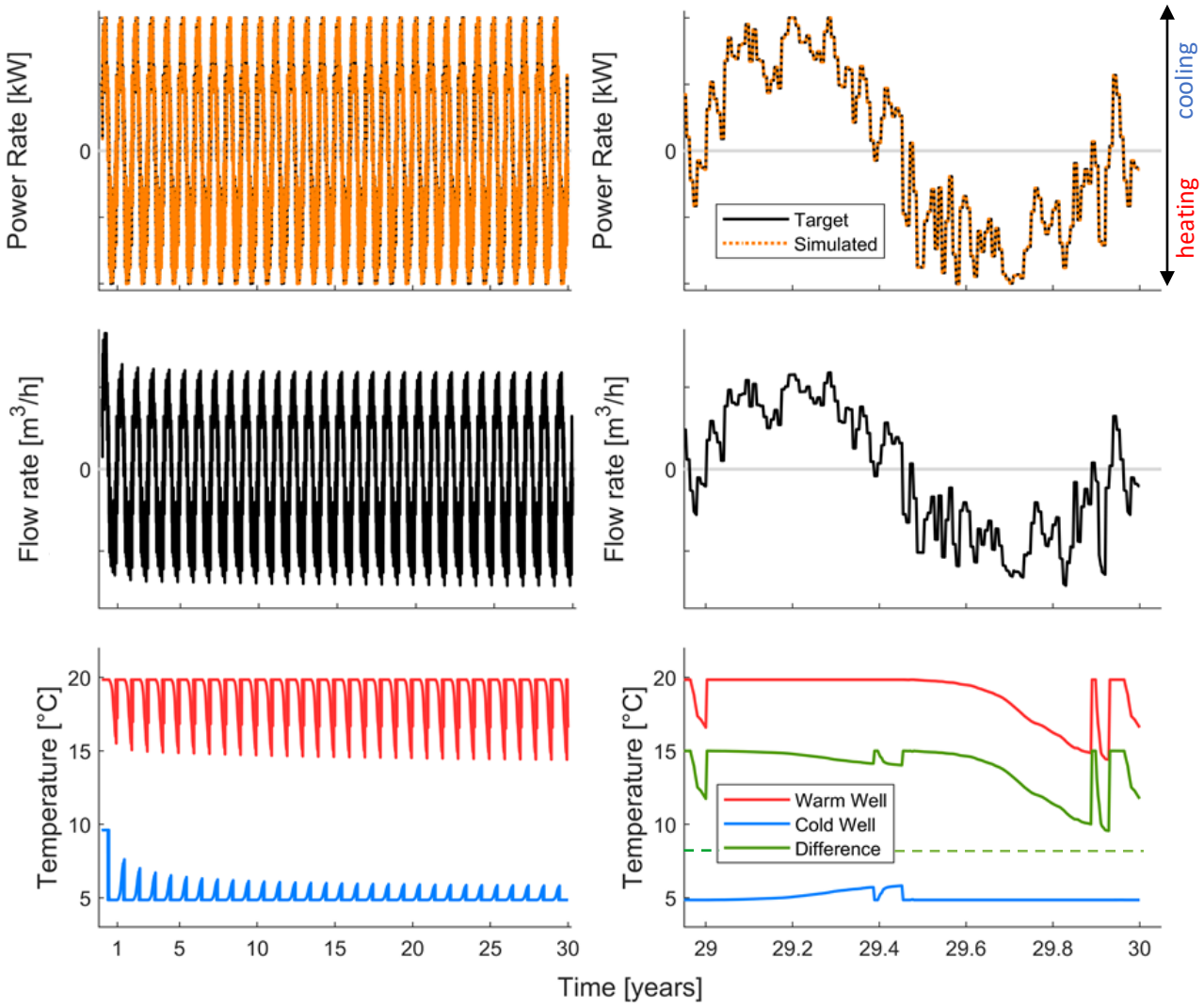
- balanced injection / extraction of heat
- minimum ΔT: 8°C btw. inflow and return temperatures
- dynamic adjustment of pumping rate:

$$Q = \frac{P}{c\rho_w \Delta T} \leq Q_{max}$$

with Q_{max} limited by allowable head change

- For K_f = 2.5·10^{-4} m/s and 40 m storage thickness

→ATES layout with 2 well doublets



Findings:

