Aquifer Thermal Energy Storage in Germany

Peter Seibt & Frank Kabus

Geothermie Neubrandenburg GmbH
www.gtn-online.de

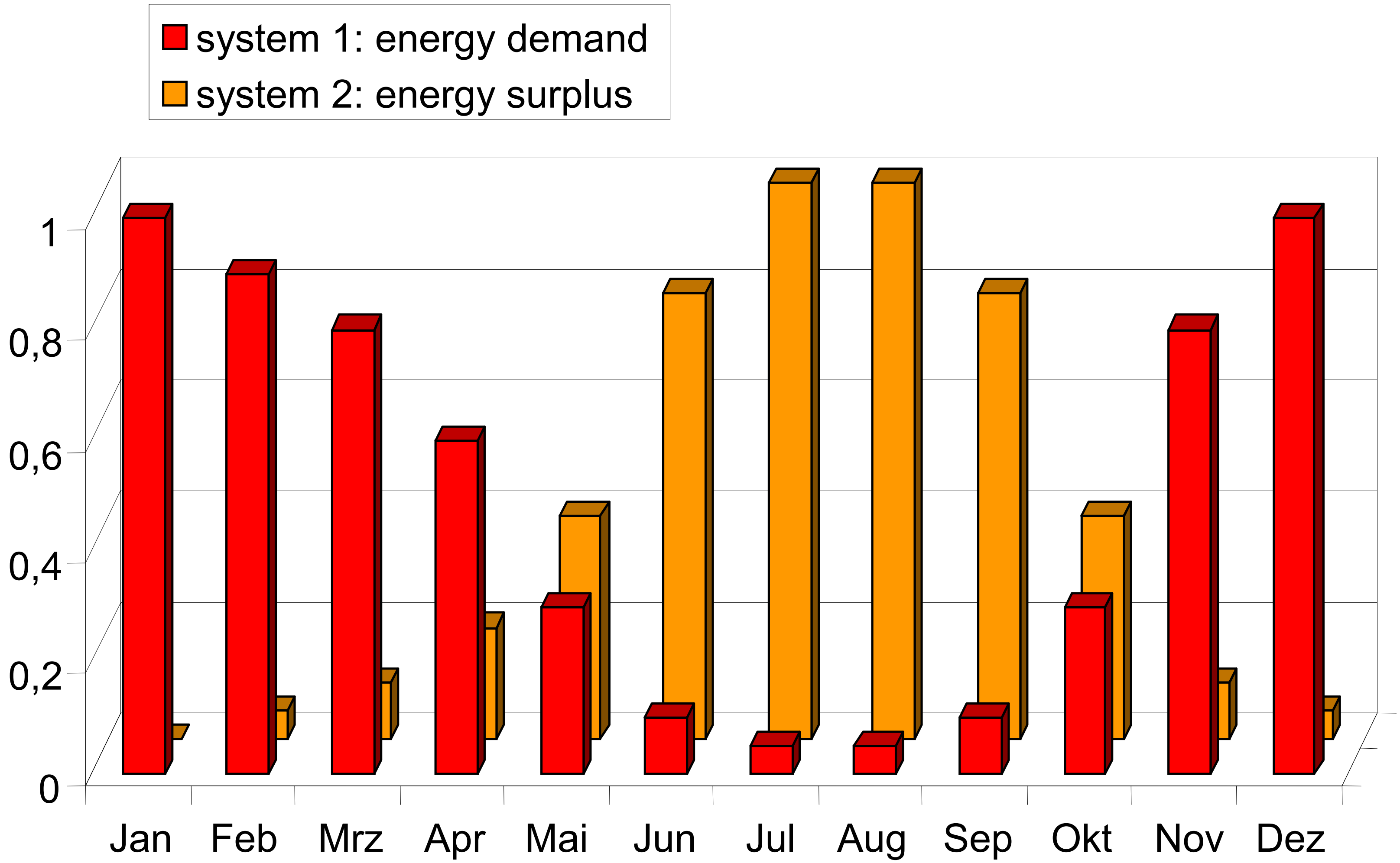
GTN INGENIEURE & GEOLOGEN

Contents

- Demand / surplus scenarios
- Classification
- Aquifer thermal energy storage
  - Introduction
  - Site assessment
  - Geological conditions
  - Technical dimensioning
- Selected projects
  - Rostock-Brinckmanshöhe
  - Neubrandenburg
  - Reichstag building / Berlin (seat of the German Parliament)

GTN INGENIEURE & GEOLOGEN

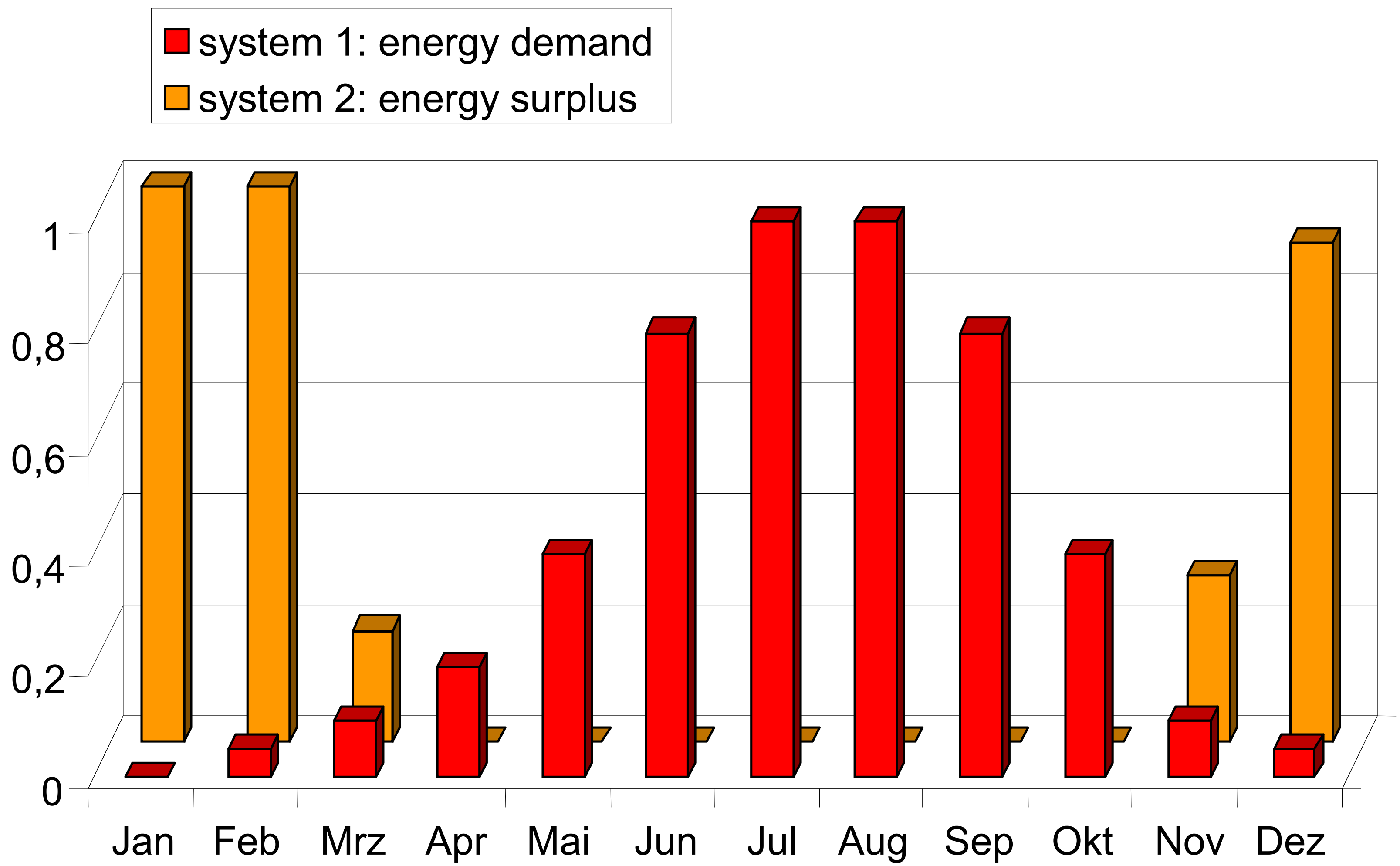
Demand / surplus scenarios



Heating / solar heat

GTN INGENIEURE & GEOLOGEN

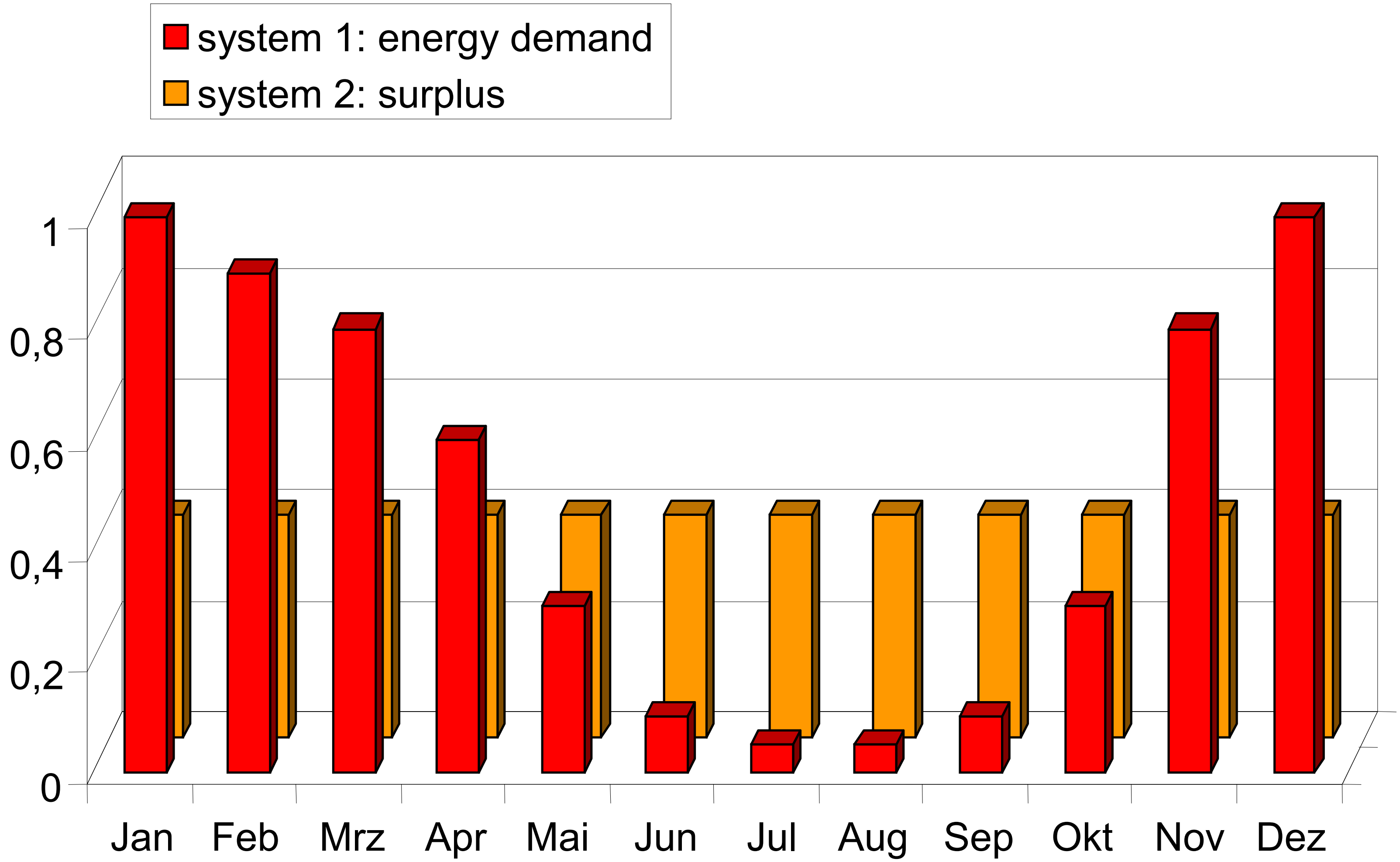
Demand / surplus scenarios



Cooling / ambient air

GTN INGENIEURE & GEOLOGEN

Demand / surplus scenarios



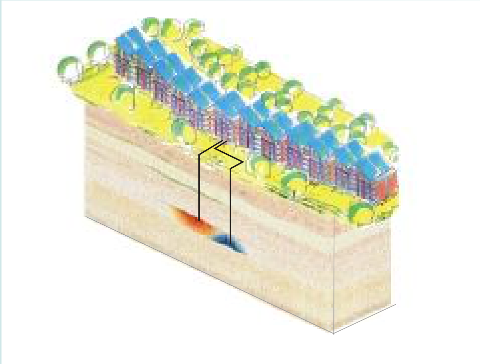
Heating / waste heat
from power generation

GTN INGENIEURE & GEOLOGEN

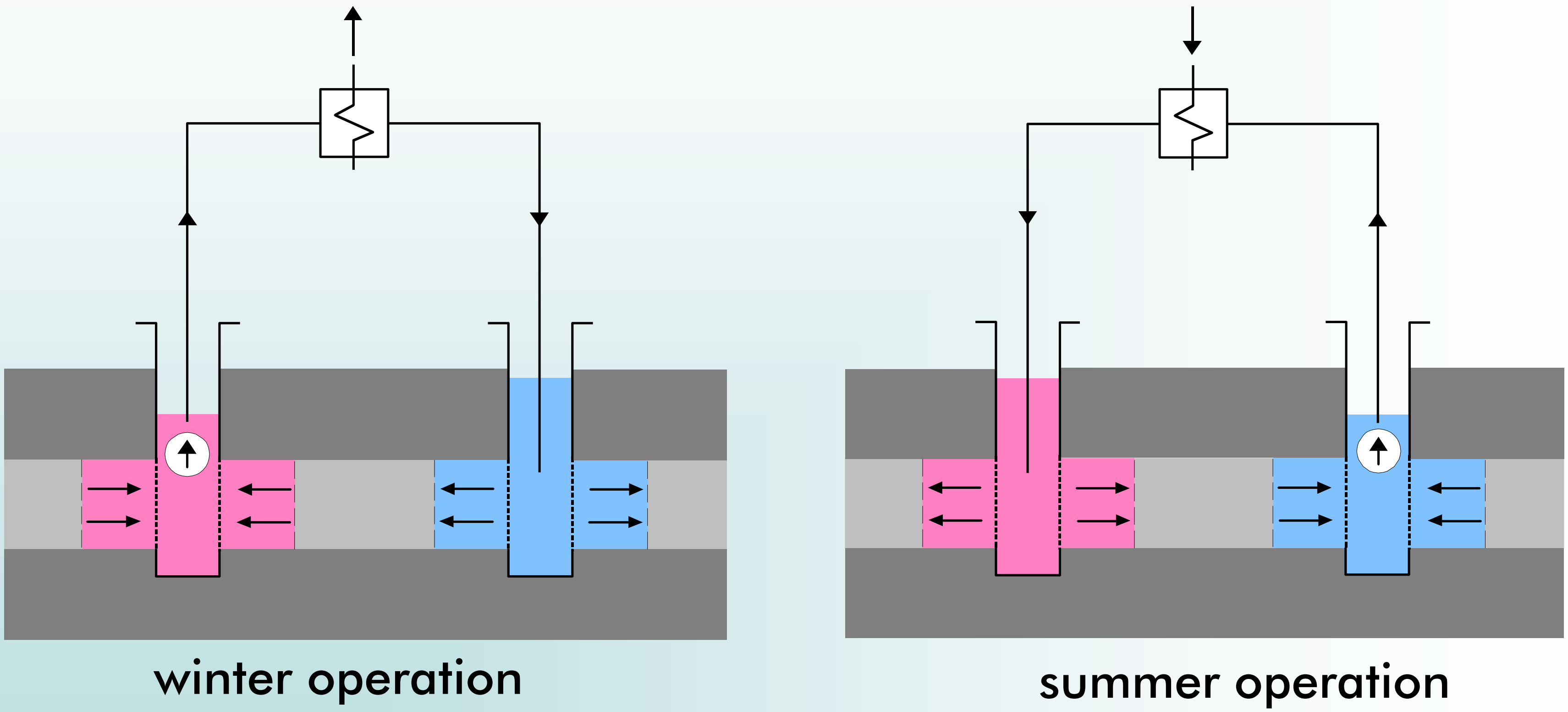
Classification

Underground thermal energy storage

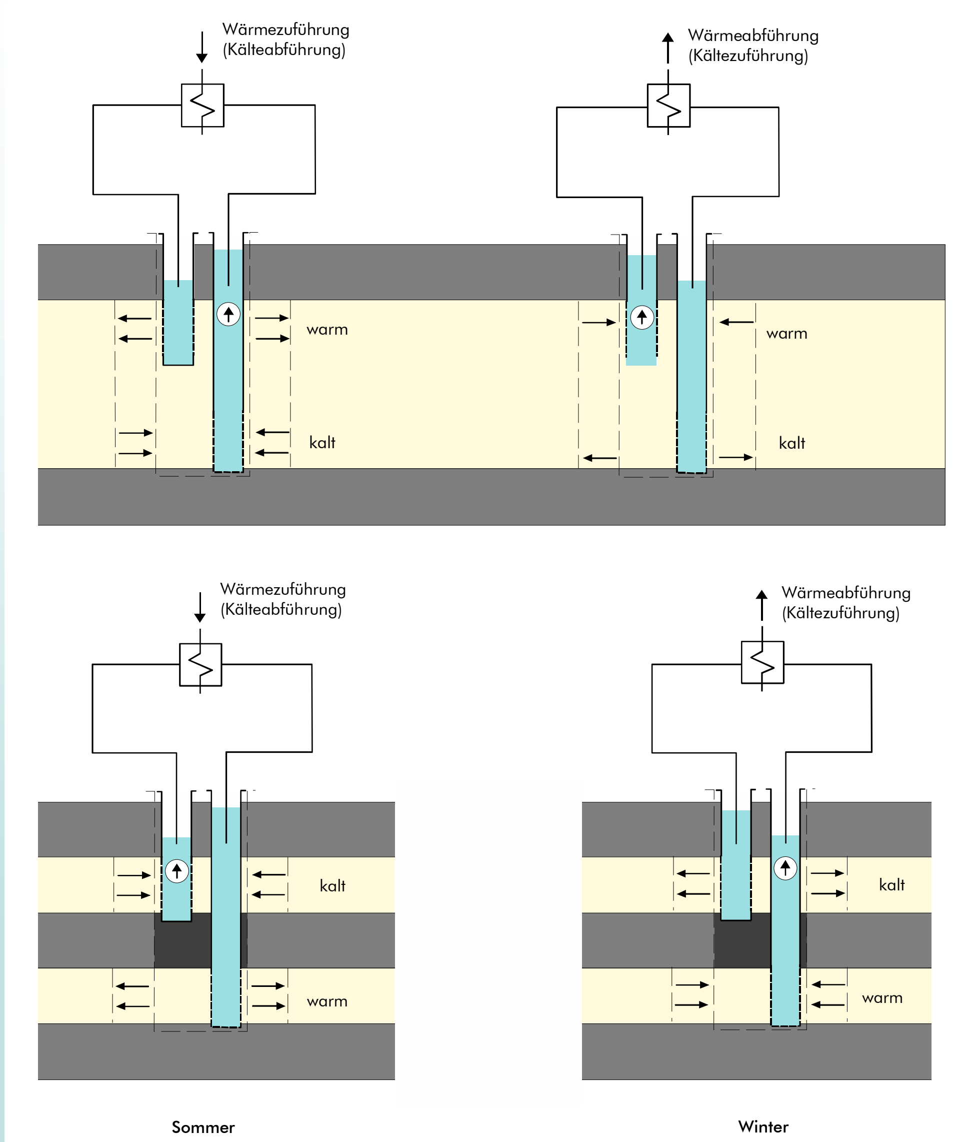
- **Borehole Heat Exchangers (vertical, horizontal)**
- **Aquifers (groundwater-bearing beds)**
- **Caverns/ shafts**



