ATES in Germany – Projects and insight from research on HT-ATES

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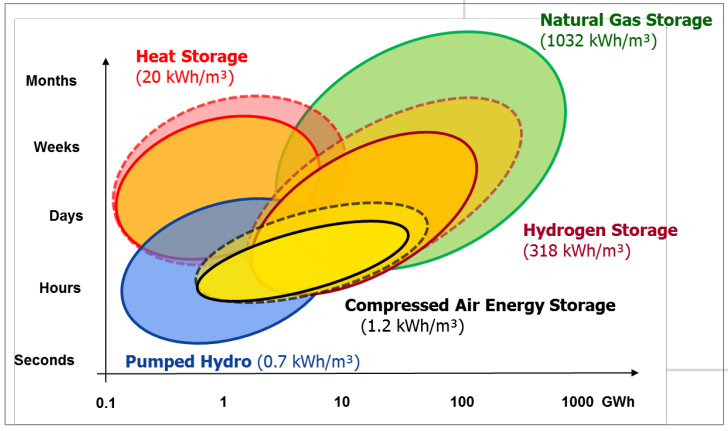


Applied Geosciences, Institute of Geosciences at Kiel University

Research for and Teaching of Applied Geosciences at the Institute of Geosciences at Christian-Albrechts-University Kiel

Working Groups

- **Aquatic Geochemistry and Hydrogeology (Prof. Andreas Dahmke)**
- **Geohydromodelling (Prof. Sebastian Bauer)**
- **Geomechanics and Geotechnics (Prof. Frank Wuttke)**

Address current issues in the fields of hydrogeology, groundwater resources, groundwater quality, water supply, groundwater contamination, geothermal energy, use of the subsurface as a resource, underground spatial planning, geotechnics, geomechanics.

- Operation of own laboratories for geotechnics and aquatic geochemistry
- Operation of a test field site for process analysis, impact determination, and method verification of geothermal energy storage and use
- Teaching focused in the Master's program "Applied Geosciences”

Competence-Centre Geo-Energy

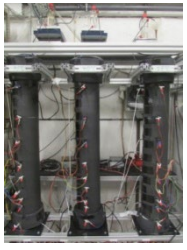
Establishment and operation of a Geo-Energy Competence Center for cooperation between industry and science in the field of applied geoscientific energy and energy transition research

Topics:

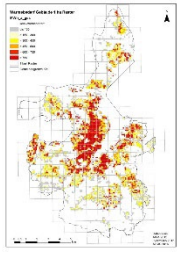
- Subsurface Energy and Mass Storage in the context of the energy and heat transition
- Digitalisation and sustainable use of the geological subsurface
- Climate adaptation measures in urban and coastal areas

Research and Utilization:

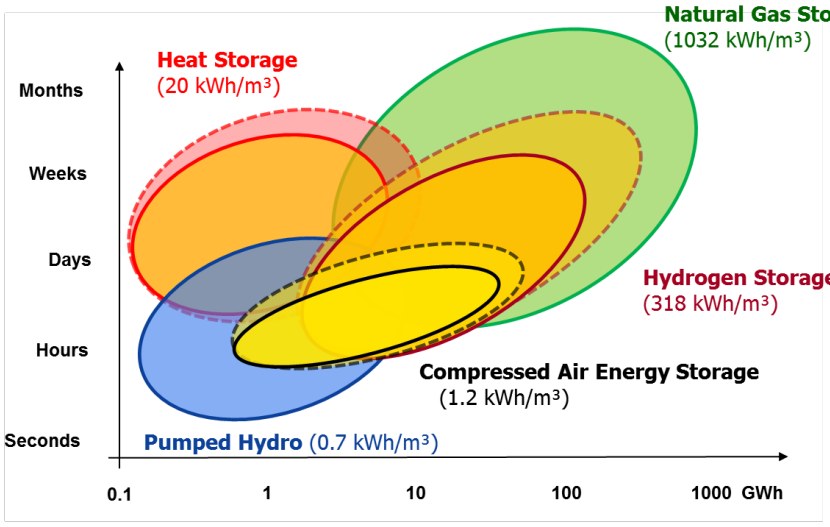
- Experimental Investigations and numerical simulation of storage processes and induced effects of geological energy systems
- Potential analyses and applications for geothermal systems
- Scientific support for real-scale applications

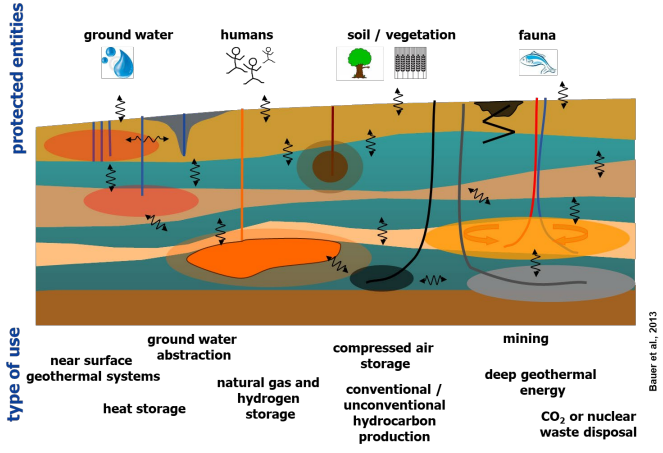








Use of the geological subsurface





ANGUS – projects

Use of the geological subsurface for energy storage as part of the energy transition

- Development and application of numerical simulation methods for geotechnical energy storage
- System integration of storage sites into energy networks
- Analysis of induced effects in the subsurface
- Monitoring
- Parameterization