- ATES able to meet the load demand
- Margins for Q and ΔT

Geological Uncertainty

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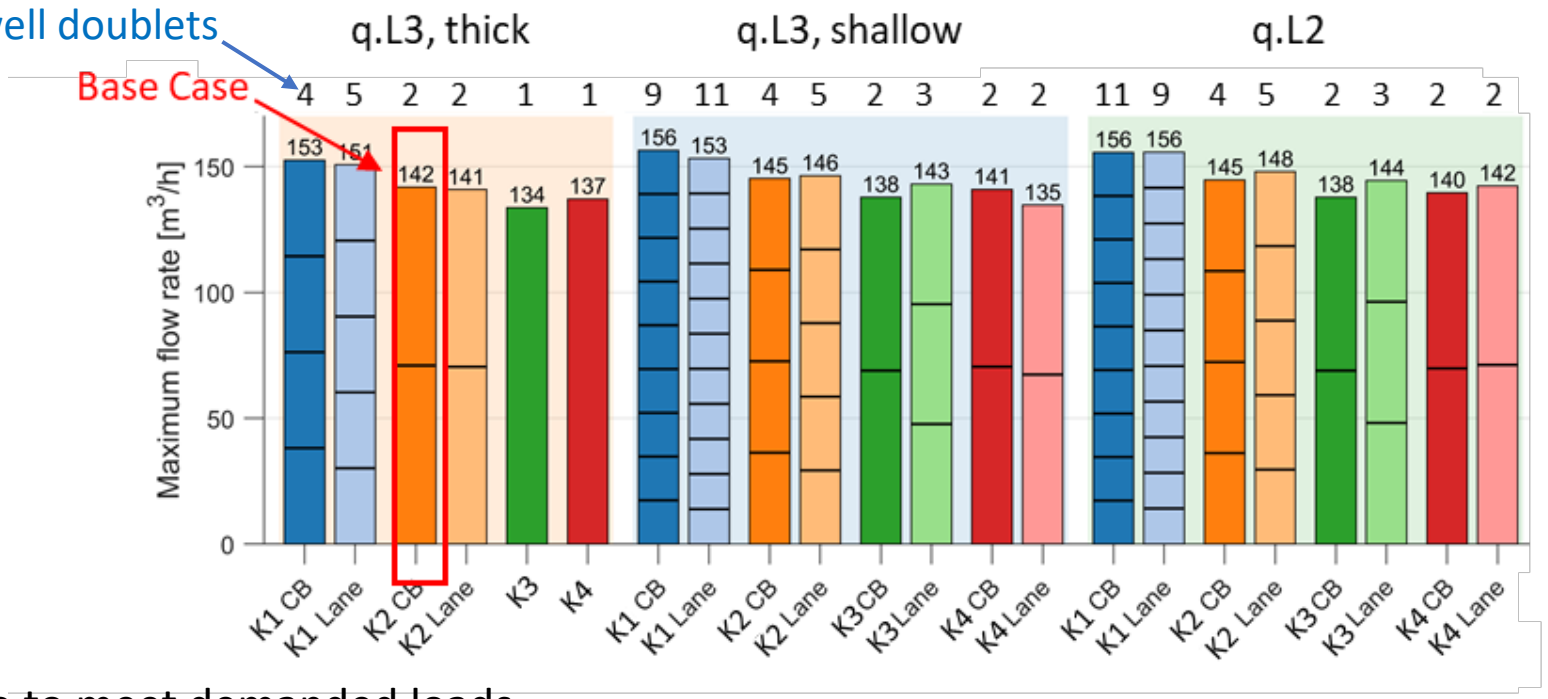
Significant uncertainty in planning stage

- K_f in the range of 10^{-4} - 10^{-5} m/s
- aquifer thickness between 20 - 40 m
- alternative aquifer at shallower depth

→ 12 × 2 scenarios (lane & checkerboard)



Findings:

- ATES can be dimensioned for each scenario to meet demanded loads
- similar total maximum pumping rates across all scenarios
- However: 1 – 11 well doublets necessary depending on hydraulic conditions
- Thermal plumes from well doublets remain on site

Assessment of ATES Layout Robustness by Scenario Simulations

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Increased outdoor temperatures due to climate change

- shifted in balance from heating to cooling
- increases peak loads

Findings

- ATES layout is robust against temperature increase of +2°C
- Increased cooling demand requires higher pumping rates
- peak load increases > 25% may require adjustments of load distribution in the heating / cooling network

Building energy demand uncertainty

- Delayed connection to heating / cooling network
- Repurposing due to changing scientific needs
- uncertain data center loads

Findings:

- ATES layout is robust against planning changes
- ATES underutilization may allow downsizing of ATES by shift of cooling peak loads to compression chillers

Uncertainty of warm well injection temperature

- restrictive approval conditions may limit permittable groundwater temperature increase
- unaccounted heat losses

Findings:

- ATES meets the load demand at lower injection tempratures
- Higher pumping rates required to offset smaller warm / cold well temperature spread

Flexibility options for ATES at the University Campus CAU Kiel

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Geological uncertainties have small impact on overall performance, but significantly affect the ATES layout.

With proper layout according to local hydrogeological conditions and expected load demands, the ATES proves to be robust in face of

- changes in planning progress
- decline in heat source temperature
- rising cooling load due to climate change

Thank you for your attention!

Questions? jan.nordheim@ifg.uni-kiel.de