GTN
INGENIEURE
& GEOLOGEN

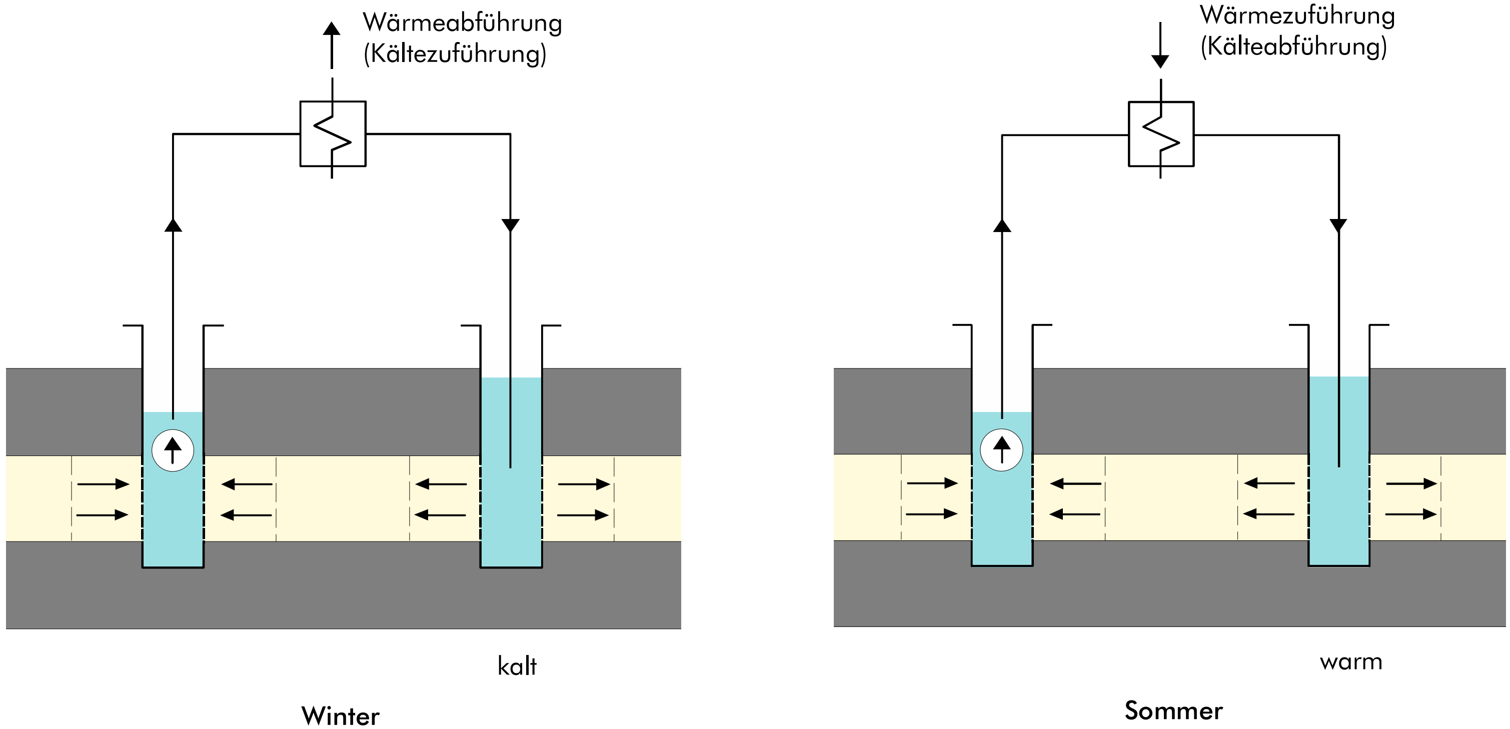


Mode of functioning



Other schemes of ATES - principle of alternate operation

GTN INGENIEURE & GEOLOGEN



Scheme of an aquifer store – flow-through principle

GTN
INGENIEURE
& GEOLOGEN

Geological conditions

Principally, aquifers (groundwater-bearing beds) which are intended for thermal energy storage should come up to the following requirements:

- Max. depth of 1000 m:
  At present, a depth of up to 200 m represents the most favourable variant for the installation of low-enthalpy stores in terms of cost.

- Covered (confined) groundwater-bearing bed:
  On condition that adequate technological storage parameters are selected, even phreatic aquifers can be used according to most recent studies.

GTN INGENIEURE & GEOLOGEN

Geological conditions

- Max. effective reservoir thickness approx. 30 m:
  If thicker, special production techniques would be required due to the horizontal propagation of the thermal front.

- Homogeneous aquifer structure:
  Strong interstratification may result in a smaller coefficient of recovery.

GTN INGENIEURE & GEOLOGEN

Geological conditions

- Geometrical aquifer structure:
  Major differences in level relative to the aquifer top may lead to problems when re-producing the fluid accumulating in the top sections.

- Low regional base flow or detailed knowledge on the regional groundwater flow parameters:
  Appropriate siting of the wells can influence the propagation of the thermal front which is important for long-term operation.

GTN
INGENIEURE
& GEOLOGEN

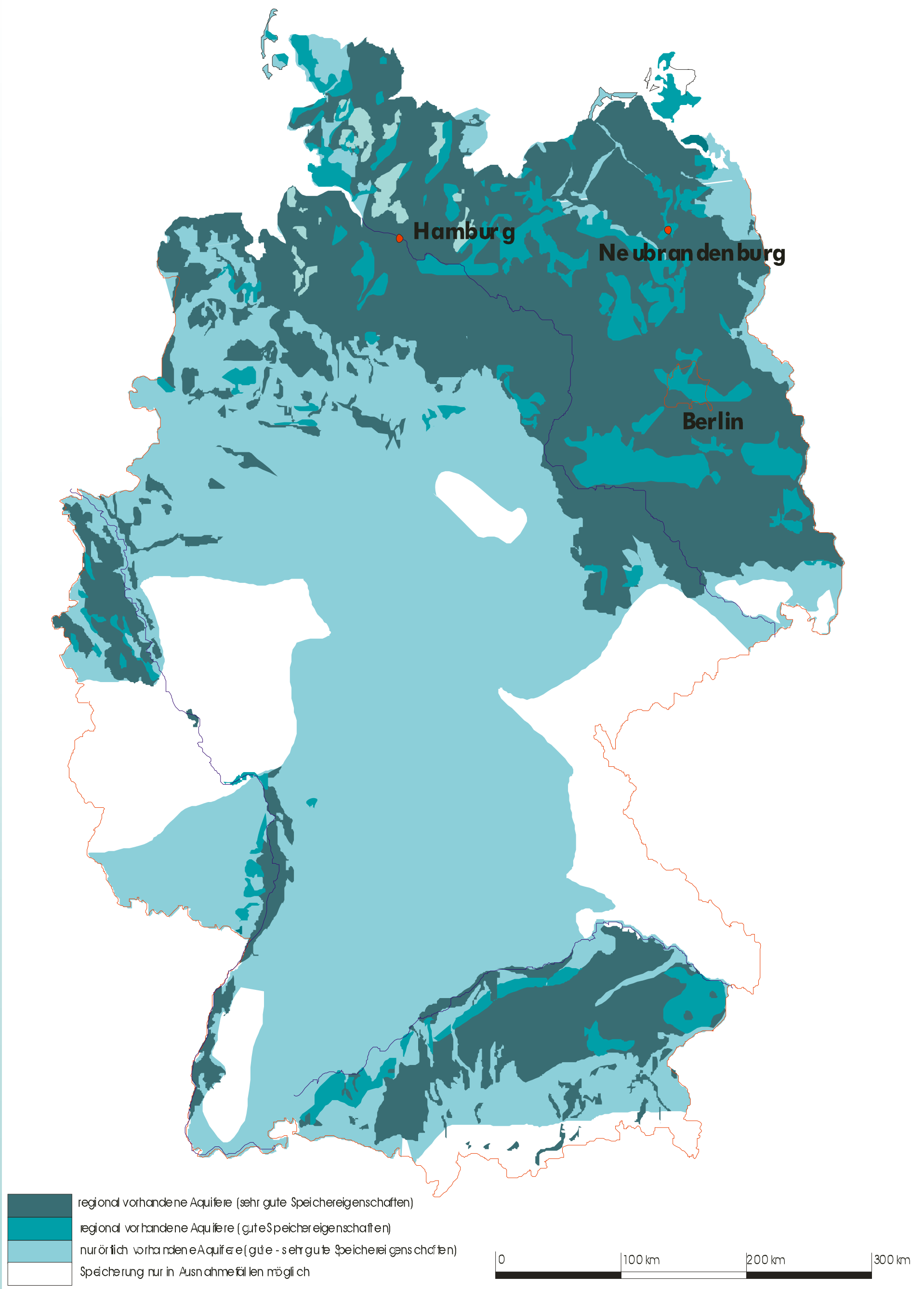
Geological conditions

- Appropriate chemical composition of reservoir fluid (heat transfer medium) and matrix:
  Changes of the state in the working section of the reservoir must not affect reinjection.

- Store installation out of groundwater catchment areas:
  Interference and quality impairment must be avoided.

GTN INGENIEURE & GEOLOGEN

Geological conditions



Geological potentials of aquifer thermal energy storage

GTN INGENIEURE & GEOLOGEN

Site assessment

- Depending on the state of the geological knowledge, at least two exploratory wells should be drilled down on the site, followed by geophysical logging giving evidence on:
  - * depth and thickness of the aquifers
  - * existence of aquicludes in the under- and overlying sections of the aquifer intended for thermal energy storage
  - * non-homogeneities in the aquifer

- Pump and injection tests – duly recording the changes of the water level in the water and oberservation wells - are to determine the productivity and injectivity of the water well.

GTN INGENIEURE & GEOLOGEN

- Objectives of the laboratory analysis of matrix and fluid:
    * Mineralogical investigations of the matrix to describe potential damages to the reservoir caused by precipitation or intrastratal solution caused by temperature changes
    * Determination of the grain size distribution to characterise the reservoir

GTN
INGENIEURE
& GEOLOGEN

Site assessment

* Geochemical investigation of the groundwater to identify the water components with regard to their reaction behaviour in changed temperature conditions
* Determination of the actual microbiological state of the groundwater to identify the sensitivity of the reservoir to temperature increases

GTN INGENIEURE & GEOLOGEN

* Isotope-hydrogeological analysis to determine the hold-up time of the groundwater and to derive a potential geohydraulic communication among neighbouring wells

- As the geometrical aquifer structure is especially important, shallow seismics proved to be an efficient method to enhance the state of hydrogeological knowledge

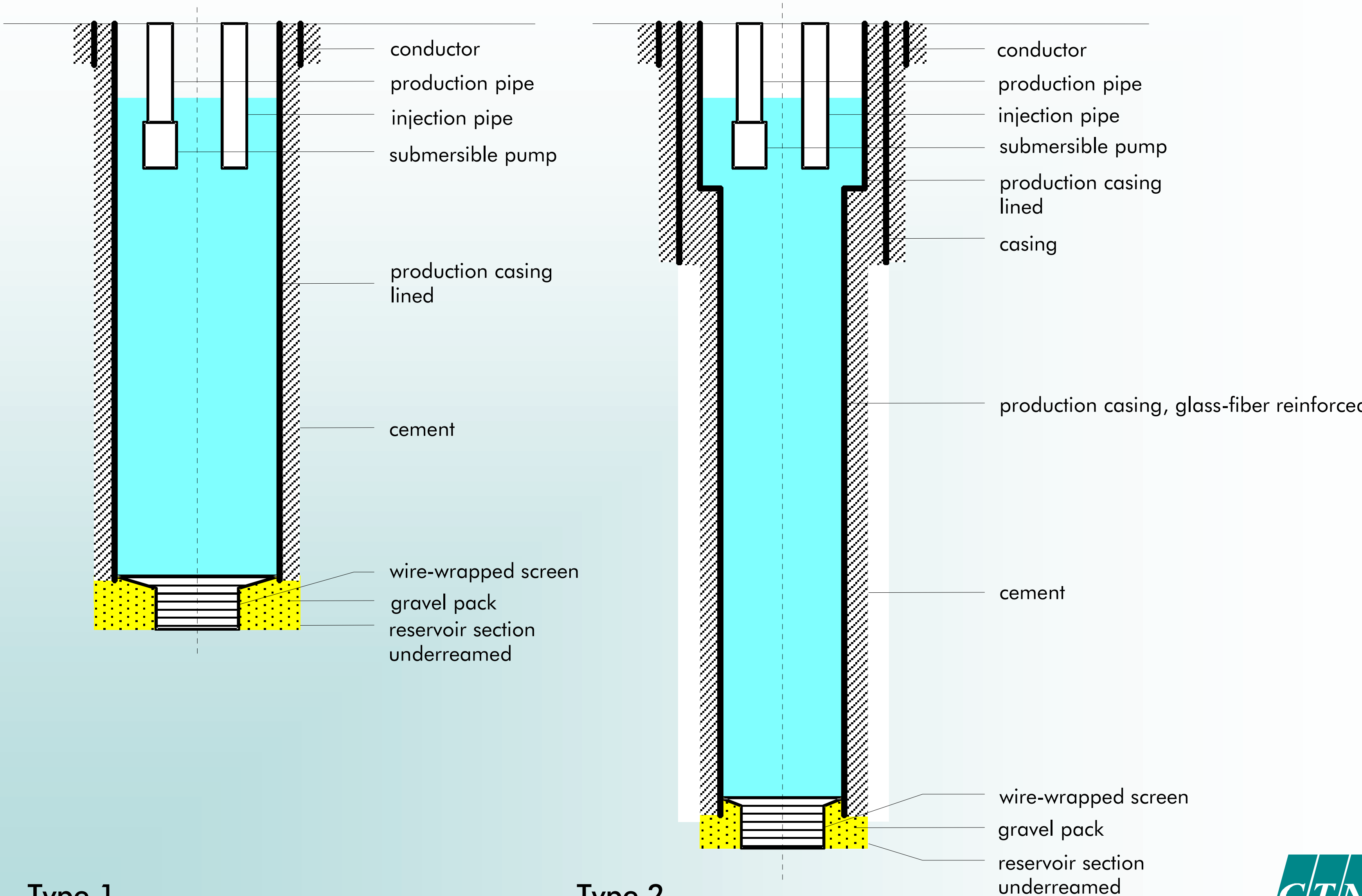
GTN INGENIEURE & GEOLOGEN

Comparing	Water well	ATES well
Water temperature	constant	cold/warm
Injection	no	yes
Mode of operation	continuous throughout the year	seasonal
Flow	continuous	discontinuous
Direction of flow	one direction	two directions

Technical requirements on the wells

GTN INGENIEURE & GEOLOGEN

Technical dimensioning



Type 1

(down to a depth of approx. 400 m)

Type 2

(down to depths from approx. 400 to 1,000 m)

