

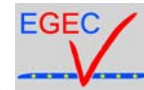
Deep Saline Aquifers for Geological Storage
of CO₂ and Energy
Rueil-Malmaison, France
17. April 2009



Thermal energy storage in aquifers - three decades of experience gained, and what are future prospects?

Burkhard Sanner¹ and Jörn Bartels²

¹ European Geothermal Energy Council, Brussels



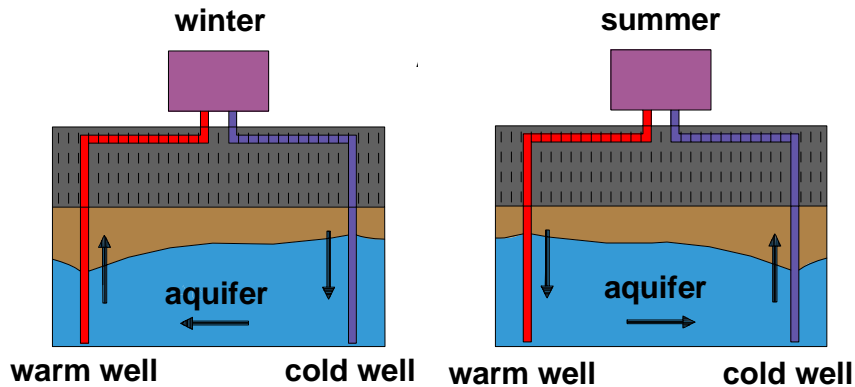
² Geothermie Neubrandenburg GmbH,
Neubrandenburg, Germany



ATES Principle



Aquifer Thermal Energy Storage,
principle of seasonal cycling



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First ideas of using aquifers for energy storage



Heat storage in the ground, using borehole heat exchangers was proposed by:

Brun, G. (1964): La régularisation de l'énergie solaire par stockage thermique dans le sol. - Revue Gén. de Thermique 44

In the early 1970s, the storage of heat in aquifers was suggested for the first time (temperatures of up to 340 °F / ca. 170 °C):

"This would utilize the aquifer for the storage of heat on a cyclic basis and would improve the thermodynamic efficiency of the process by the salvage of waste heat" (Kazman, 1971:520, Exotic Uses of Aquifers).

"Heat storage wells may be the key to using the high-quality heat produced as electricity is generated; the seasonal heat loads can, through heat storage, be matched to electrical demand" (Meyer & Todd, 1973a:42)

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ATES experiments and projects



List of early projects

Year	Event
	In 1960's some huge ATES plants in China (Shanghai, Changzou)
1974	Univ. Neuchâtel, CH, small aquifer experiment
1976	Auburn Univ., Al., USA, aquifer experiment
	Formation of modeling groups in Berkeley, USA, and Lund, Sweden
1982	"SPEOS", Lausanne-Dorigny, CH, ATES experiment Yamagata Univ., Yonezawa, J, ATES experiment Hørsholm, DK, high temperature ATES experiment Univ. Minnesota, St. Paul, USA, HT-ATES experiment Hokkaido Rehabil., Sapporo, J, ATES, heating Univ. Alabama, Tuscaloosa, USA, ATES, cooling
1983	224 flats, Aulnay-sous-bois, F, ATES, with HPs
1985	Scarborough Ctr., Toronto, CAN, ATES, H & C
1987	Plaisir-Thiverval-Grignon, F, HT-ATES experiment Head Office SAS, Frösundavik, S, ATES, H & C Perscombinatie, Amsterdam, NL, ATES, cooling
1991	Utrecht Univ., Utrecht, NL, HT-ATES

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ATES experiments and projects



List of early projects

- ★ ATES experiment
- ☆ ATES demonstration



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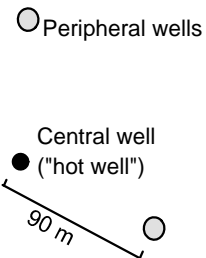
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t
EGEC