Bauer et al. (2013), Kabuth et al. (2017)

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
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Bundesministerium für Bildung und Forschung
ENERGIESPEICHER
Forschungsinitiative der Bundesregierung

ATES in Germany

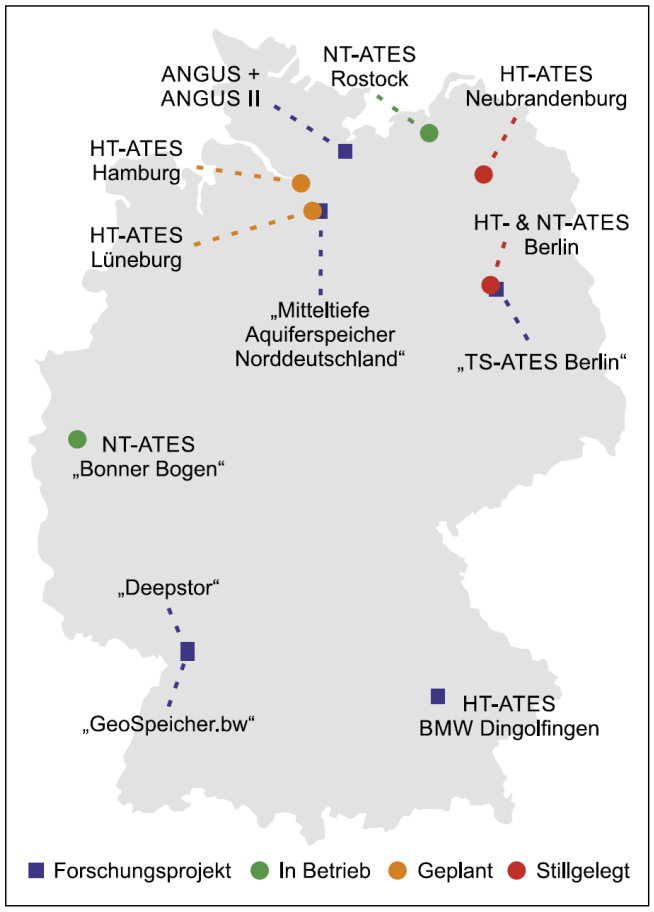


Abb. 2 Übersicht stillgelegter, in Betrieb und in Planung befindlicher Aquiferspeicher in Deutschland
Fig. 2 Spatial distribution of abandoned, operating and planned ATES projects in Germany

Worldwide:

- 2800 ATES systems
- > 99% LT-ATES (<25°C)
- 85% of all ATES in Netherlands

Germany:

- Tiny fraction of worldwide ATES systems in Germany
- Only two systems operational
- Some research projects
- Some abandoned projects and systems

Tab. 1 Zusammenfassung der technischen, energetischen und finanziellen Parameter der Aquiferspeicher in Deutschland
Table 1 Summary over technical, energetic and financial parameters of German ATES systems

Standort	Einrichtung	Zweck	Baujahr	Status	Tiefe (m)	Geologie	Anzahl an Bohrungen	Maximale Fördermenge (m^3/h)	Einspeisetemperatur (°C)	Fördertemperatur (°C)	Leistung (MW)	Investitionskosten (Mio. €)	Amortisierungszeit (–)	CO_2 Einsparungen (t/a)	Referenzen
Berlin	Regierungsgebäude	Heizen + Kühlen	1999	Teilweise vorübergehend stillgelegt	60/300	Sandstein	16	100/320	[a] 7 70[c]	[b] 16 11[c] 30–65[d]	–	–	–	–	Sanner und Knoblich (2004), Sanner et al. (2005), Kranz und Frick (2013); Holstenkamp et al. (2017)
Neubrandenburg	Fernwärme	Heizen	2005	Stillgelegt	1200	Sandstein	2	100	85–90	75–80	3,3	–	–	–	Kabus et al. (2006, 2008); Holstenkamp et al. (2017)
Rostock	Fernwärme	Heizen	1999	In Betrieb	20	Sande	2	15	50	50	–	1,02	–	–	Schmidt und Müller-Steinhagen (2004), Seibt und Kabus (2006)
Bonn	Gebäudeareal	Heizen + Kühlen		In Betrieb	30	Sande, Kiese	6–	300	13 20	–	–	–	–	400	Mands et al. (2010)

[a]Mittlere Einspeisetemperatur nach der Regenerierung beim flachen Kältespeicher
[b]Mittlere Fördertemperatur vor der Regenerierung beim flachen Kältespeicher (aus Kranz und Frick 2013)
[c]Mittlere Fördertemperaturen nach der Regenerierung über Rückkühlwerke
[d]Temperaturen beim tiefen Wärmespeicher (aus Holstenkamp et al. 2017)

Fleuchhaus et al. (2021)