GTN INGENIEURE & GEOLOGEN

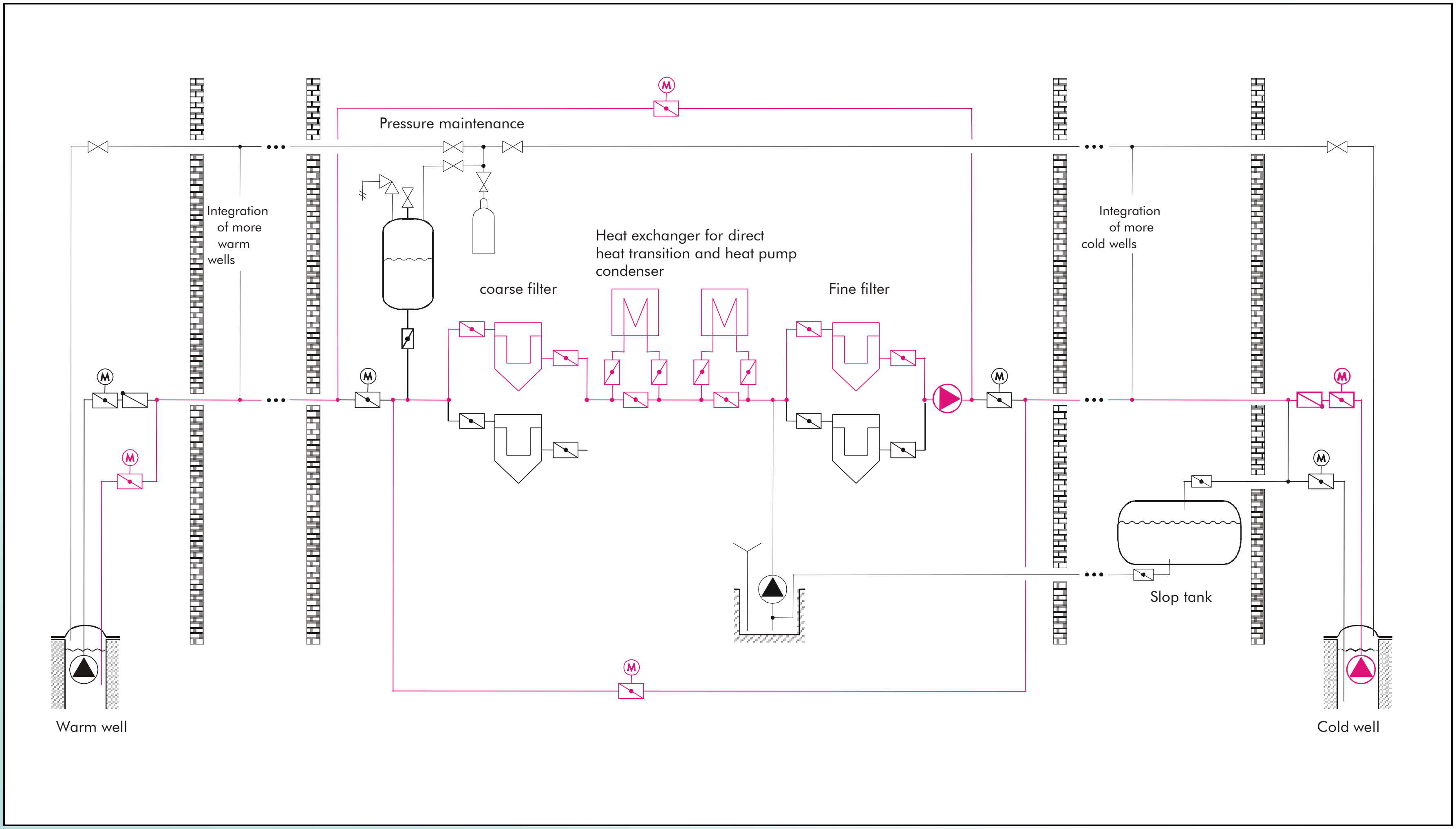
- The most important parameter is the well diameter which depends on several criteria to be observed:
  * laminar flow in order to prevent the precipitation of ochre and incrustations in the screen section
  * non-overspeeding of the critical flow velocity against the screen

GTN INGENIEURE & GEOLOGEN

Technical dimensioning

- the diameter required for installation of the submersible pump
- resistance of the equipment to thermal shocks and corrosion

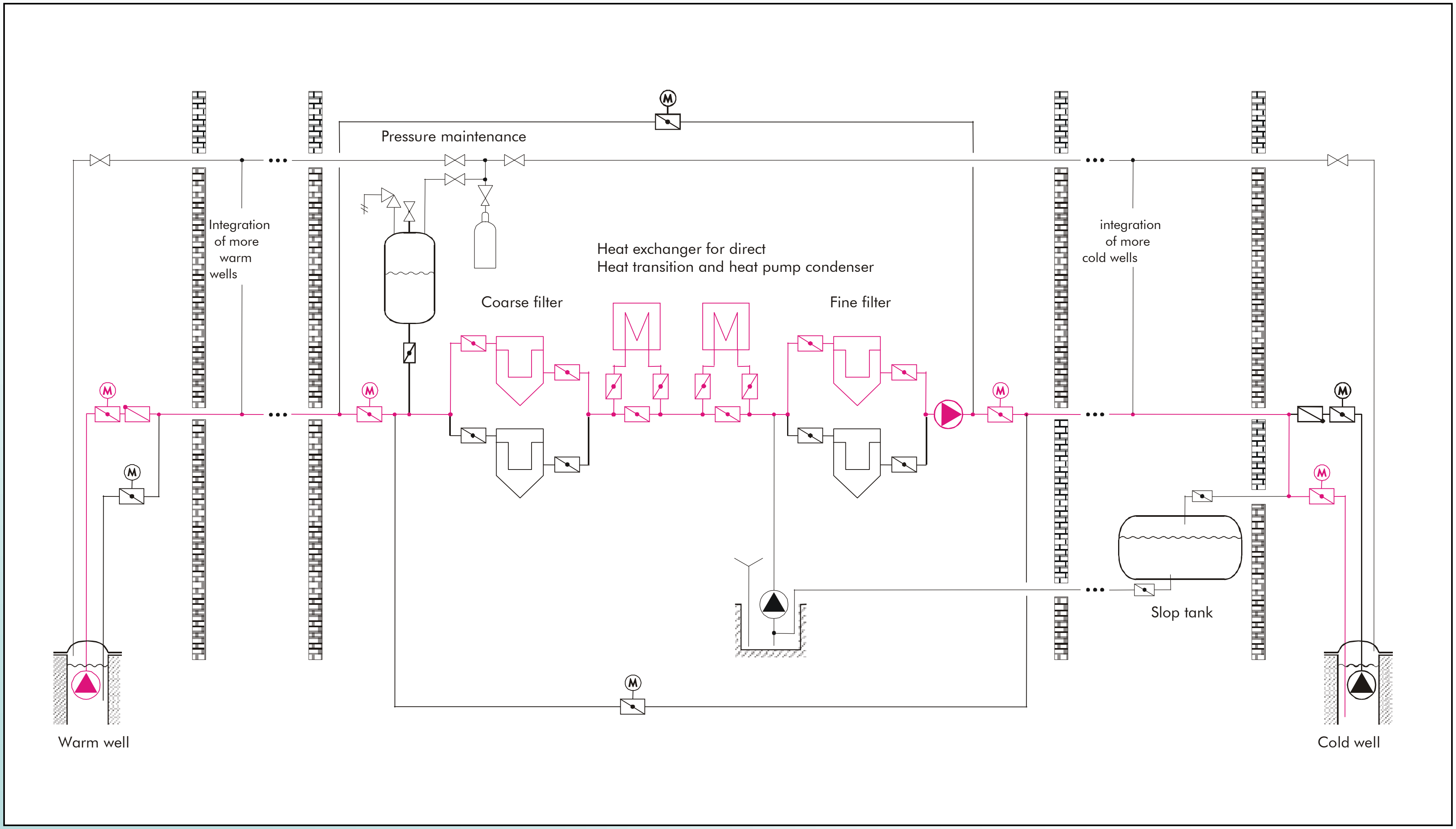
Technical dimensioning



Principle scheme of the surface storage loop (when charging)

GTN INGENIEURE & GEOLOGEN

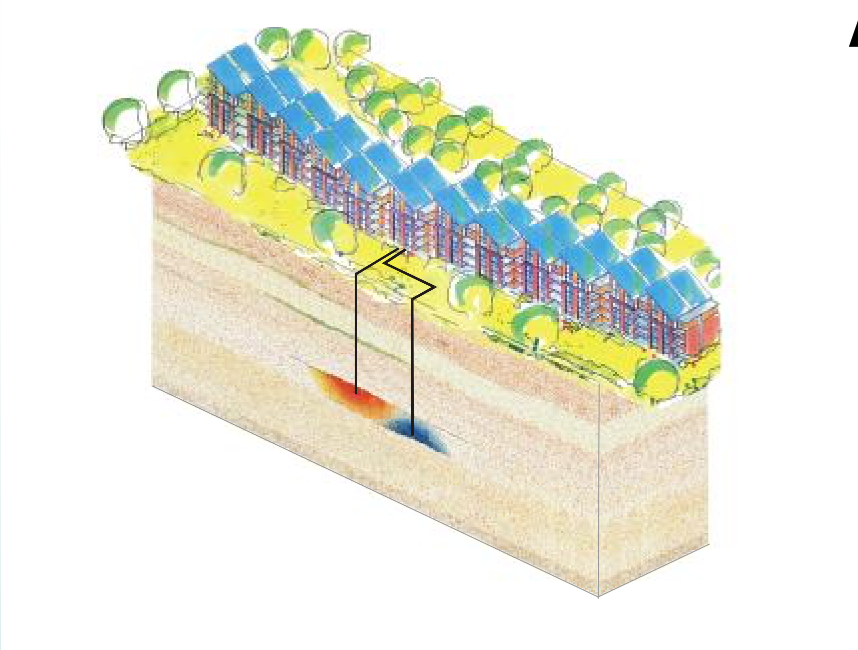
Technical dimensioning



Principle scheme of the surface storage loop (when discharging)