First high temperature ATES experiments



Test in Le Plaisir, Thiverval-Grignon, 1980-1990

- 4 wells 500 m deep
- 2 straight, 2 inclined
- bottom-hole distance ca. 90 m
- Flow rate for loading 90 m³/h, for unloading 120 m³/h
- water heating in steps up to 70 °C and finally to 180 °C
- operational since 1987
- retrieval system destroyed in 1999



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Practical examples in NL



The only projects using

- deeper wells
- for heat storage at elevated temperatures
- and running several years

in the 1990s where in the Netherlands:

- Uithof Campus, Utrecht University, Utrecht
- Hooge Burch Hospital (near Gouda)

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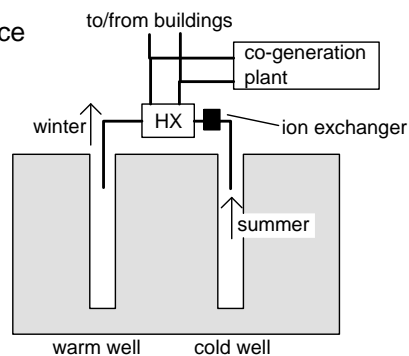


Practical examples in NL



Campus „De Uithof“ of Utrecht University, Utrecht

- 2 wells 260 m deep at 70 m distance
- Flow rate for loading 100 m³/h, for unloading 50 m³/h
- two heat and power co-generation plants with 3.8 and 4.0 MW
- water heating up to 90 °C
- heat stored (from CHP) up to 950 kW_{th}
- heat use in winter ca. 2.6 MW_{th}
- operational since 1991
- abandoned ca. 2000



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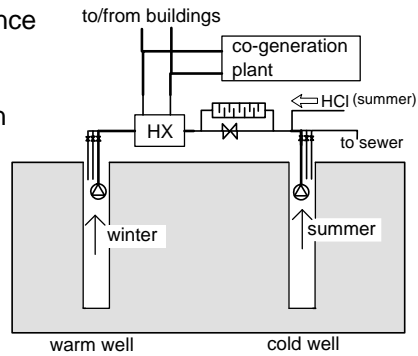


Practical examples in NL



Hooge Burch Hospital (near Gouda)

- 2 wells 150 m deep at 70 m distance
- Flow rate for loading 20 m³/h, for unloading 25 m³/h
- two heat and power co-generation engines
- combined electric power output 610 kW_{el}
- water heating up to 90 °C
- heat stored (from CHP) up to 950 kW_{th}
- heat use in winter ca. 600 kW_{th}
- operational since 1998



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Practical examples of the last decade



Three projects in Germany:

- Residential area Brinckmannshöhe, Rostock (with HP, not further discussed here)
- Reichstag building (main building for the German Parliament, Bundestag, in Berlin)
- Deep ATES for district heating in Neubrandenburg

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ATES for the Reichstag building in Berlin



The buildings of the German Parliament (Bundestag) in Berlin



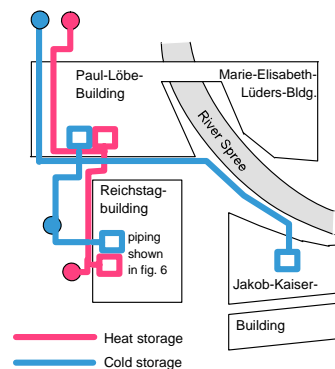
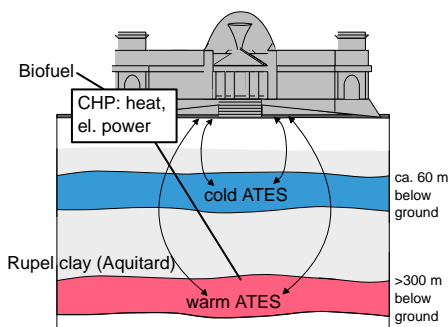
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ATES for the Reichstag building in Berlin