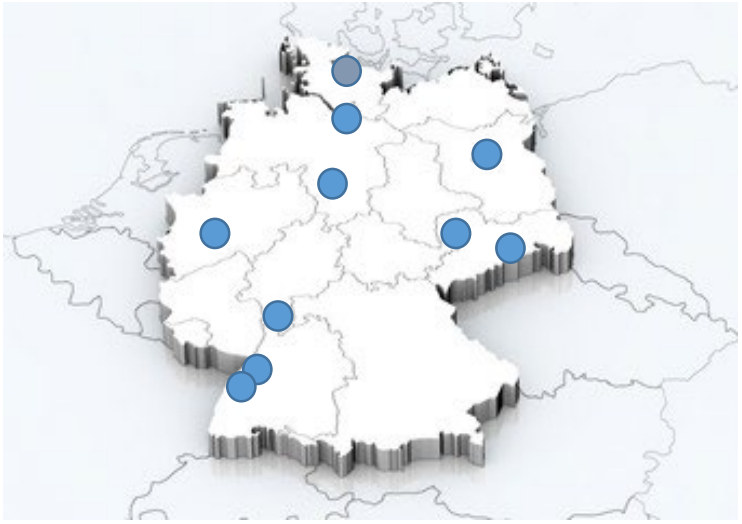
Cluster-Projects

Current initiative by **German Ministry of Education and Research (BMBF)** for focussed reasearch on ATES systems:

„Possibilities and limitations of thermal energy storage in aquifers"

„Möglichkeiten und Grenzen thermischer Energiespeicherung in Aquiferen"
as part of the GEO:N programm

Duration: 2022 – 2025



Location of consortia leaders

- Open Call for research consortia
- Total of 9 collaborative projects approved
- Mainly energy focussed
- Mix of universities and research centres as well as some companies participate
- Projects started only last year, no public results so far

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GEO:N – Geoforschung für Nachhaltigkeit
Fachprogramm im Rahmenprogramm „Forschung für Nachhaltige Entwicklung (FONA³)"

Cluster-Projects

OptInAquiFer
Optimized integration of thermal aquifer storage into district heating systems

UnClog-ATES
Clogging and concrete countermeasures in ATES: experiments, modelling and forecasts taking into account biogeochemical influences

Winzer
Heat storage in mines in the Ruhr area

KONATES
Pilot project for the use of contaminated aquifers for heat management with ATES systems

GEOTES
Possibilities and limits of thermal energy storage in deep aquifers (georeservoirs) in the context of the heat transition 2030

PotAMMO
Potentials of aquifer heat storage in the model regions of Mannheim and Offenbach

Demospeicher
Development and monitoring of seasonal heat and cold storage for the demonstration of an aquifer storage facility in Germany

MineATES
Use of groundwater-filled mining cavities as thermal energy storage

SpeicherCity
Models for system integration of aquifer storage in cities

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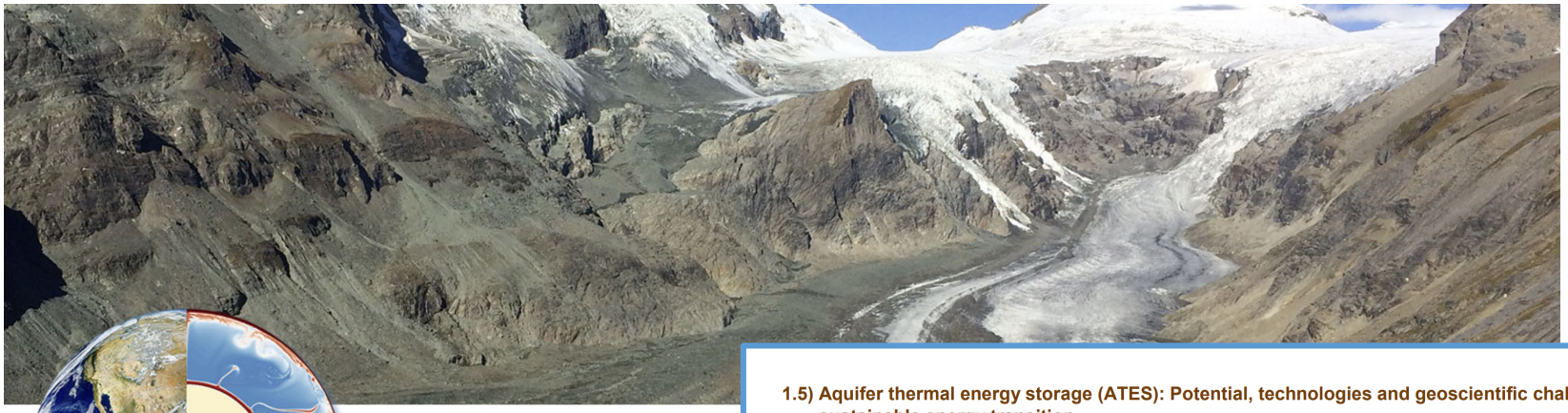
ATES call GeoBerlin 2023



GeoBerlin 2023 –

Geosciences Beyond Boundar

150th PGLA (BGR) Anniversary a

Berlin | 3 – 7 September 2023

NEWS

Call for Abstracts (open)
Deadline: 3 May 2023

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

1848 2023 DGGV Deutsche Geologische Gesellschaft Geologische Vereinigung 175 Jahre

1.5) Aquifer thermal energy storage (ATES): Potential, technologies and geoscientific challenges for a sustainable energy transition

Bauer, Sebastian (1); Bayer, Peter (2); Blum, Philipp (3); Virchow, Lioba (4); Neumann, Thomas (5); Scheytt, Traugott (6)
1: Institute of Geosciences, Christian-Albrechts-Universität zu Kiel, Germany;
2: Institute of Geosciences and Geography, Martin-Luther-Universität Halle, Germany;
3: Institute of Applied Geosciences, Karlsruhe Institute of Technology, Germany;
4: Helmholtz Centre Potsdam, Potsdam, Germany;
5: Institute of Applied Geosciences, Technical University Berlin, Germany;
6: Technical University Bergakademie Freiberg, Freiberg, Germany