GTN INGENIEURE & GEOLOGEN

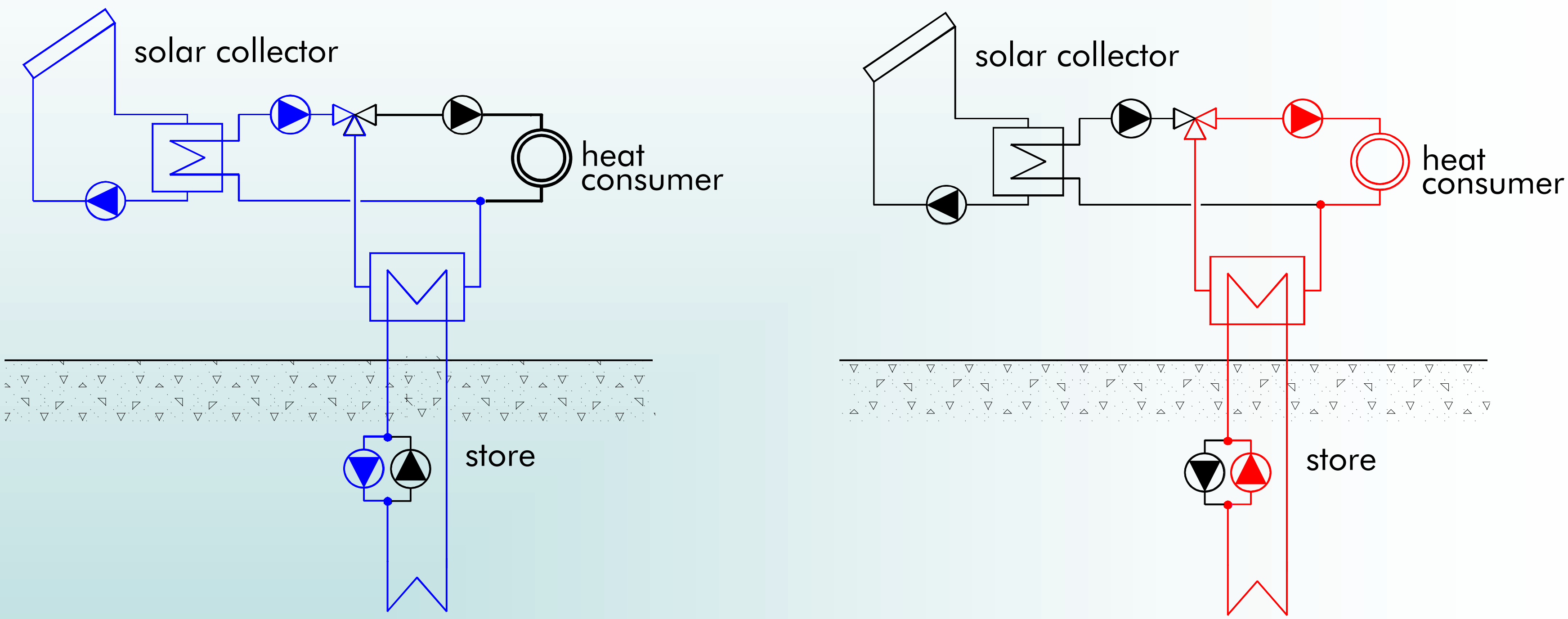
ATES Rostock-Brinckmanshöhe



Design and present view

GTN INGENIEURE & GEOLOGEN

ATES Rostock-Brinckmanshöhe

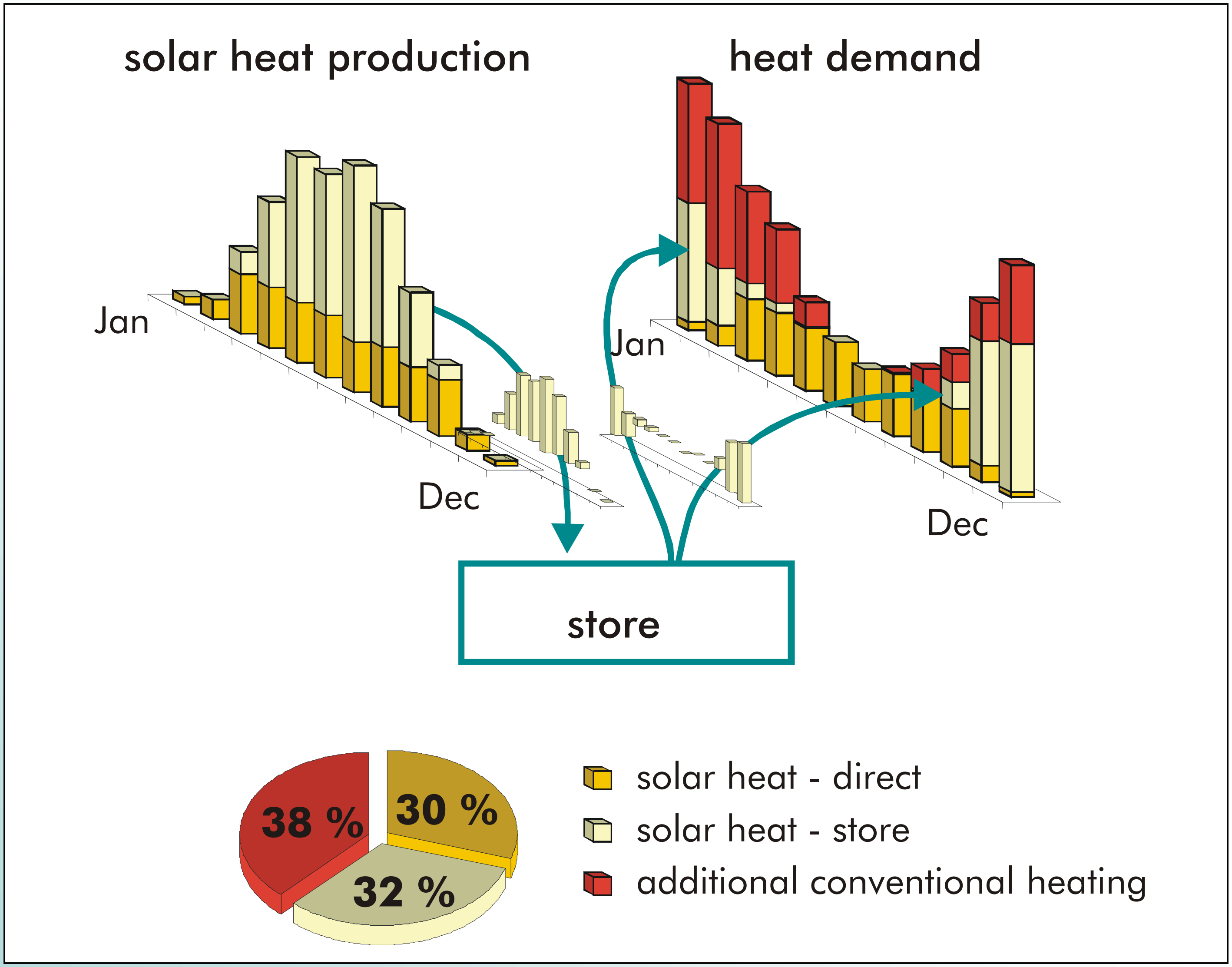


summer   winter

Technical concept of solar energy storage

GTN INGENIEURE & GEOLOGEN

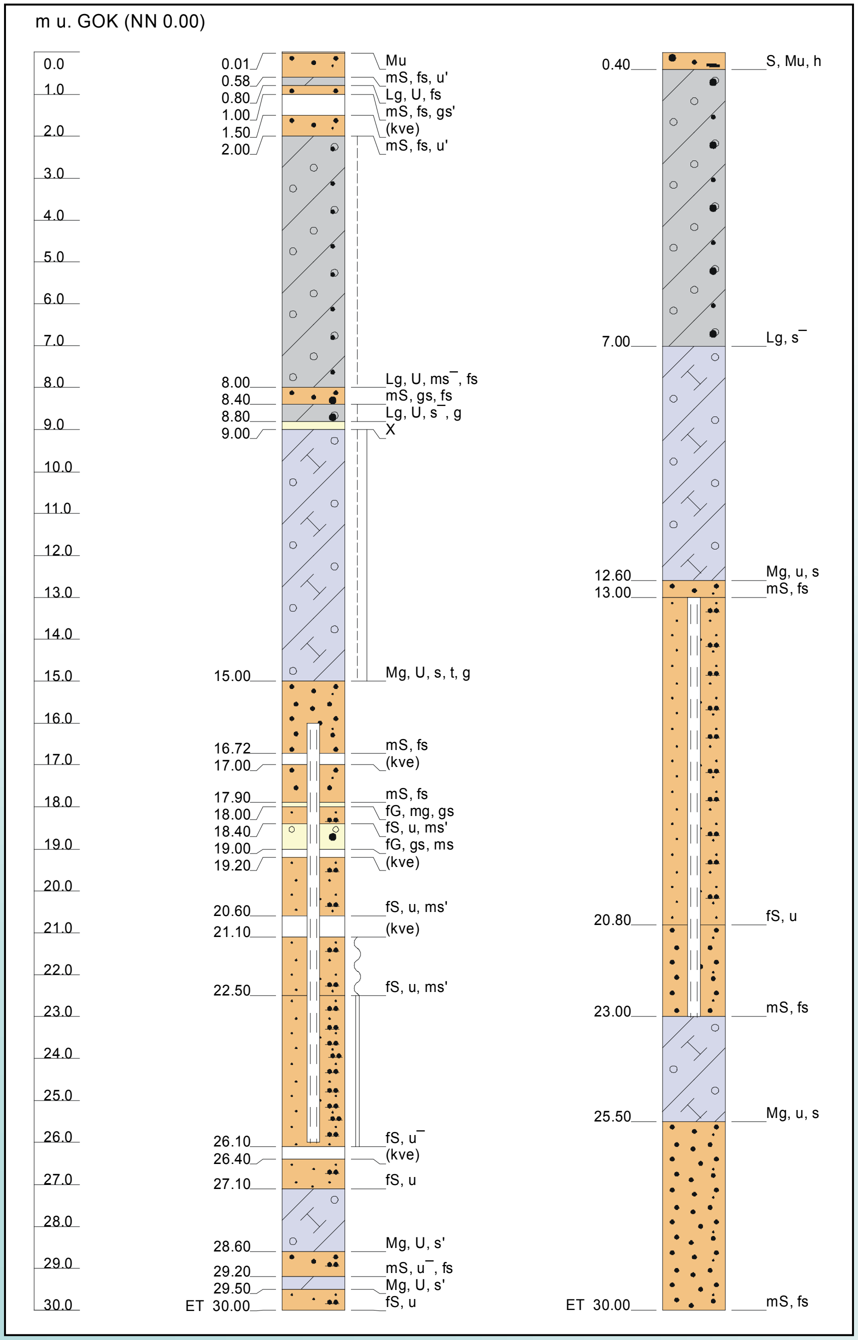
ATES Rostock-Brinckmanshöhe



Energy balance of heat production

GTN INGENIEURE & GEOLOGEN

ATES Rostock-Brinckmanshöhe



INGENIEURE
& GEOLOGEN

ATES Rostock-Brinckmanshöhe

Siting of the heat store wells

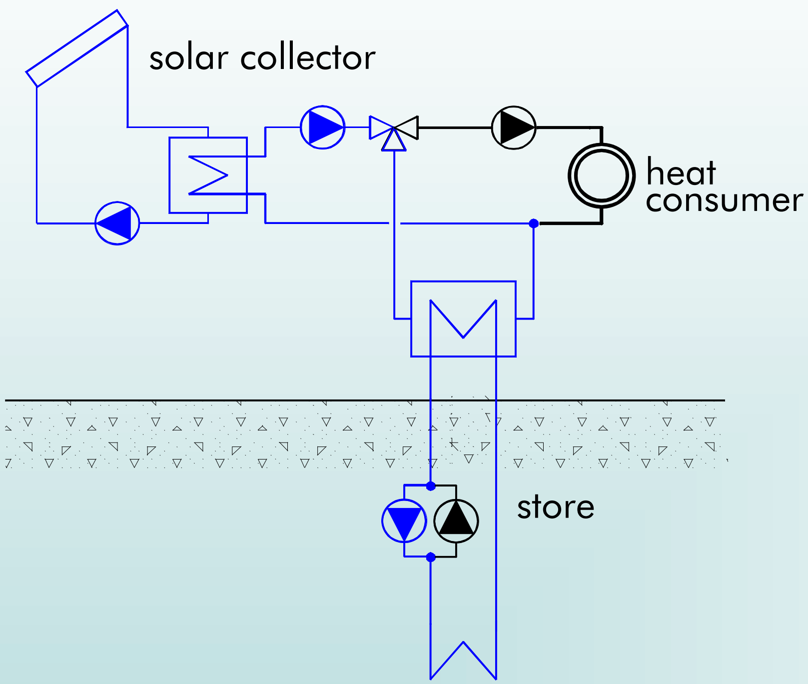
GTN INGENIEURE & GEOLOGEN

ATES Rostock-Brinckmanshöhe

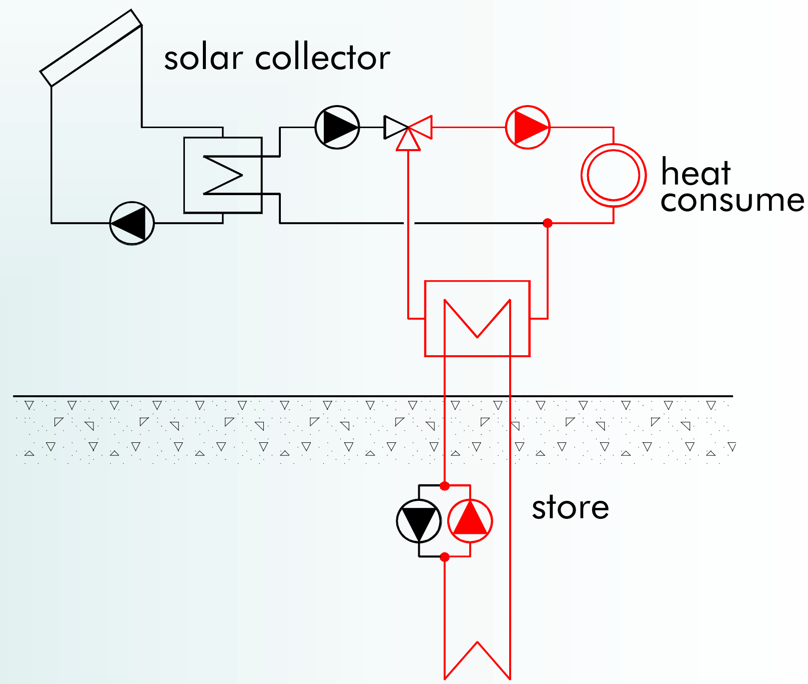
• geological formation:	Quaternary
• depth:	13 m - 27 m
• store temperature:	11 °C
• porosity:	~20 %
• permeability:	0.25- 0.5 μm^2
• number of wells:	2
• internal distance:	55 m
• production and injection flowrate:	20 m^3/h
• injection temperature:	50 °C
• charging heat:	234 MWh/a
• discharging heat:	222 MWh/a

GTN INGENIEURE & GEOLOGEN

ATES Rostock-Brinckmanshöhe



summer

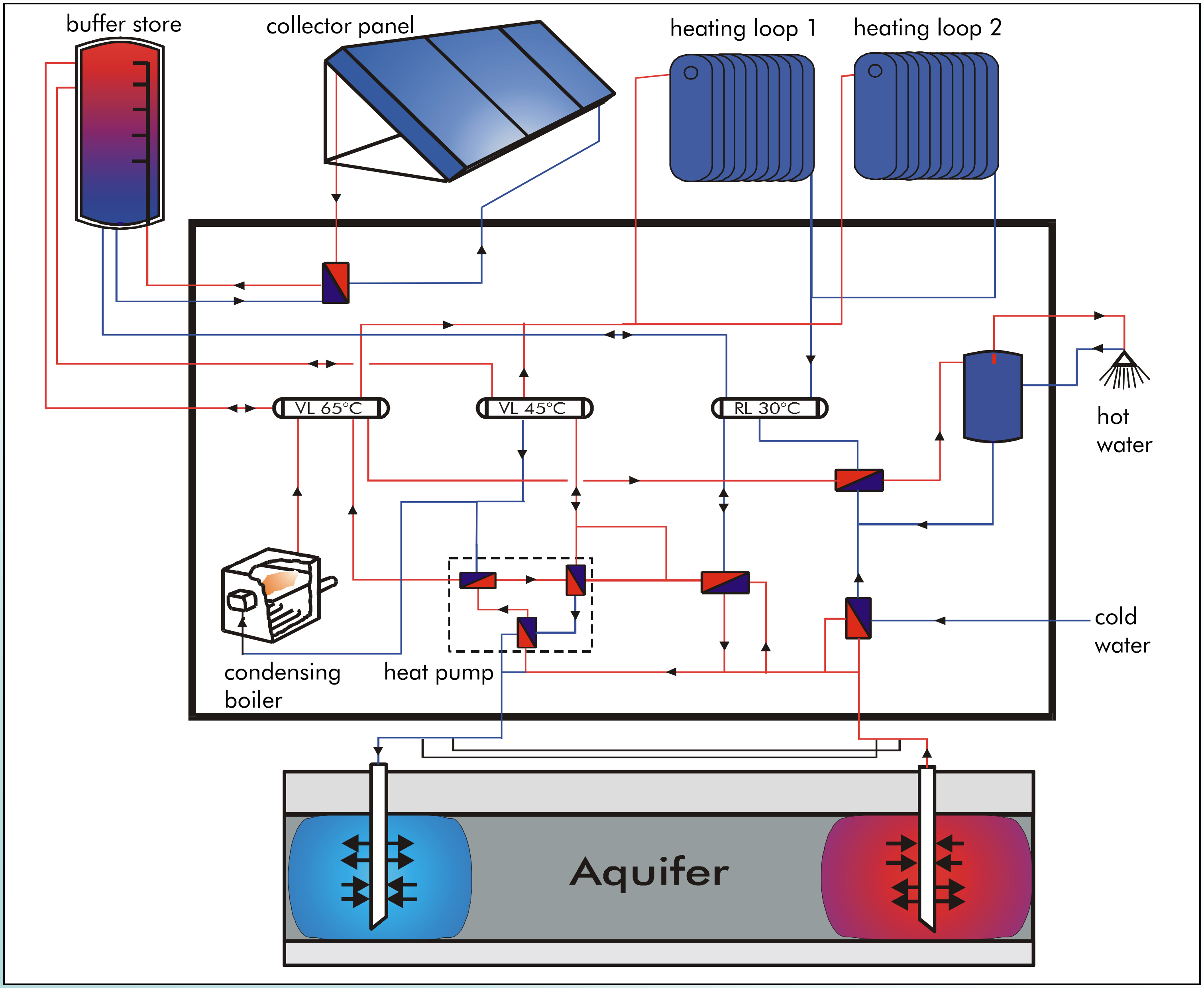


winter

Technical concept of solar energy storage

GTN INGENIEURE & GEOLOGEN

ATES Rostock-Brinckmanshöhe



ITW
Universität Stuttgart
Solare Nahwärme

GTN
INGENIEURE & GEOLOGEN

ATES Rostock-Brinckmanshöhe

Collector roofs during construction

External view of the warm well cellar

GTN
INGENIEURE
& GEOLOGEN

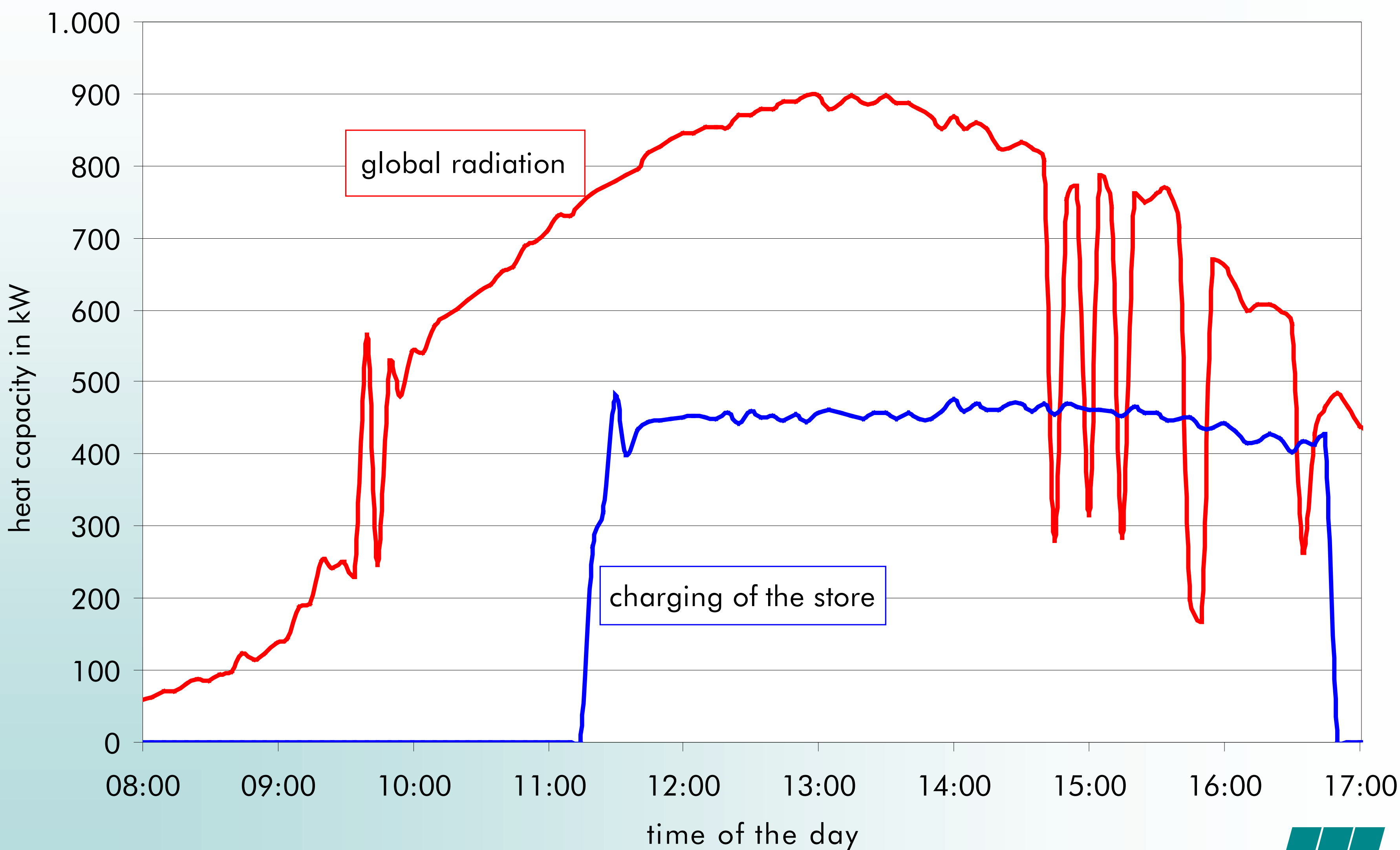
ATES Rostock-Brinckmanshöhe

Heat exchangers for charging and discharging (left) and heat pump (right)