Two ATES at different levels for the German Parliament (Bundestag) in Berlin



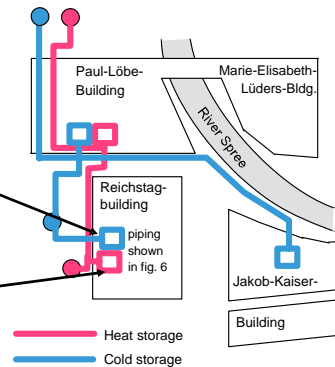
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ATES for the Reichstag building in Berlin



Two ATES at different levels for the Bundestag in Berlin



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ATES for the Reichstag building in Berlin



Design data for cold storage

Summer (retrieving)	production temperature	6 ... 10°C
	injection temperature	15 ... 28°C
	cold retrieved	3.950 MWh/a
Winter (loading)	mean production temp.	22°C
	injection temperature	5°C
	cold stored	4.250 MWh/a
Balance	energy for pumping	220 MWh
	ratio of cold retrieved to cold stored	93 %



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ATES for the Reichstag building in Berlin



Design data for heat storage

Summer (loading)	mean production temp.	20°C
	injection temperature	70°C
	stored heat	2.650 MWh/a
Winter (retrieving)	production temperature	65 ... 30 °C
	heat retrieved	2.050 MWh/a
Balance	energy for pumping	280 MWh
	ratio of heat retrieved to heat stored	77 %



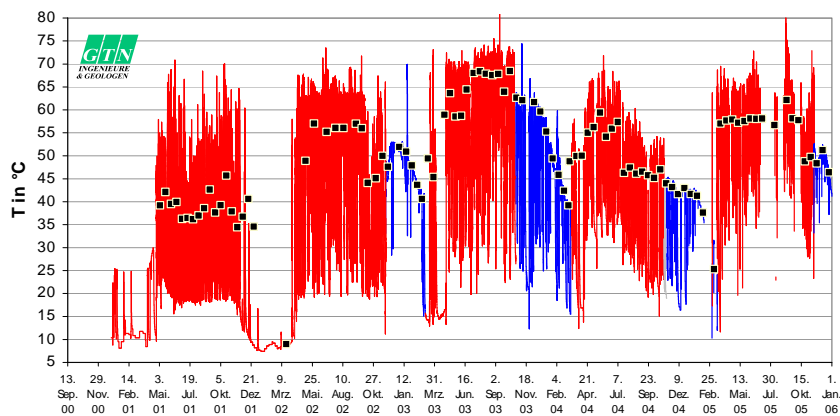
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ATES for the Reichstag building in Berlin



Temperature development 2001-2005, well WS1



wellhead temperatures „warm“ side
red: recharge, blue: discharge

Datum



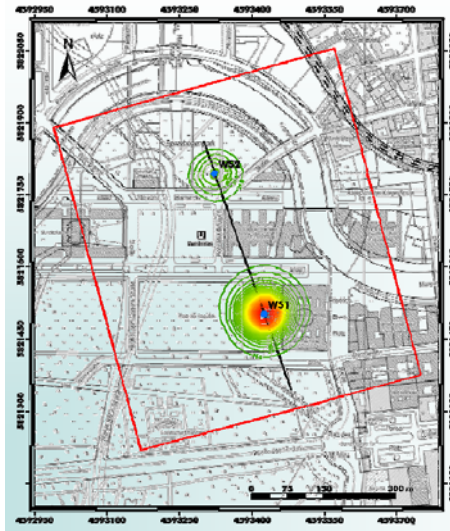
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ATES for the Reichstag building in Berlin