Large scale and up to seasonal storage of heat in the urban subsurface allows to integrate renewable or fossil-free heat sources into the urban energy and heat supply systems. Aquifer thermal energy storage (ATES) may provide the large rates and storage capacities required. Successful application of this technology relies on an appropriate characterisation of the subsurface geosystem, the determination of spatially and temporally resolved heat supply and demand, the successful integration of the storage operation into the heat supply system and the characterization of coupled processes leading to performance reduction and impacts on the subsurface environment.
This session addresses all topics, technologies and concepts related to the successful implementation and operation of ATES systems as well as the characterization of induced impacts and aims at providing a state-of-the-art overview of current national and international activities.
Relevant topics include but are not limited to:

- Identification and characterization of suitable storage formations
- Identification and determination of key site-specific parameters
- Development and application of suitable simulation approaches
- Concepts for integrated energy systems and their analysis
- Evaluation of data needs and data availability
- ATES scenarios contributing to reduced electricity needs and low carbon future
- Determination of induced geochemical and microbiological effects during operation
- Quantification of spatial subsurface requirements
- Site investigations for groundwater quality and environmental impacts
- Monitoring strategies and indicators for efficiency changes and adverse reactions
- Presentation of pilot and operating ATES systems

GeoBerlin 2023

3 – 7.9.2023, Berlin

Dedicated ATES session !

Abstract call open till May 3rd

www.geoberlin2023.de

HT-ATES studies by Kiel University

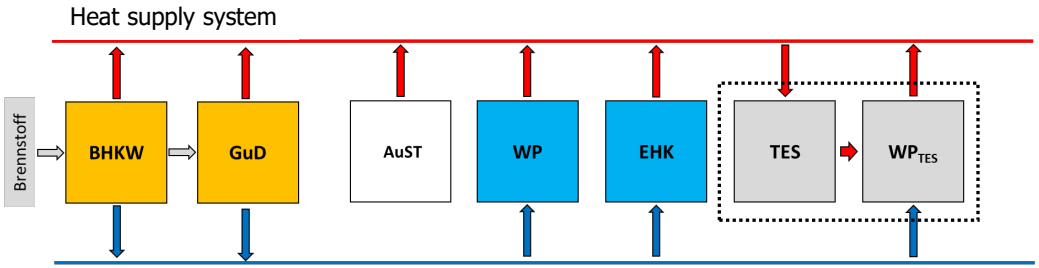
The Applied Geosciences working groups at Kiel University are participating in these ongoing research efforts and have been conducting research on LT-ATES and HT-ATES systems for more than 10 years.

- Modelling of storage operations and integration in energy networks
- Quantification and numerical simulation of thermal and hydraulic effects
- Identification and quantification of induced geochemical and microbiological effects as well as ecological impacts
- Subsurface space planning
- Participation in design studies for ATES systems
- Field test of a HT-ATES for method verification

Example results:

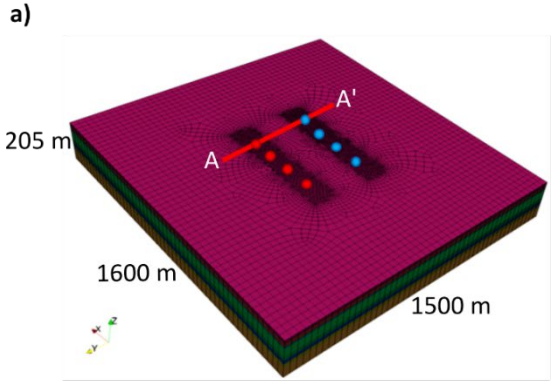
- Integration of HT-ATES in an energy and heat supply system
- Induced thermal impacts and space demand of an HT-ATES
- Field research experiment on HT-ATES on induced thermal, geochemical and biological impacts

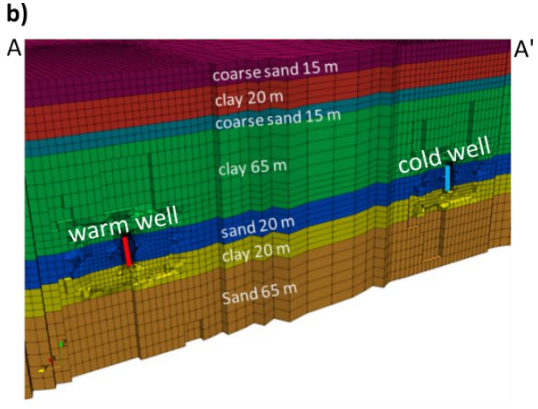
Integration of ATES in future energy systems



BHKW Combined heat and power plant
GuD Gas and Steam turbine
AuST Waste heat and solar thermal
WP Heat Pump
EHK Electric heater
TES Thermal Energy Storage

- The heat supply system incorporates controllable (CHP, EHK) and must-run (AuST) components.
- District heating temperatures vary between 70°C and 90°C.
- Scenarios with varying contributions of Power and Heat Cogeneration, Power to Heat and Must-Run capacities.





- The hypothetical ATES consists of 4 well doubletts assuming a typical setting of sandy and marly layers for northern Germany
- Target capacity is 25 GWh and target power 12 MW.
- Loading is directly from the heating network, unloading via a heat pump.