Well head during construction

GTN
INGENIEURE
& GEOLOGEN

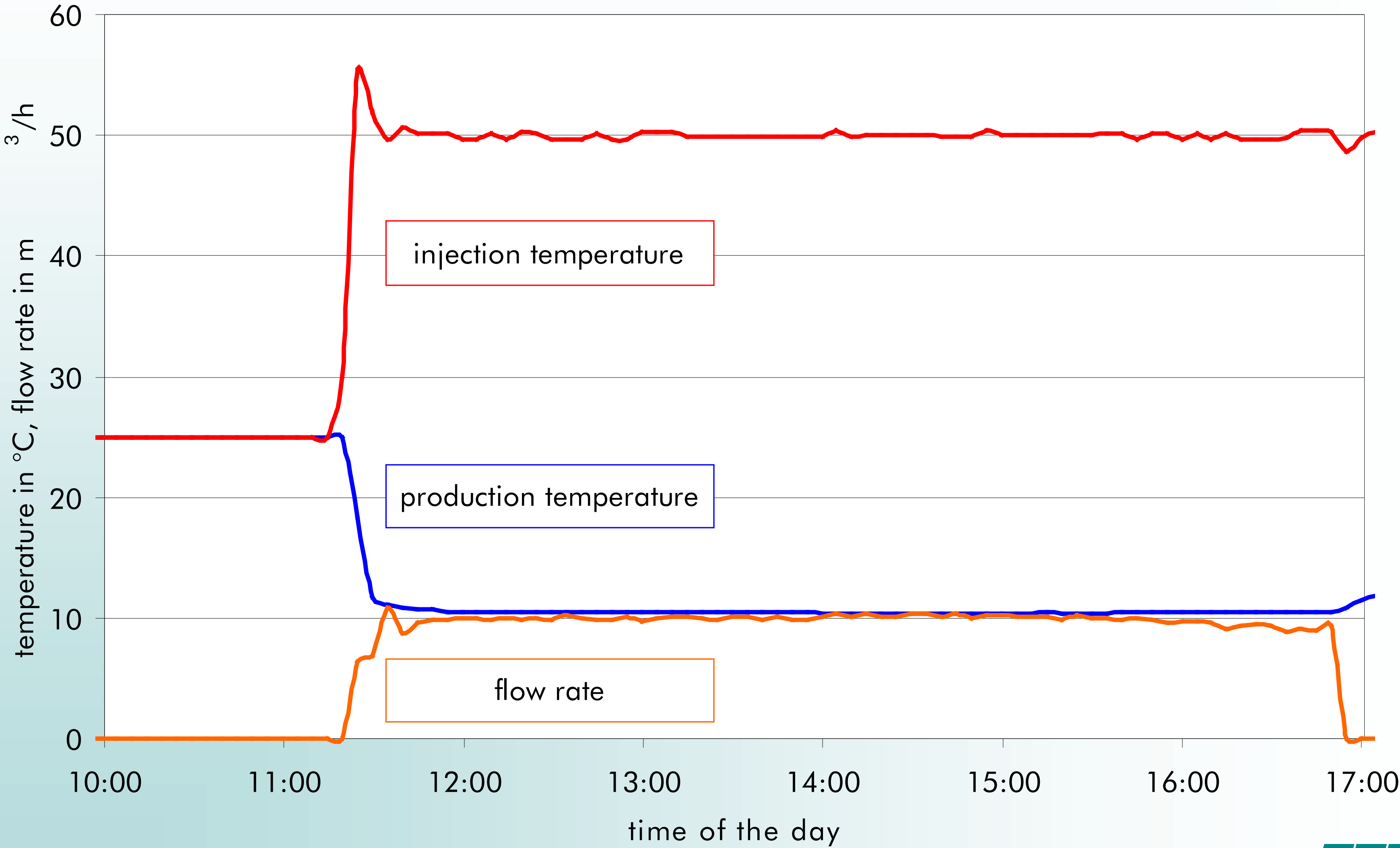
ATES Rostock-Brinckmanshöhe



Heat capacities, 23.08.2002

GTN
INGENIEURE
& GEOLOGEN

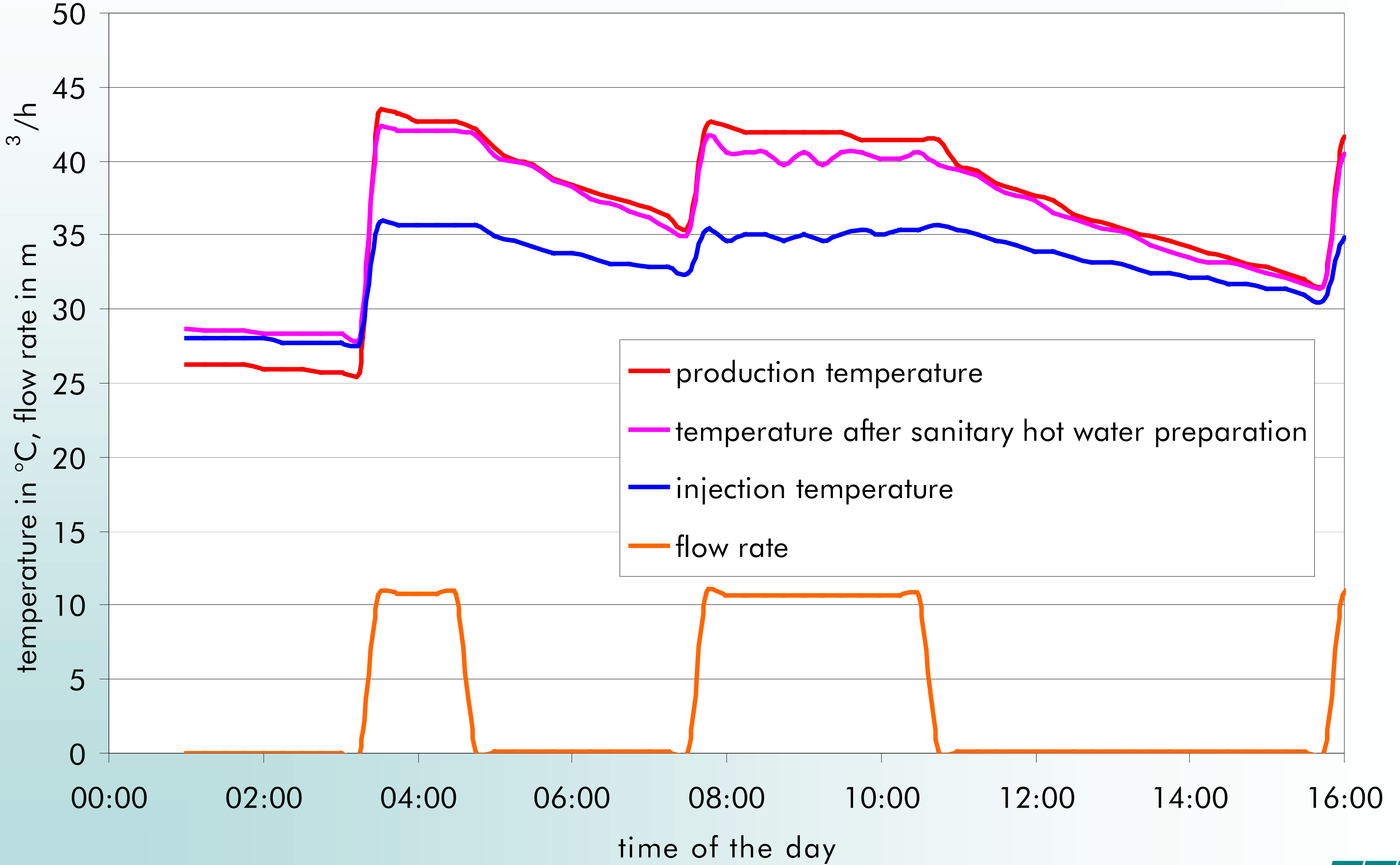
ATES Rostock-Brinckmanshöhe



Storage loop parameters, charging, 23.08.2002

GTN INGENIEURE & GEOLOGEN

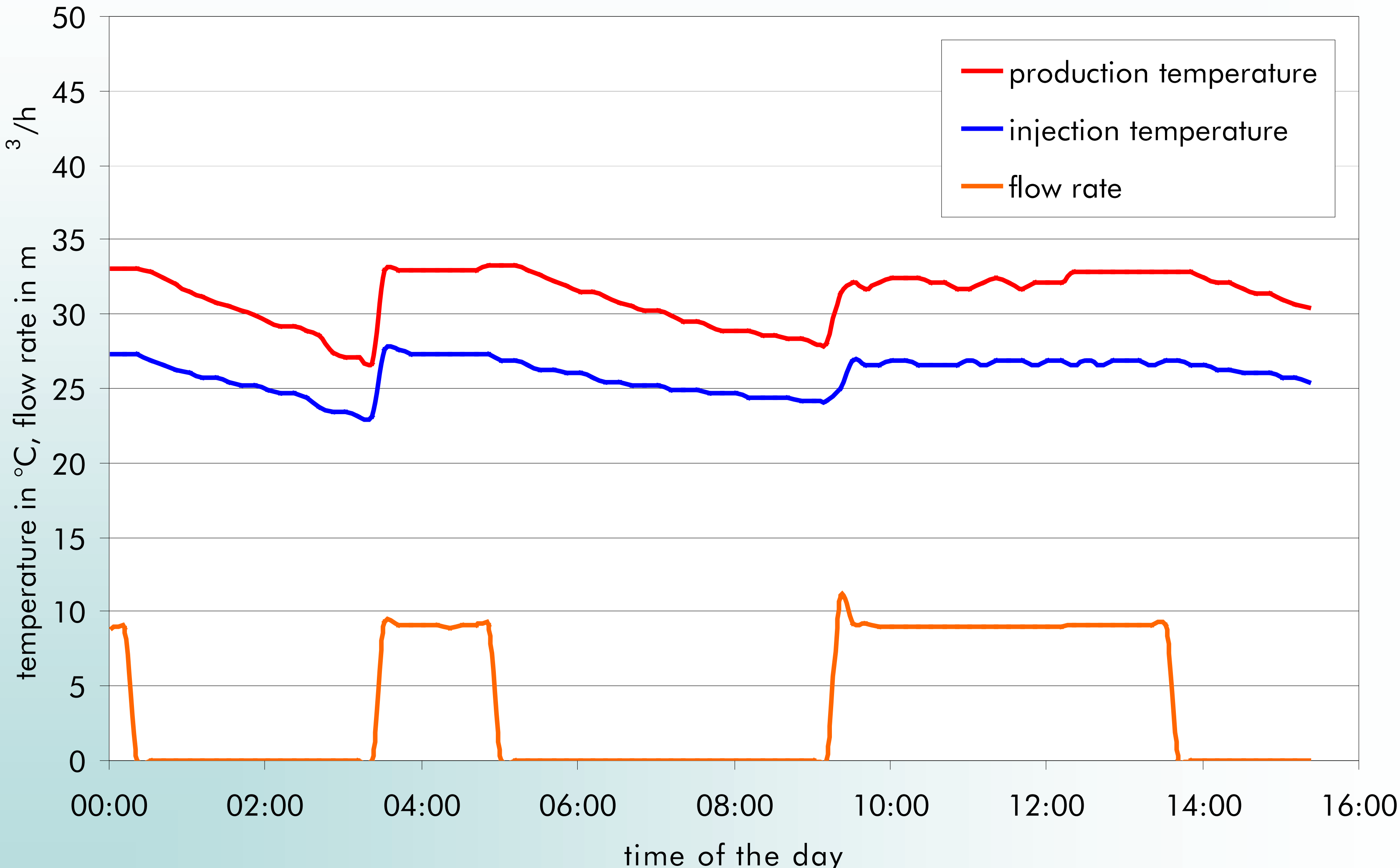
ATES Rostock-Brinckmanshöhe



Storage loop parameters, discharging, 1.9.2002

GTN
INGENIEURE
& GEOLOGEN

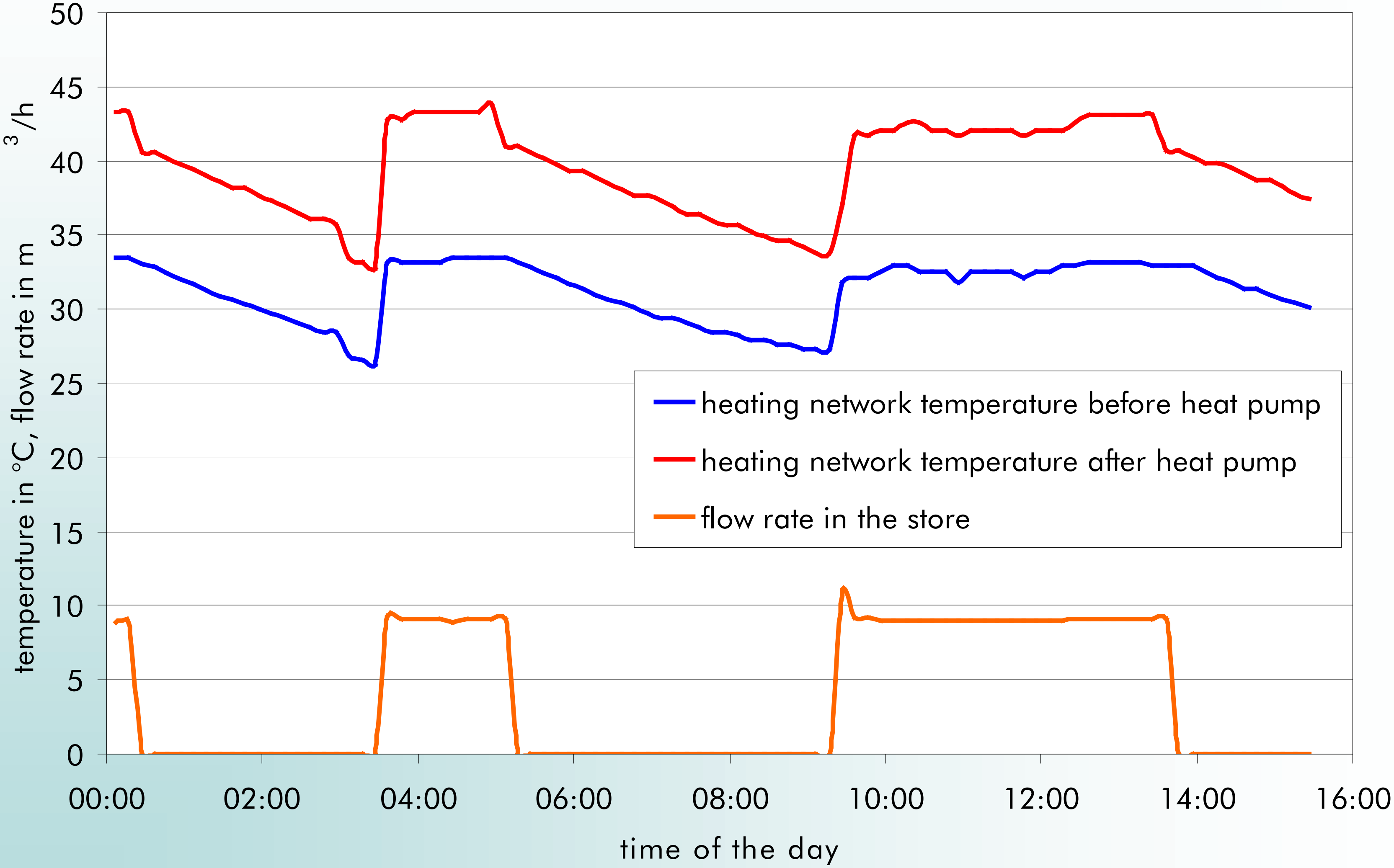
ATES Rostock-Brinckmanshöhe



Storage loop parameters, discharging, 27.11.2002

GTN INGENIEURE & GEOLOGEN

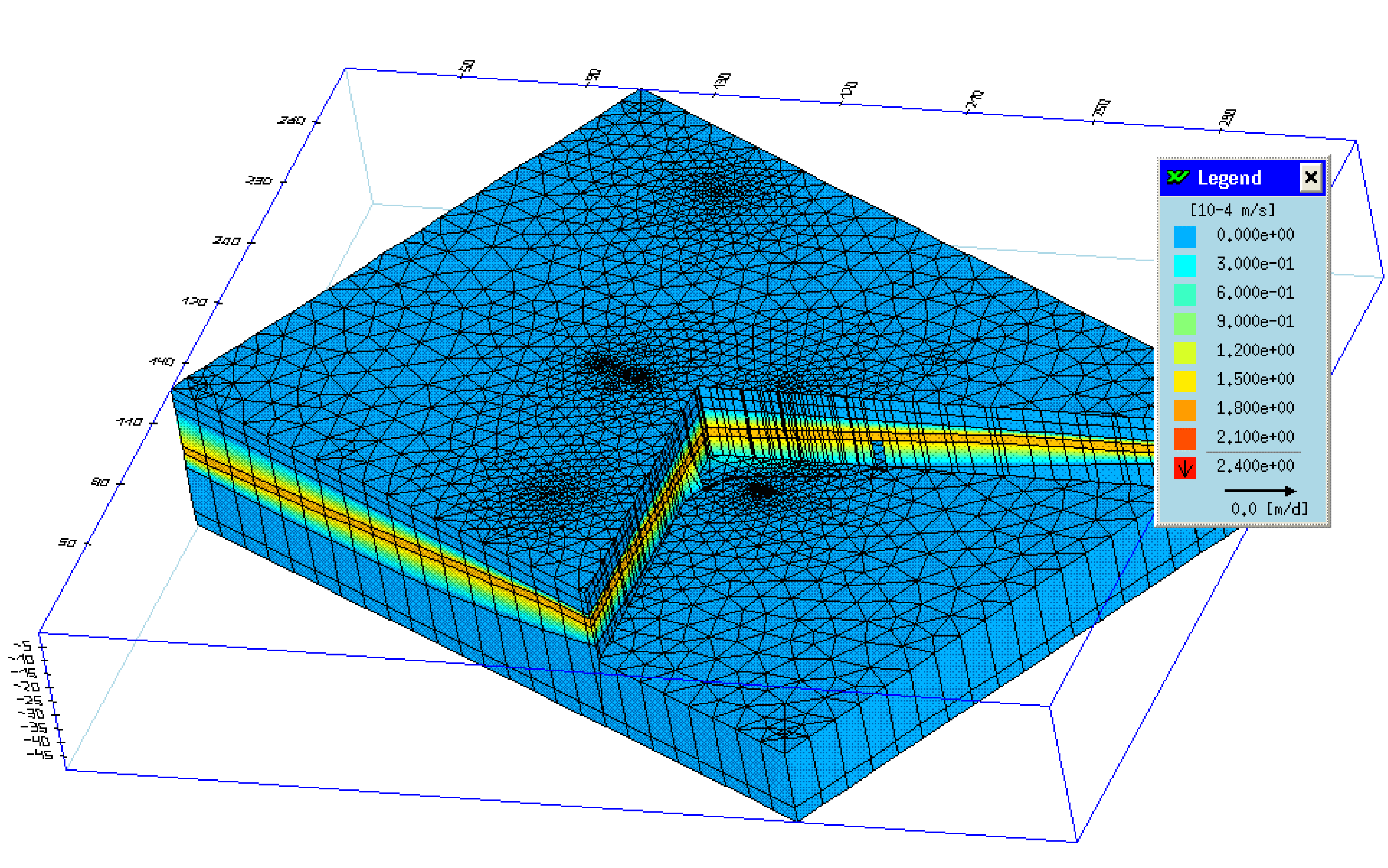
ATES Rostock-Brinckmanshöhe



Parameters at the heat pump condenser, discharging, 27.11.2002

GTN INGENIEURE & GEOLOGEN

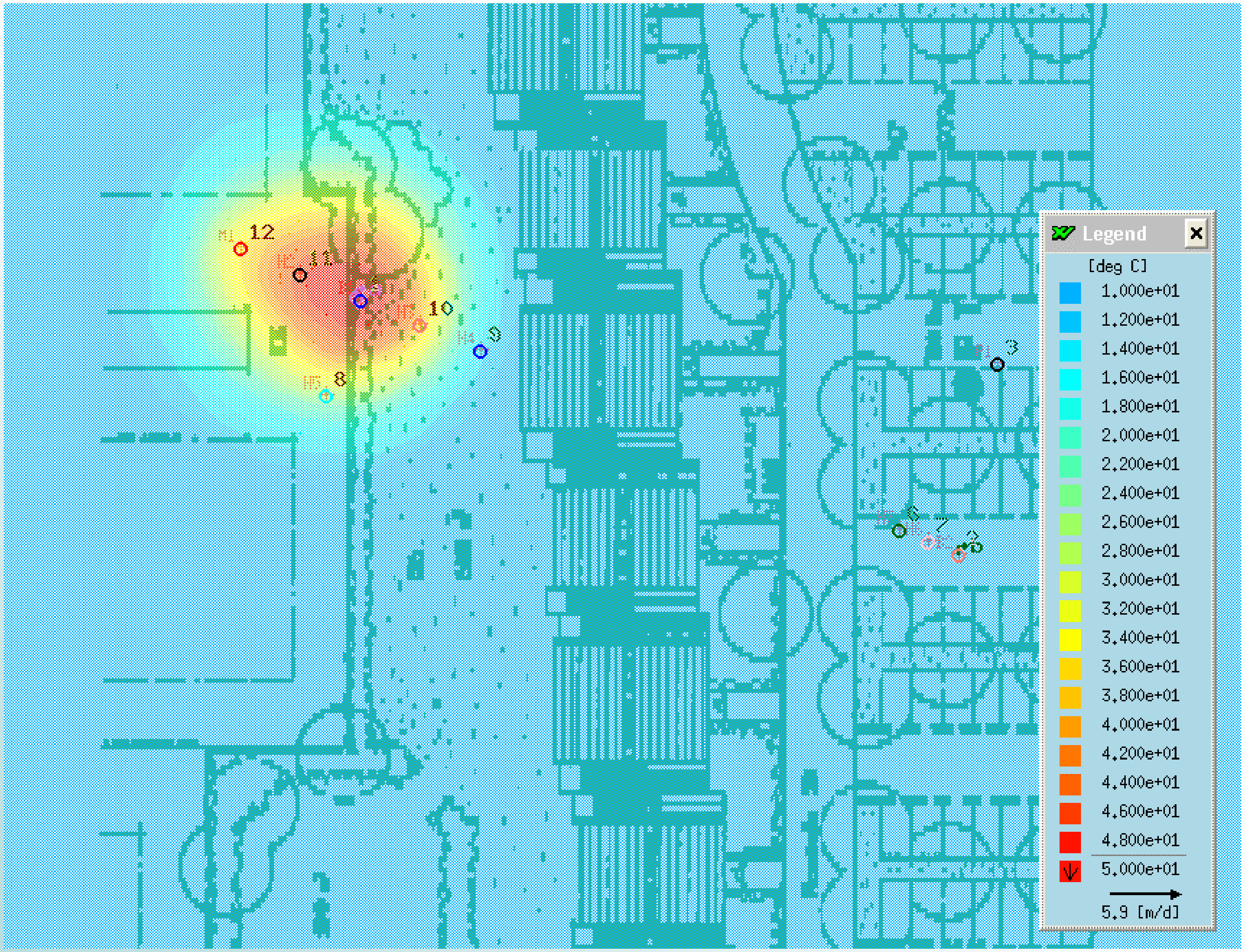