Horizontal extent of the thermally influenced zones at 31.10.2008



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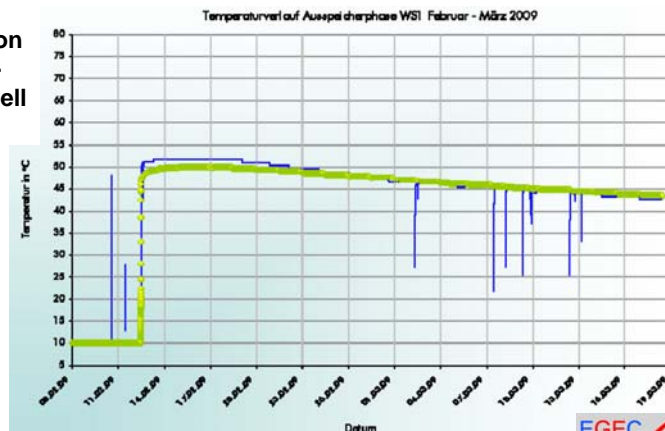


ATES for the Reichstag building in Berlin



Verification of numerical simulations with discharge temperatures winter 2008/09

green: simulation result of a combined aquifer-well model



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ATES in deep aquifer in Neubrandenburg



Geothermal heating plant with low-temperature network „Rostock street“ (12 MW, 80°C/45°C)



Gas and steam cogeneration plant (77 MW electrical, 90 MW thermal)

with

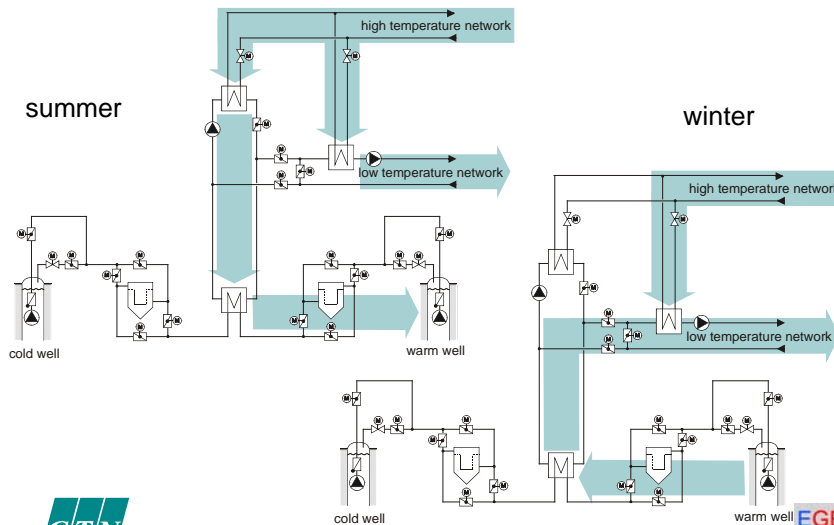
High-temperature network (200 MW, 130°C / 60°C)



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ATES in deep aquifer in Neubrandenburg



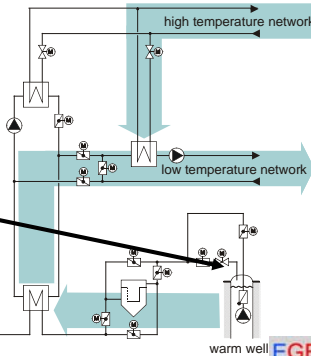
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ATES in deep aquifer in Neubrandenburg



winter



cold well

warm well



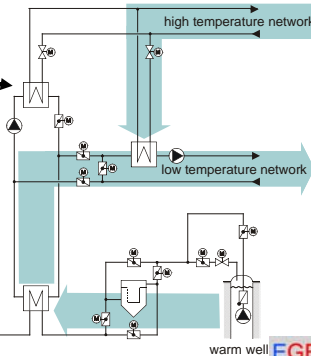
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ATES in deep aquifer in Neubrandenburg



winter



cold well

warm well



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ATES in deep aquifer in Neubrandenburg



Geological formation	Upper Postera sandstone
Depth	1,228 m – 1,268 m
Reservoir temperature	55 °C
Mineralisation	135 g/l
Porosity	26.6 %
Permeability	0.94 μm^2 – 2.8 μm^2
Number of wells	2
Internal distance	1,300 m
Production and injection flow rate	100 m³/h
Start of operation	2004
Injection temperature	80 °C
Discharging temperature (5th year)	78 °C – 72 °C