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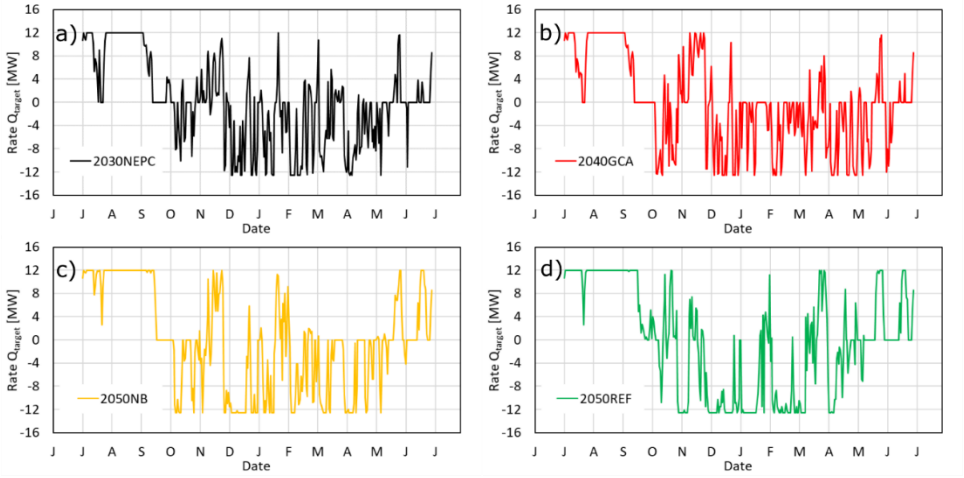
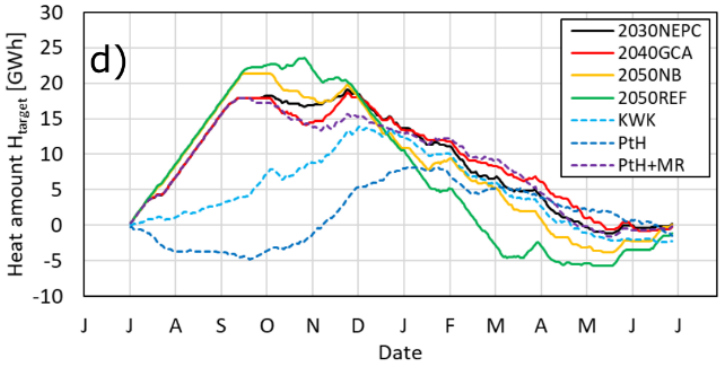
ANGUS II Report (2021), unpublished

Integration of ATES in future energy systems

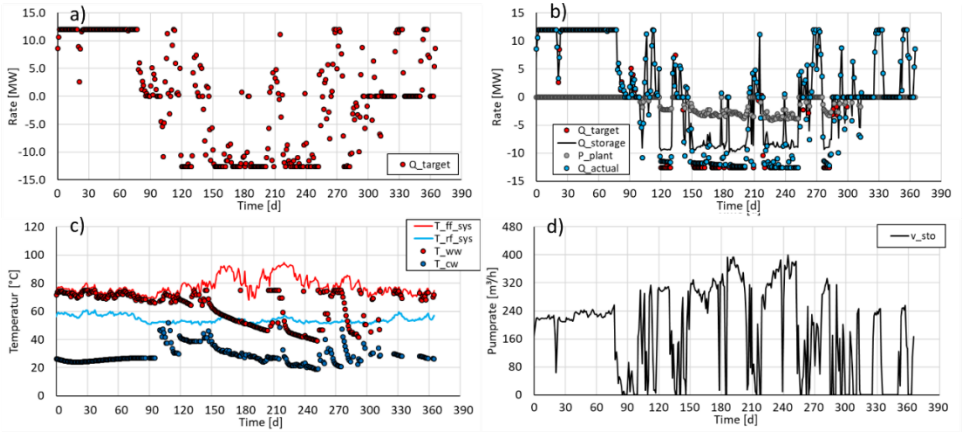
ATES-Load profiles for four scenarios



Used capacity



Scenario 2050REF



a) Target (=Requested) Load (Q_{target}) (positive values indicate loading, negativ unloading of storage)
b) Heat flow rates ($Q_{storage}$), electric power P_{plant}, total heat (Q_{actual}) and target heat (Q_{target})
c) Temperatures at inflow $T_{ff,sys}$ and return flow $T_{rf,sys}$ at warm well T_{ww} and cold well T_{cw}
d) Volume pumping rate of all 4 wells v_{sto}.