ATES Rostock-Brinckmanshöhe



Model area and grid, store section - red

GTN
INGENIEURE
& GEOLOGEN

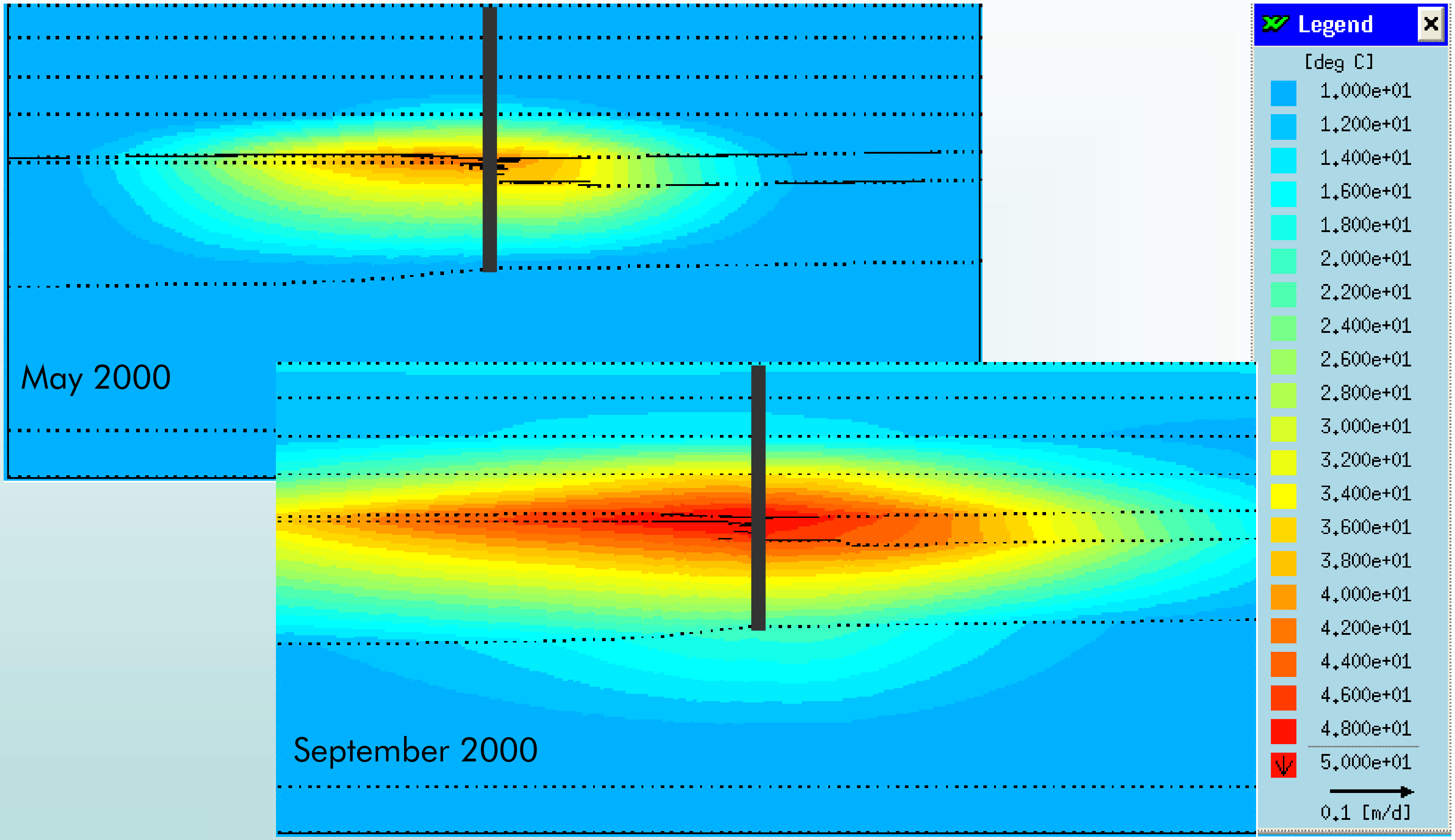
ATES Rostock-Brinckmanshöhe



Simulated temperature distribution when charging at a depth of 17 m, early September 2000

GTN INGENIEURE & GEOLOGEN

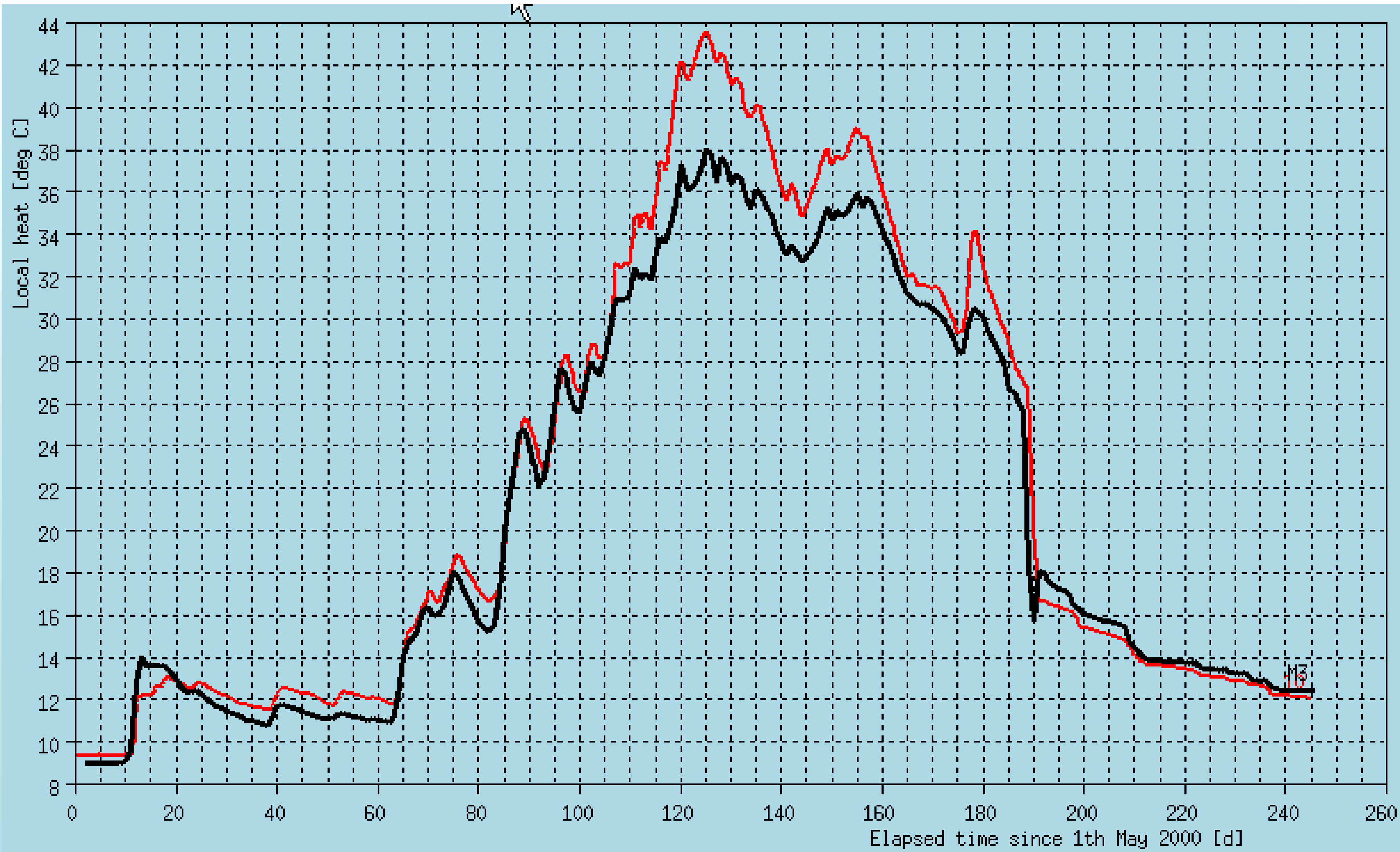
ATES Rostock-Brinckmanshöhe



Calculated temperature, model layers and velocity arrows along the track of intersection

GTN INGENIEURE & GEOLOGEN

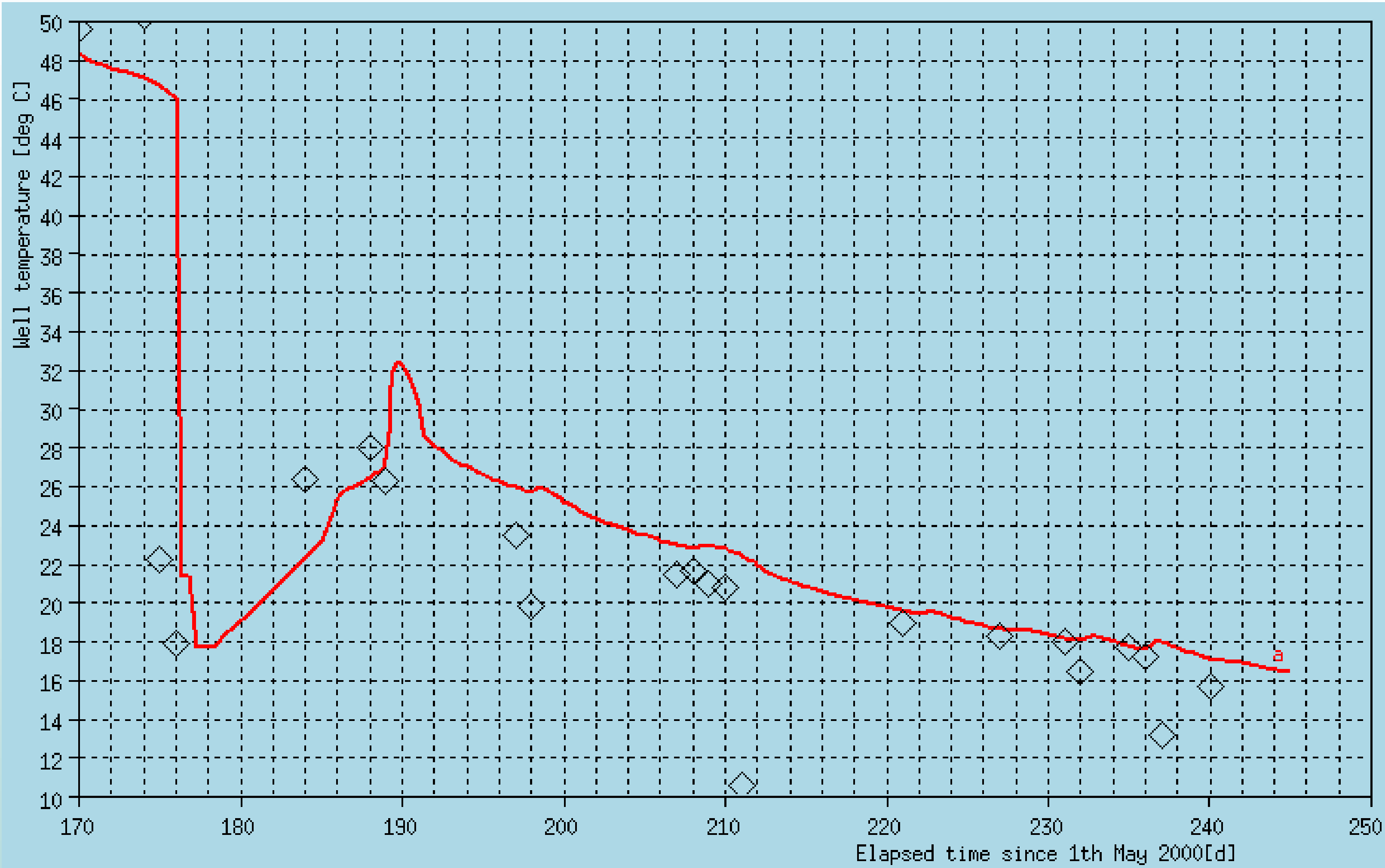
ATES Rostock-Brinckmanshöhe



Calculated (red) and measured (black) temperature behaviour at the measuring-lance M3 in 2000

GTN
INGENIEURE
& GEOLOGEN

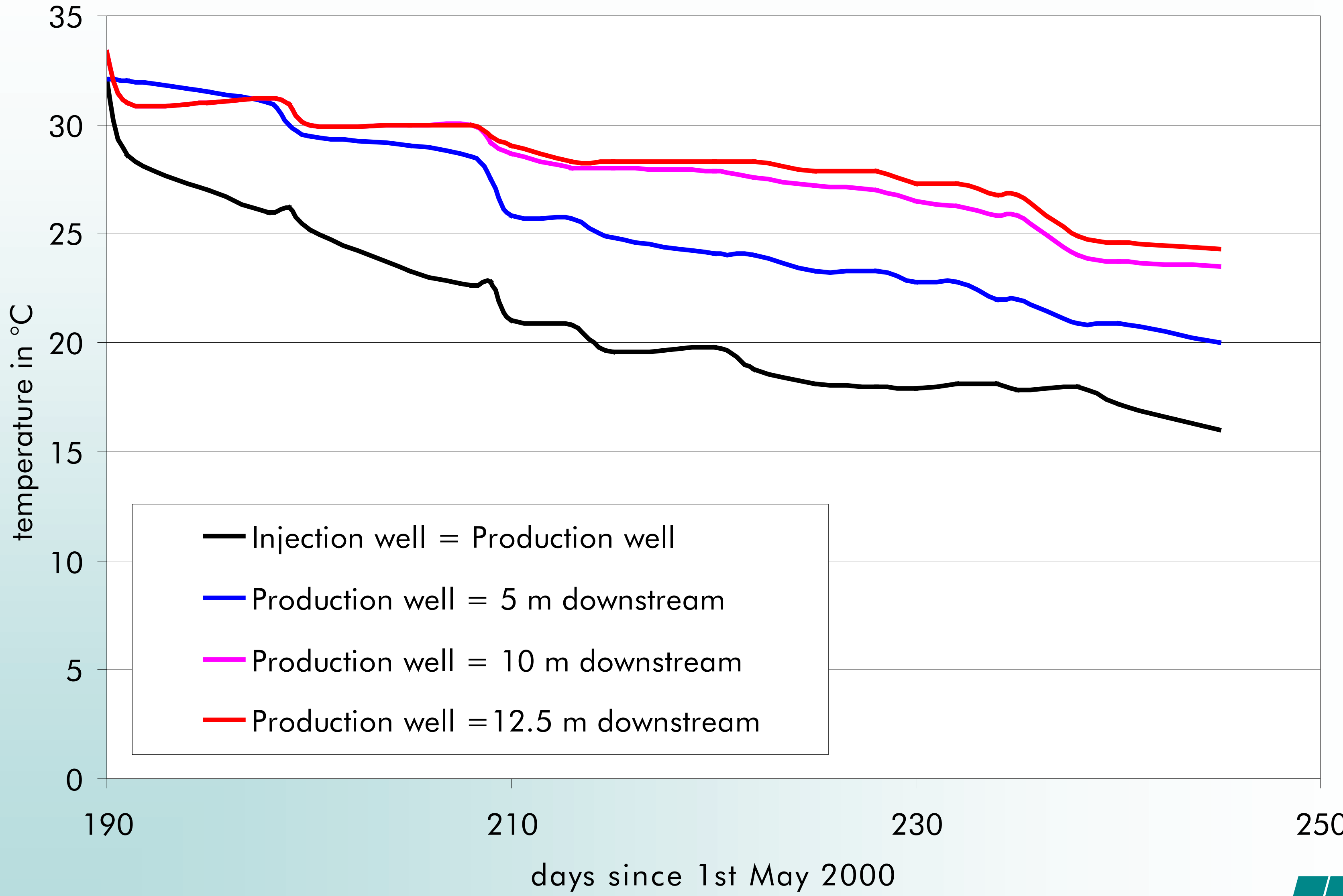
ATES Rostock-Brinckmanshöhe



Calculated (red) and measured (black rhombs) discharging temperature, end of 2000 (days since 1st May)