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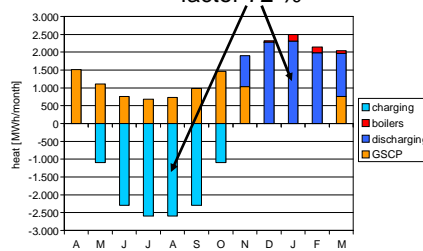
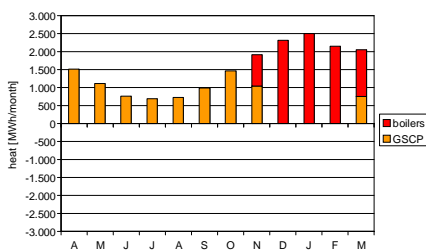


ATES in deep aquifer in Neubrandenburg

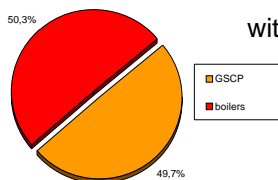


Heat demand coverage after feasibility study

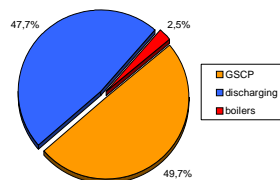
Planned heat recovery factor 72 %



without ATES



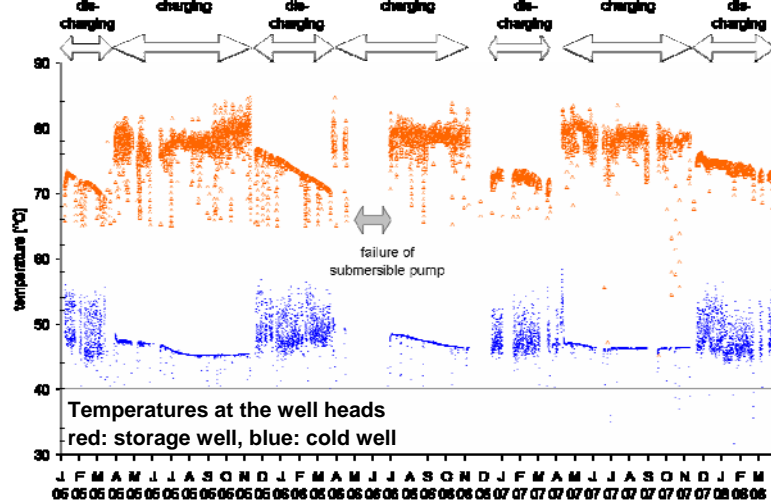
with ATES



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ATES in deep aquifer in Neubrandenburg



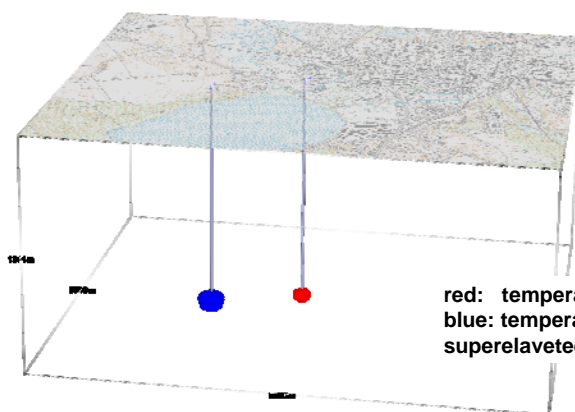
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ATES in deep aquifer in Neubrandenburg