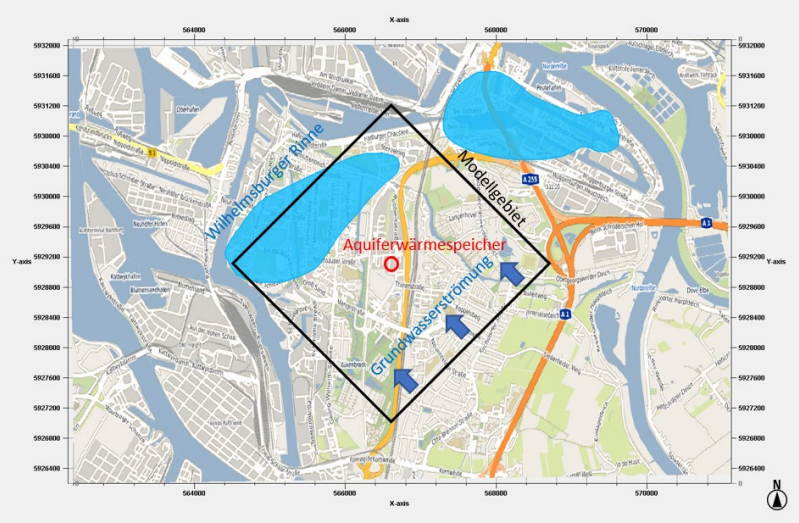
ANGUS II Report (2021), unpublished

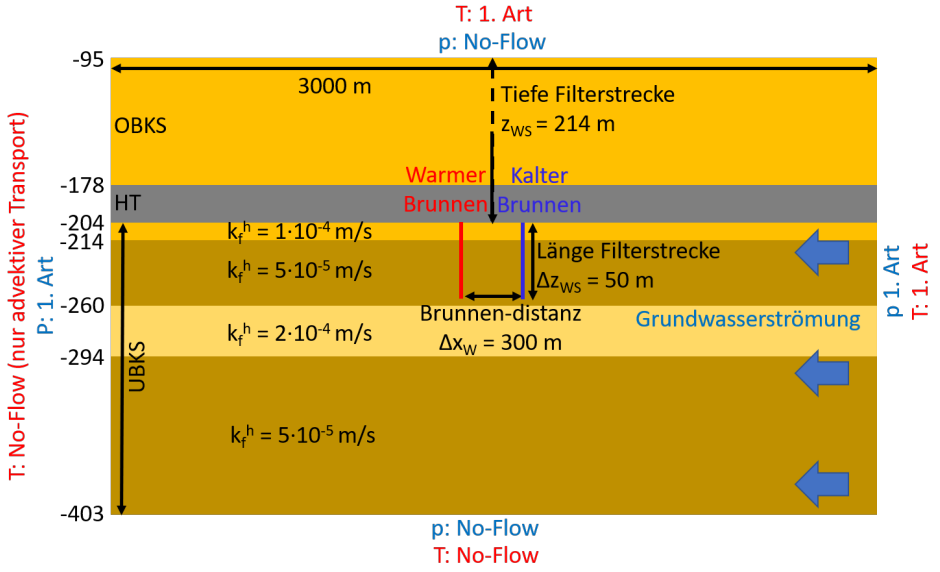
Energetic design and thermal impacts of an HT-ATES

Planned as part of project IW³ – Integrierte Wärme-Wende Wilhelsburg (Integrated Het Transition in Wilhelsburg, part of City of Hamburg)

Task: Energetic design and thermal impacts

- Load curve generated from heating demand of part of Hamburg and heat supply system with a combination of geothermal and conventional heat generation
- Connected to distric heating network, Heat pump to achieve target temperatures
- Site specific hydro-geological model of groundwater flow and ATES operations

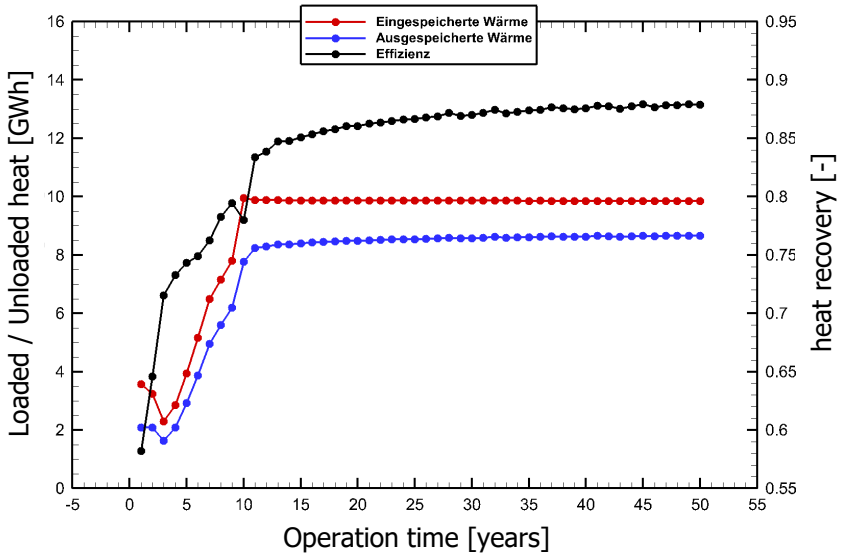




Heldt et al., unpublished

Energetic design and thermal impacts of an HT-ATES

- Load curve with increasing heat demand for first 8 years
- Fluctuating but mainly seasonal load curve
- Simulated heat recovery about 85%
- ~10 GWh annual heat stored