GTN INGENIEURE & GEOLOGEN

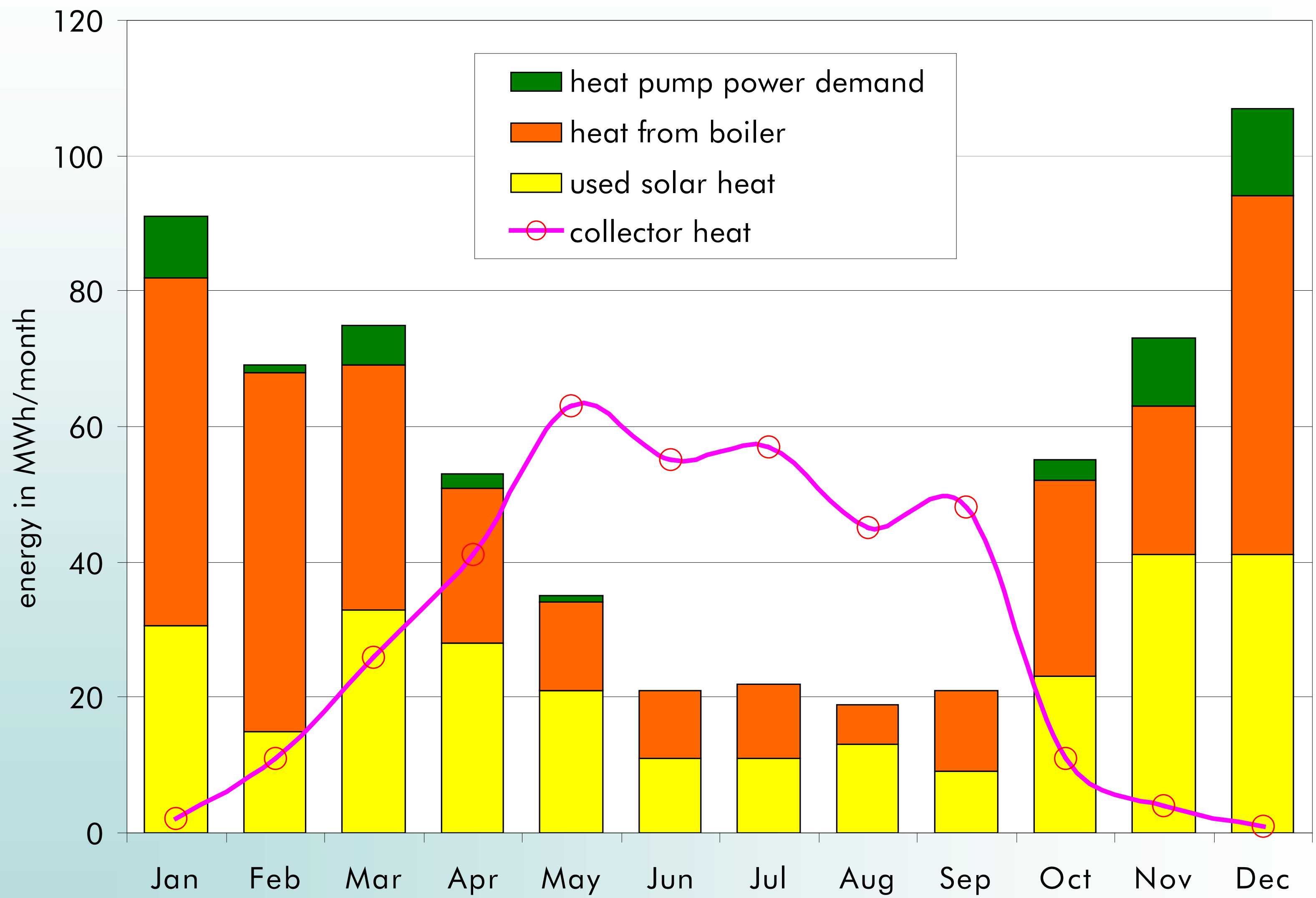
ATES Rostock-Brinckmanshöhe



Dependency of the discharging temperature on the well site

GTN INGENIEURE & GEOLOGEN

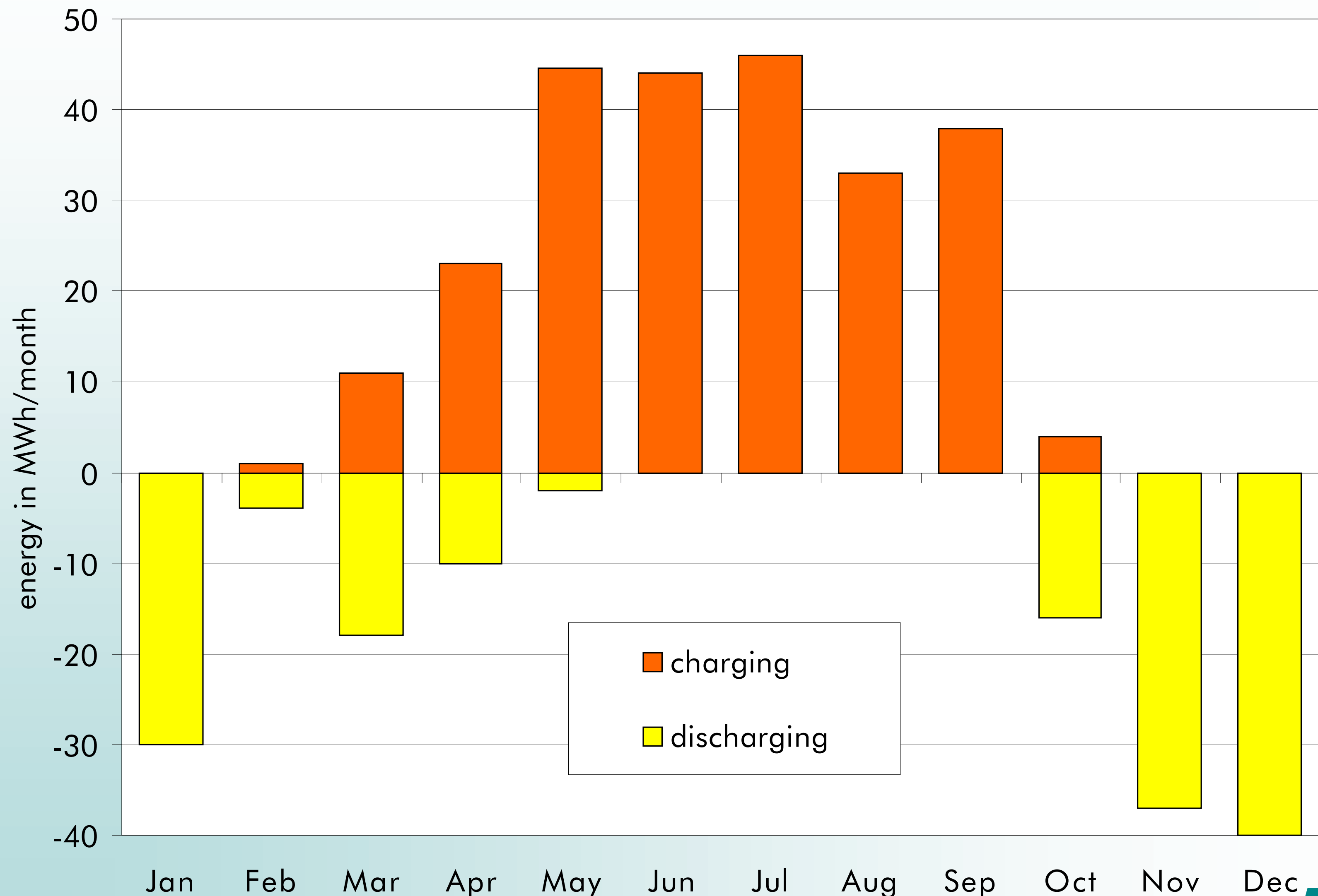
ATES Rostock-Brinckmanshöhe



Monthly heat balance of the system (2002)

GTN INGENIEURE & GEOLOGEN

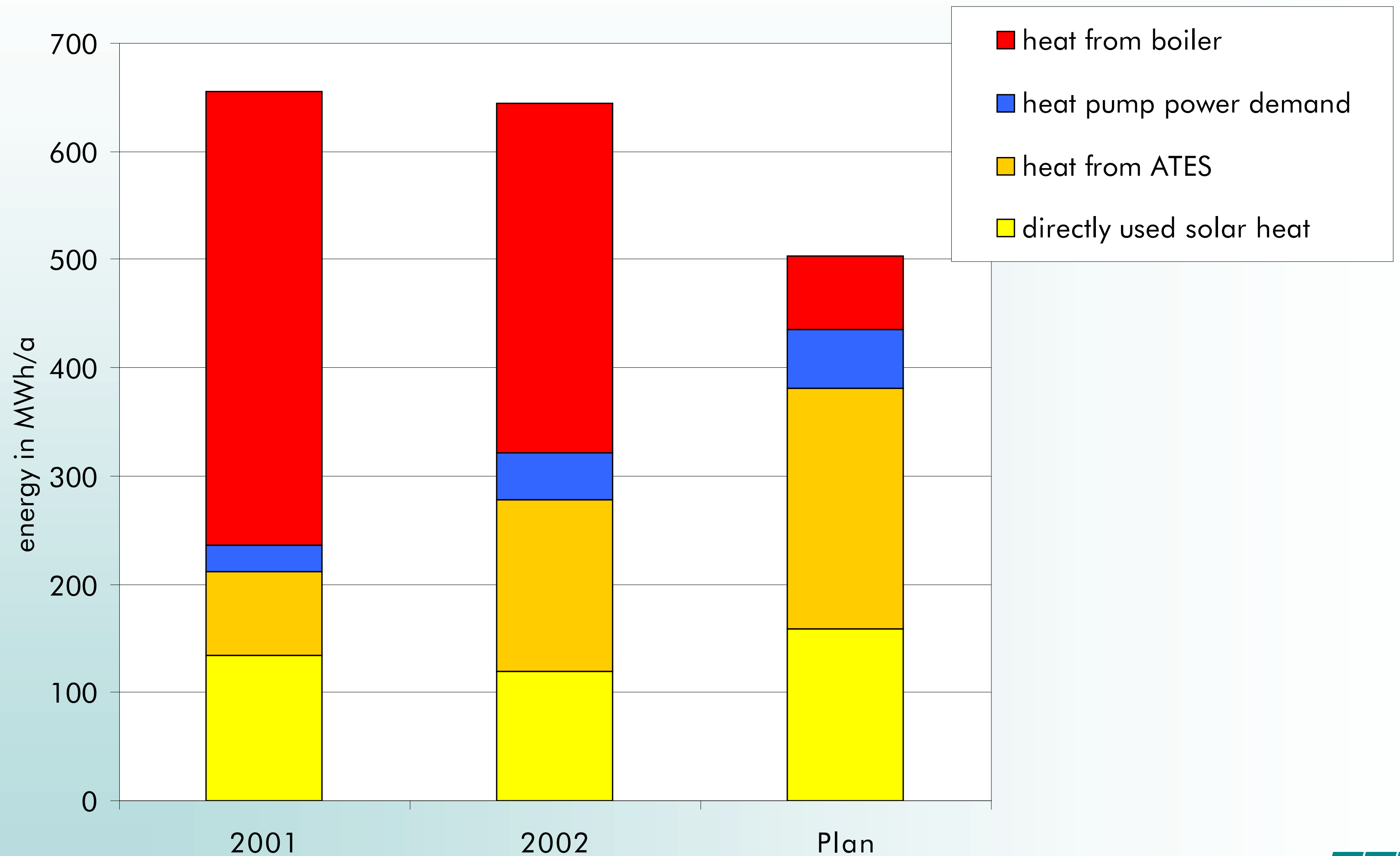
ATES Rostock-Brinckmanshöhe



Monthly heat balance of the ATES (2002)

GTN INGENIEURE & GEOLOGEN

ATES Rostock-Brinckmanshöhe



Heat balances in 2001 and 2002

GTN INGENIEURE & GEOLOGEN

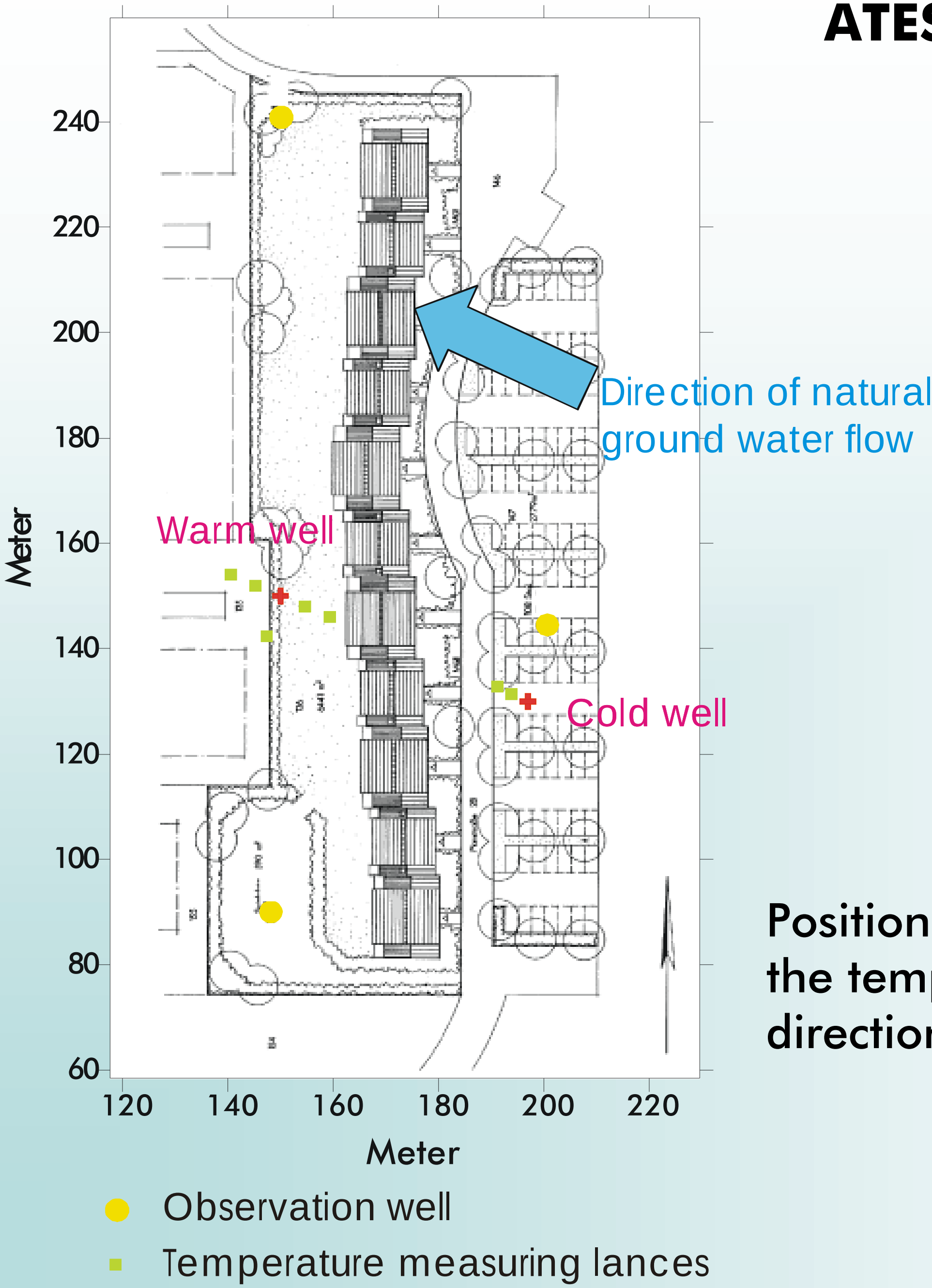
ATES Rostock-Brinckmanshöhe

	2001	2002	2004
• Solar fraction	32 %	43 %	49 %
• ATES recovery factor	36.5 %	64.5 %	48,5 %
• COP of heat pump	4.1	4.3	4,5

Essential figures

GTN INGENIEURE & GEOLOGEN

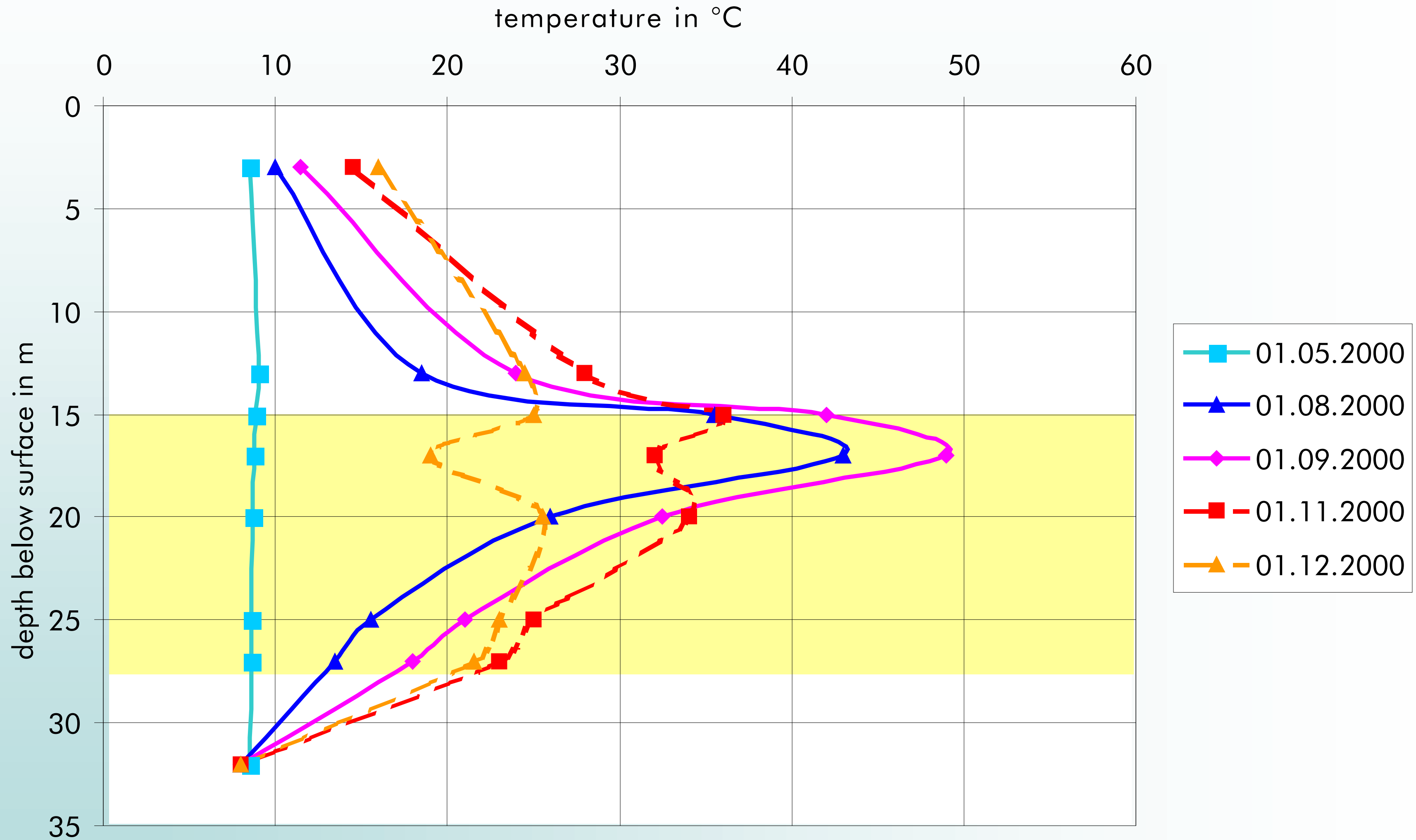
ATES Rostock-Brinckmanshöhe



Position of the wells,
the temperature measuring-lances and
direction of natural groundwater flow