Simulated extend of the thermally influenced zones at the end of recharge season 2007



red: temperature > 57 °C
blue: temperature < 51 °C
superelaveted 2:1



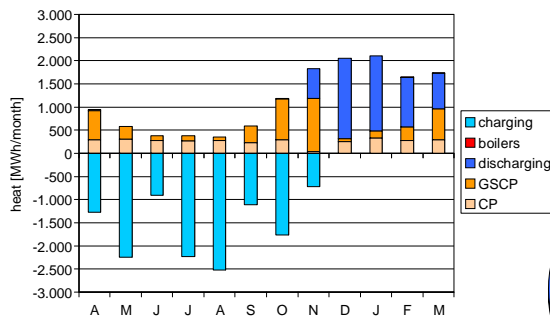
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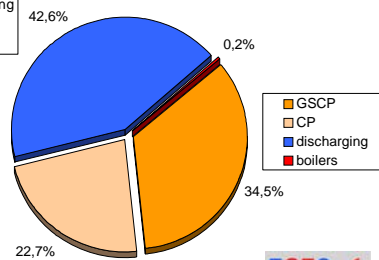
ATES in deep aquifer in Neubrandenburg



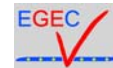
Actual coverage of demand in the „Rostock Street“ low temperature network, 2007/2008



Additional heat supplier in the system (CP, gas fired co-generation unit)



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Low-temperature ATES: Practical examples in NL



There is a total of about 500 ATES systems in the Netherlands

- Mainly relatively shallow
- Most for storage of cold or low-temperature heat



Prins-van-Oranje-Hall, Utrecht fair, ATES for cooling and for pre-heating of ventilation air

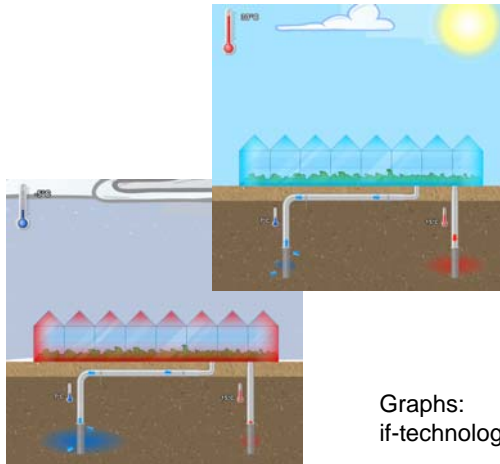
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Low-Temperature ATES: Practical examples in NL



ATES-projects for greenhouses



Graphs:
if-technology, Arnhem

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Low-Temperature ATES: Other practical examples



ATES-projects exist in:

- Sweden (mainly Southern Skania, but also in eskers in the Stockholm area)
- Belgium (cold storage for bank, hospital etc.)
- smaller numbers in Canada, Germany, China, etc.



ATES for cold storage for KLINA hospital, Braschaat/Anvers, Belgium

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Summary of Experiences



- Storage of thermal energy in aquifers is generally possible
- Recovery factors can be satisfactory after some years
- Main problems for performance on the surface system side (e.g. to high return temperatures)
- In the underground, main problems due to hydrochemistry; however, it has been shown that they can be successfully managed (by careful operation)
- Temperatures up to <math><100\text{ }^{\circ}\text{C}</math> can be handled
- Low-temperature ATES (cooling) is already economic and in some countries successfully on the market

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Expectations for the Future

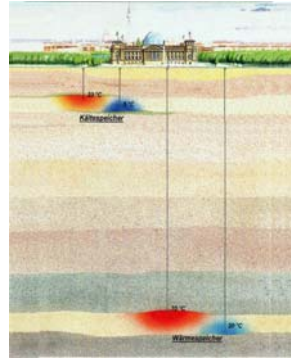


- Low-temperature ATES will see increased application
- High-temperature ATES in deep aquifers still needs further R&D and experiences from new projects
- In particular hydrochemical problems need to be investigated further, in order to allow increase of the maximum applicable storage temperature
- Possible applications for high-temperature ATES are manifold, in particular for waste heat
- Temperatures >100 °C seem to be hardly feasible in a sound and economic way

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***Thank you
for your
attention!***



**For more information:
www.egec.org
www.gtn-online.de**



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