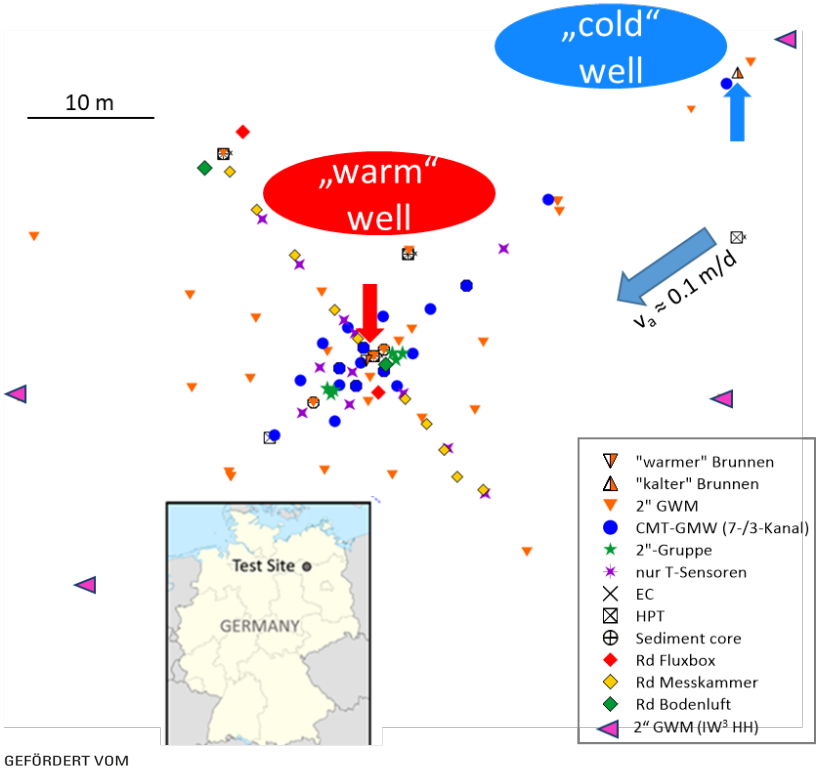


Heldt et al., unpublished

Test site „Testum“ for HT-ATES

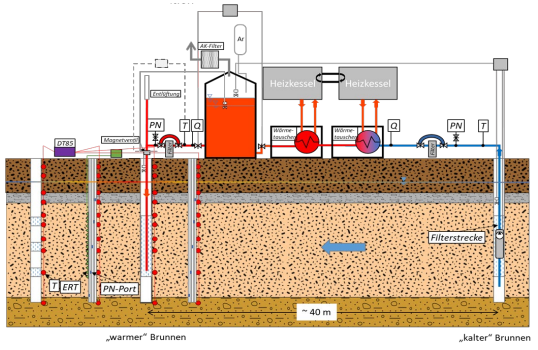
- **Test site for energy transition related technologies and their subsurface impacts**
- **Tests of hydrogen and methane gas injections as well as high-temperature heat**
- **Verification of process understanding, parameters and models**

Check Link: www.testum-aquifer.de



„heating“ system

„warm“ well



Hornbruch et al. (2023), Online Presentation

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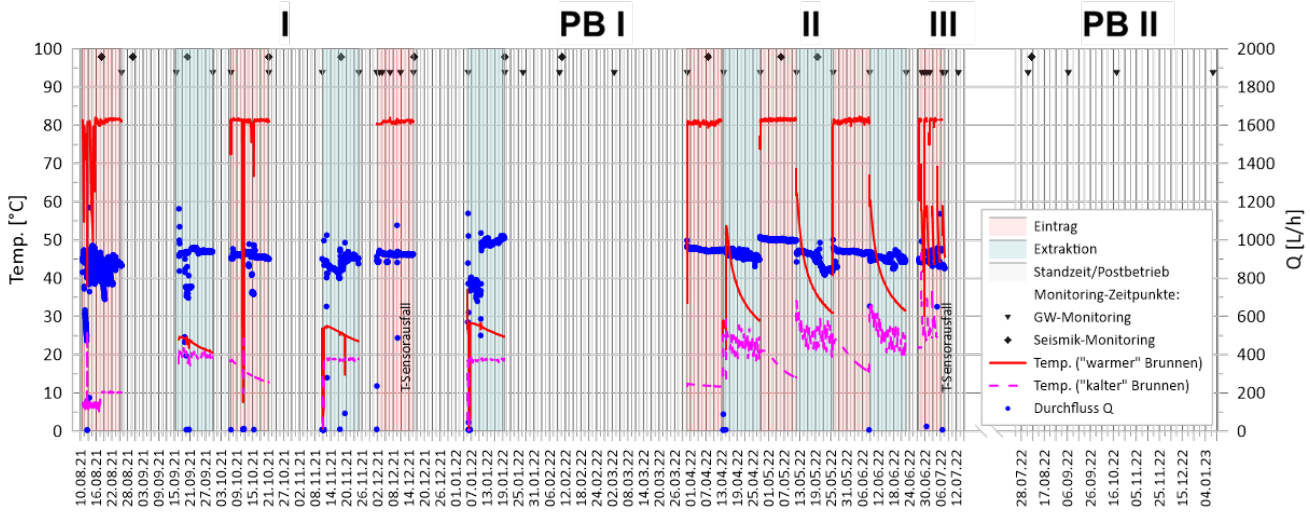
GEO:N – Geoforschung für Nachhaltigkeit

Fachprogramm im Rahmenprogramm „Forschung für Nachhaltige Entwicklung (FONA³)“

Test site „Testum“ for HT-ATES

- Hot Water injection at 80°C
- Cycle times of 2 weeks down to 1 day, resting times
- Monitoring of temperatures at ~ 600 sensors continuously
- Groundwater chemistry samples at 80 locations and 30 times each
- Microbiology at 8 locations and 15 times



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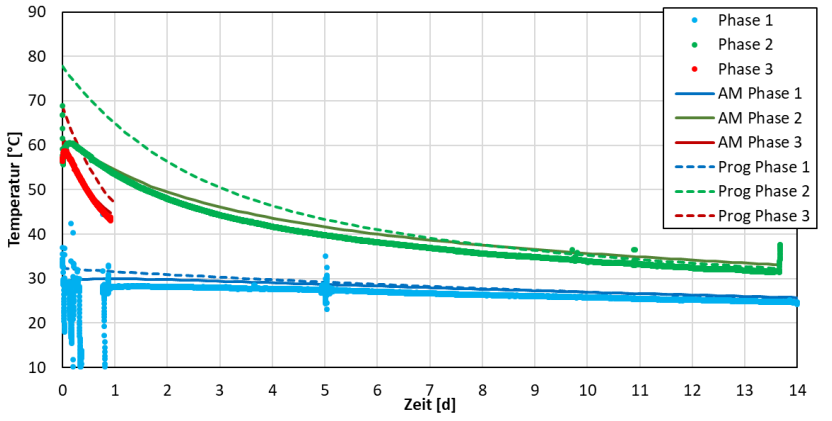
Hornbruch et al. (2023), Online Presentation

Test site „Testum“ for HT-ATES

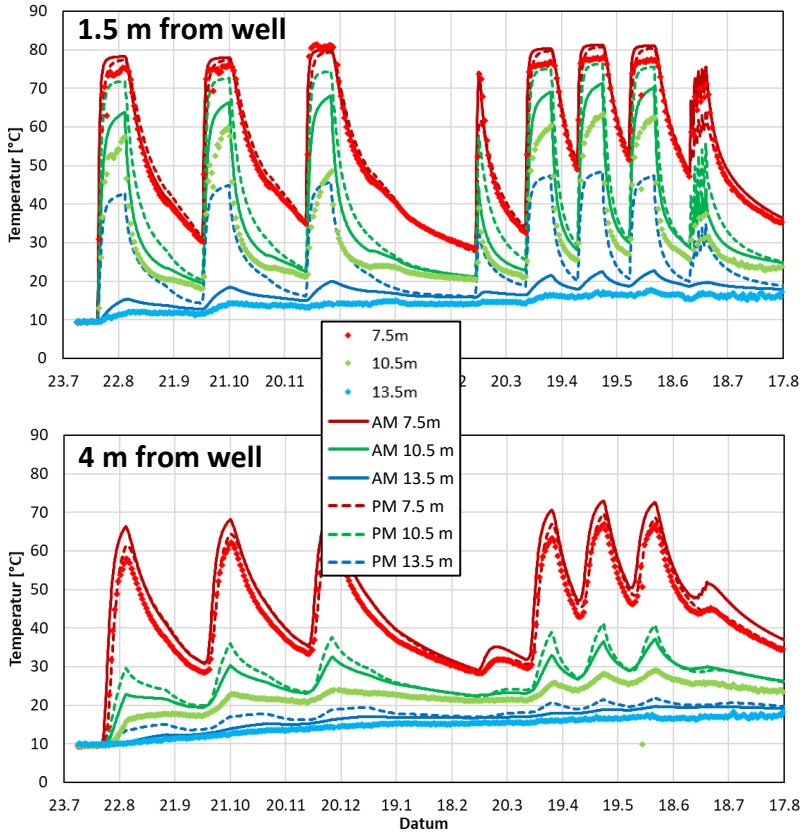
Heat transport simulation

- Good approximation of return flow temperatures
  => closed energy balance
- Good approximation of spatial temperature distribution
  => temperature impacts and spatial demands characterized
- Some local mismatches of T-stratification

Return flow temperature



Vertical temperature profiles



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Hornbruch et al. (2023), Online Presentation

Test site „Testum“ for HT-ATES

Cross section of Si- concentrations

- mobilization due to temperature increase
- vertical transport close to warm well
- interaction of mixing and temperature effects on local concentrations => challenge for regulations?
- No lasting concentration changes

Microbial characterisation

- Increase of meso- and thermophile micro-organisms at elevated temperatures

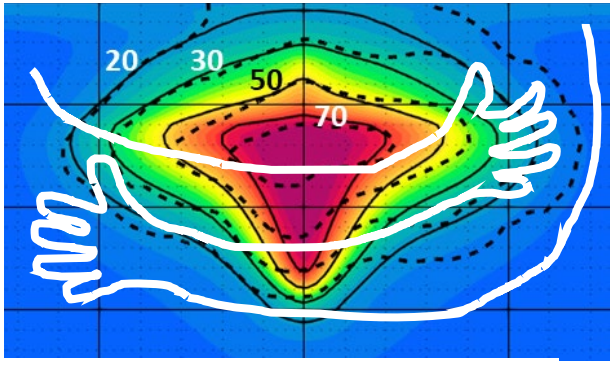
Conclusions

- Currently, very few ATES systems in Germany operational
- missing practical expertise / knowledge and know-how
- Theoretical know-how from research principally available, but missing interface to implementers
- Integration of ATES systems in heat supply systems often unclear and uncertain, due to changing cost environment and boundary conditions
- Missing local geological knowledge to determine site-specific ATES or BTES potential
- Missing / unclear regulations at elevated temperatures or financial incentives for ATES

Hug pylons not trees

© The Economist

- Demonstration systems required
  -> dissemination of know-how and practical applicability
  -> regulatory approval and state of the art
- Research required on temperature effects on H, M, C and B especially at elevated temperatures (>30°C and/or >50°C)
- Screening of ATES potential and suitable geological settings
- Clear regulatory environment with respect to climate goals



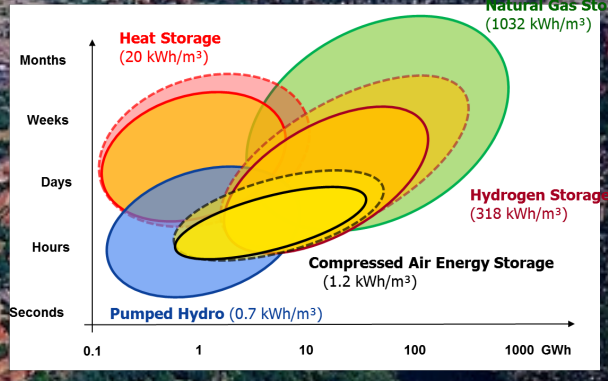
Ambition: Hug ATES and water

Thank you very much for your attention.

Contact:

Sebastian.Bauer@ifg.uni-kiel.de

For TestUm fild test site: www.testum-aquifer.de



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