GTN INGENIEURE & GEOLOGEN

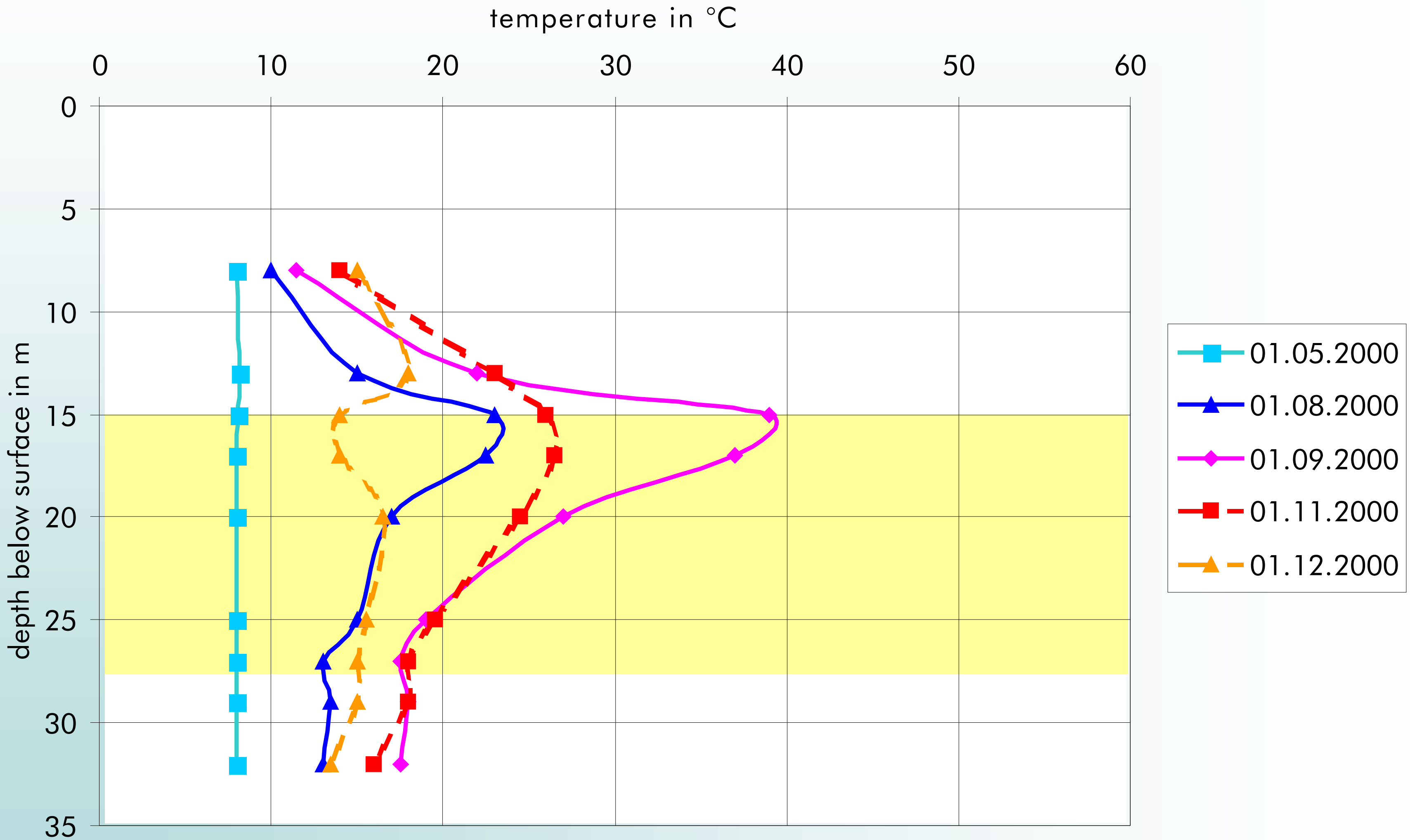
ATES Rostock-Brinckmanshöhe



Temperature profiles at measuring-lance M2,
5 m downstream of the warm well

GTN INGENIEURE & GEOLOGEN

ATES Rostock-Brinckmanshöhe

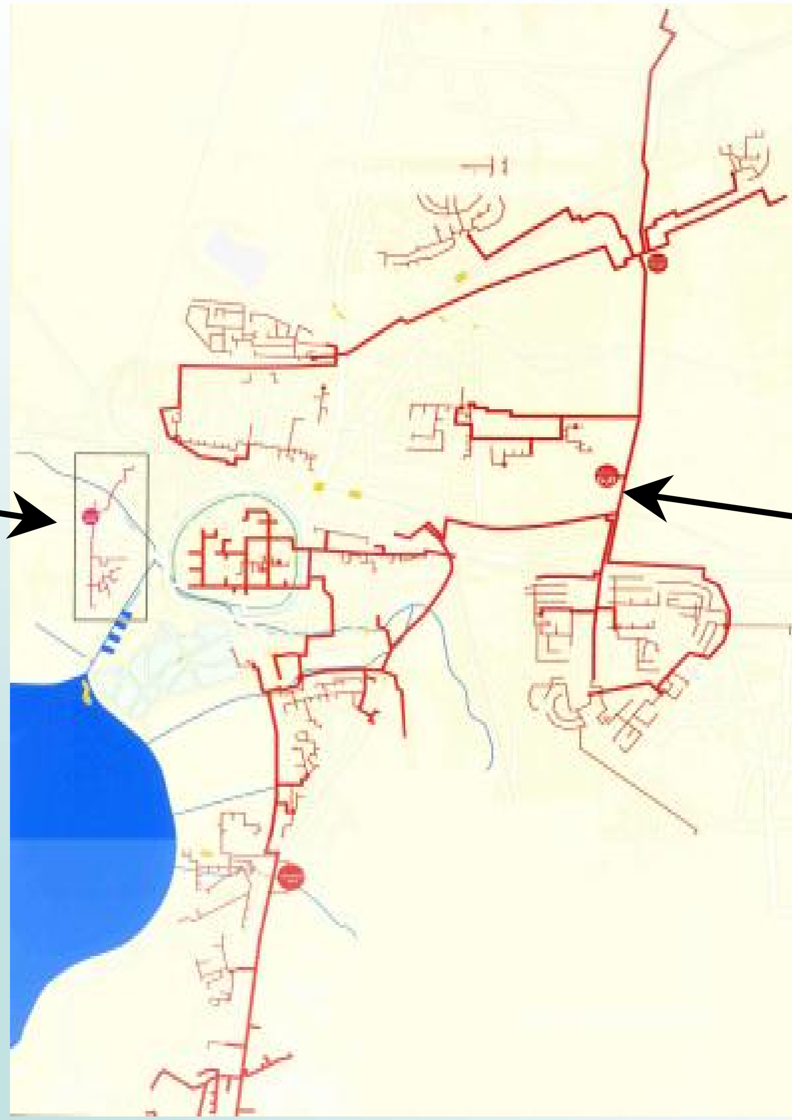


Temperature profiles at measuring-lance M3,
5 m upstream of the warm well

GTN
INGENIEURE
& GEOLOGEN

Neubrandenburg aquifer heat store

Geothermal Heating Plant and
low-temperature heating network
(12 MW, 80°C / 45°C)

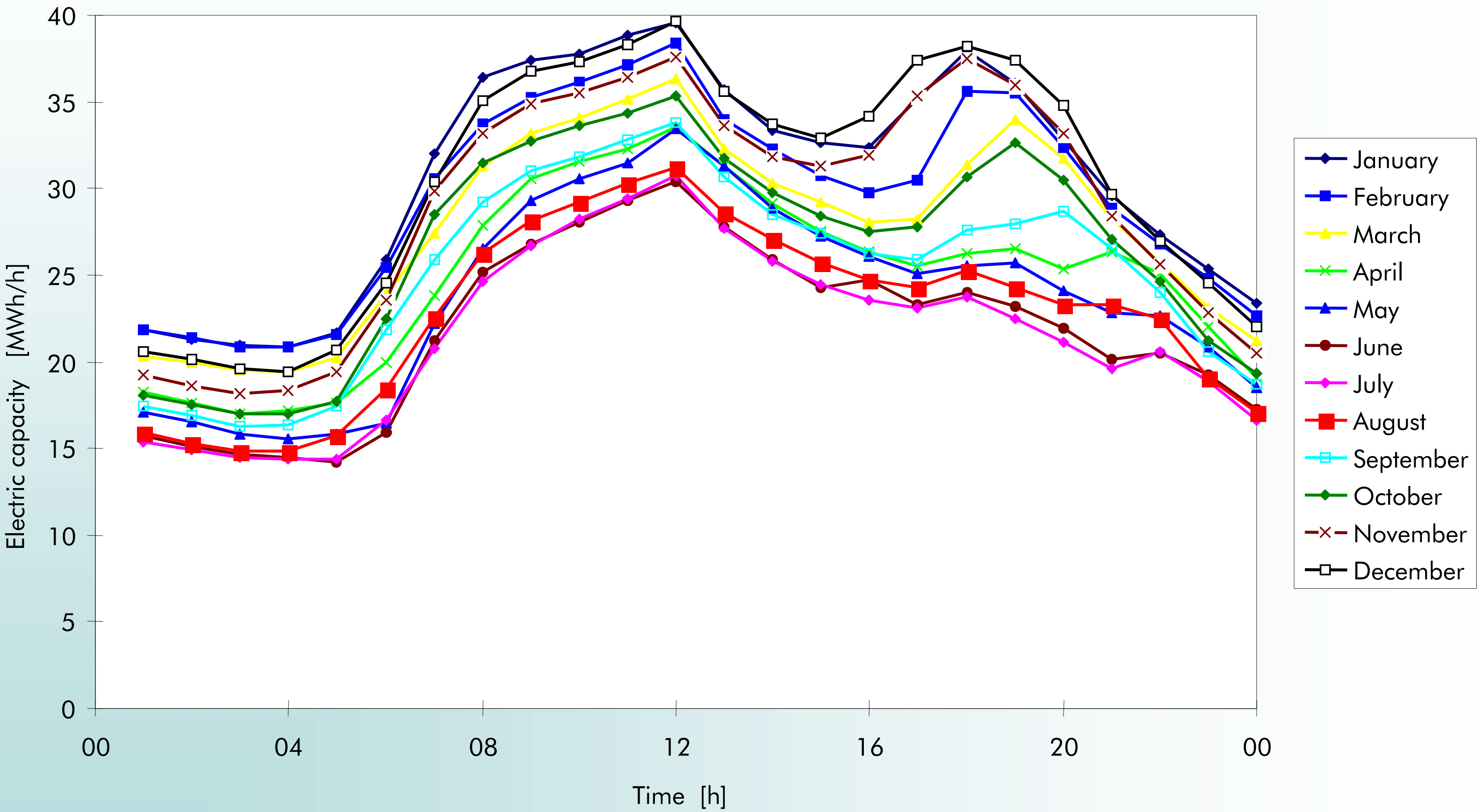


Gas and Steam Cogeneration Plant
and high-temperature heating
network (200 MW, 130°C / 60°C)

District heat supply networks of the Neubrandenburger Stadtwerke GmbH (Public Utilities)

GTN
INGENIEURE
& GEOLOGEN

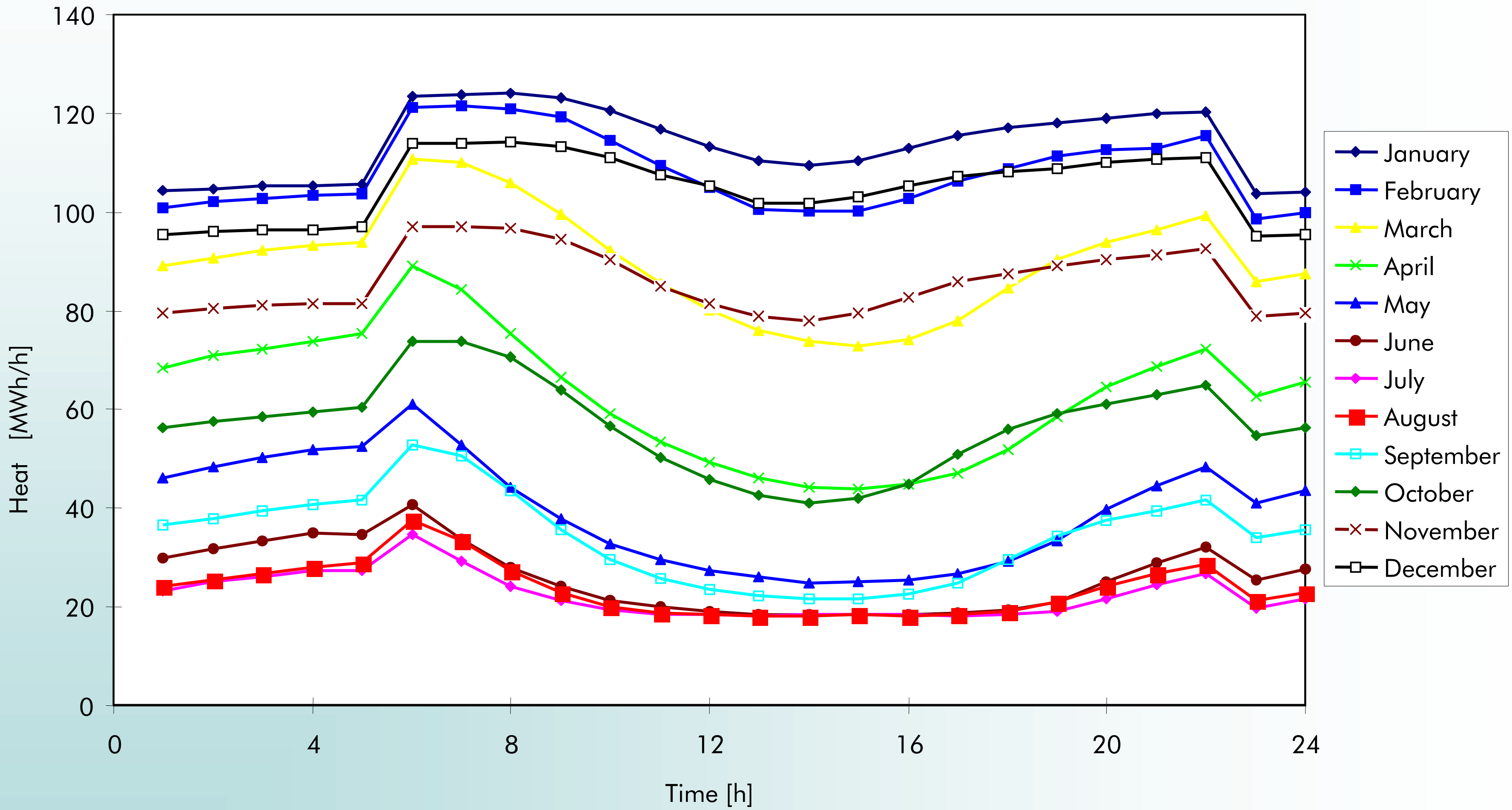
Neubrandenburg aquifer heat store



Characteristics of the power demand of the town of Neubrandenburg

GTN INGENIEURE & GEOLOGEN

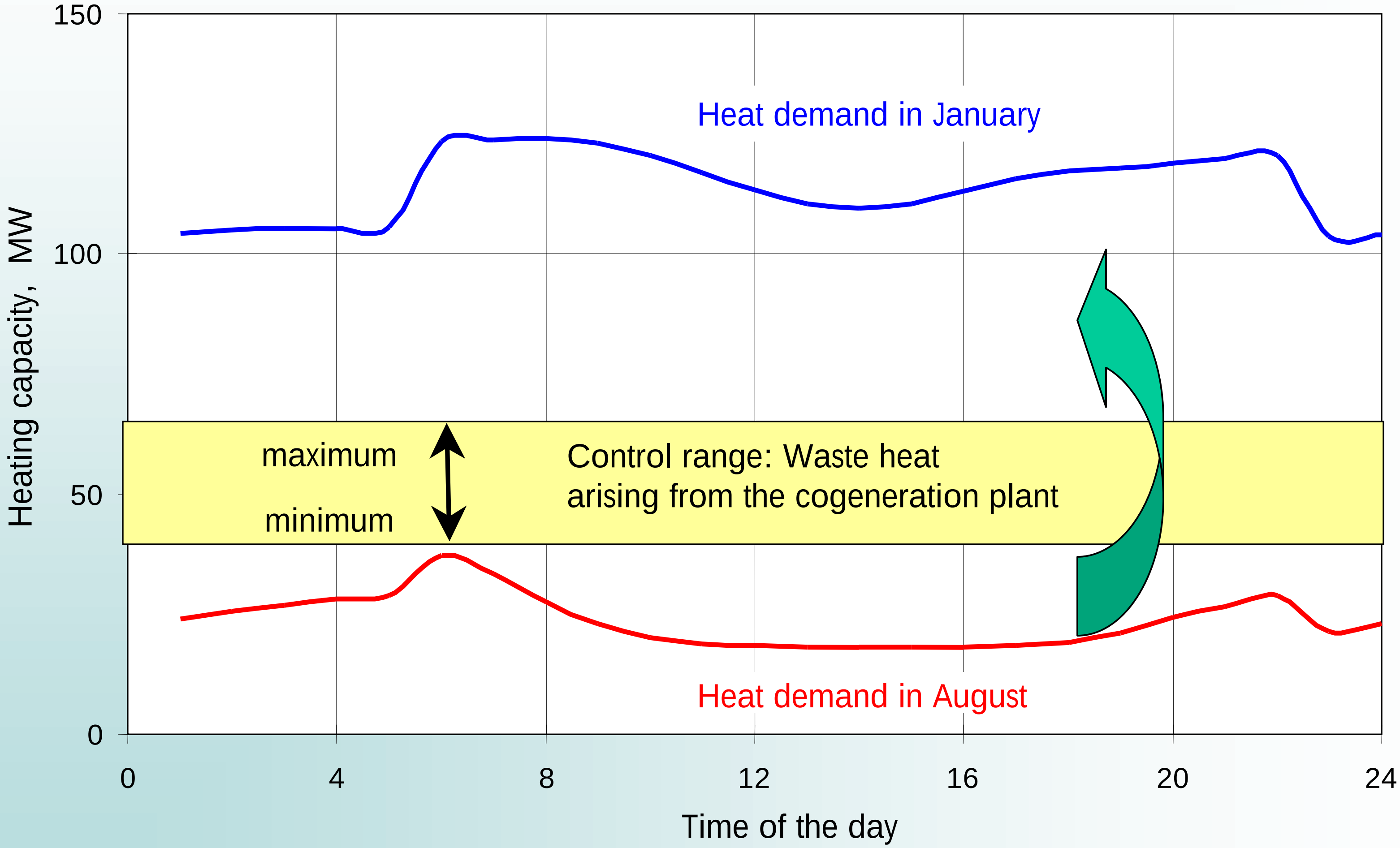
Neubrandenburg aquifer heat store



Characteristics of the heat demand of the town of Neubrandenburg

GTN INGENIEURE & GEOLOGEN

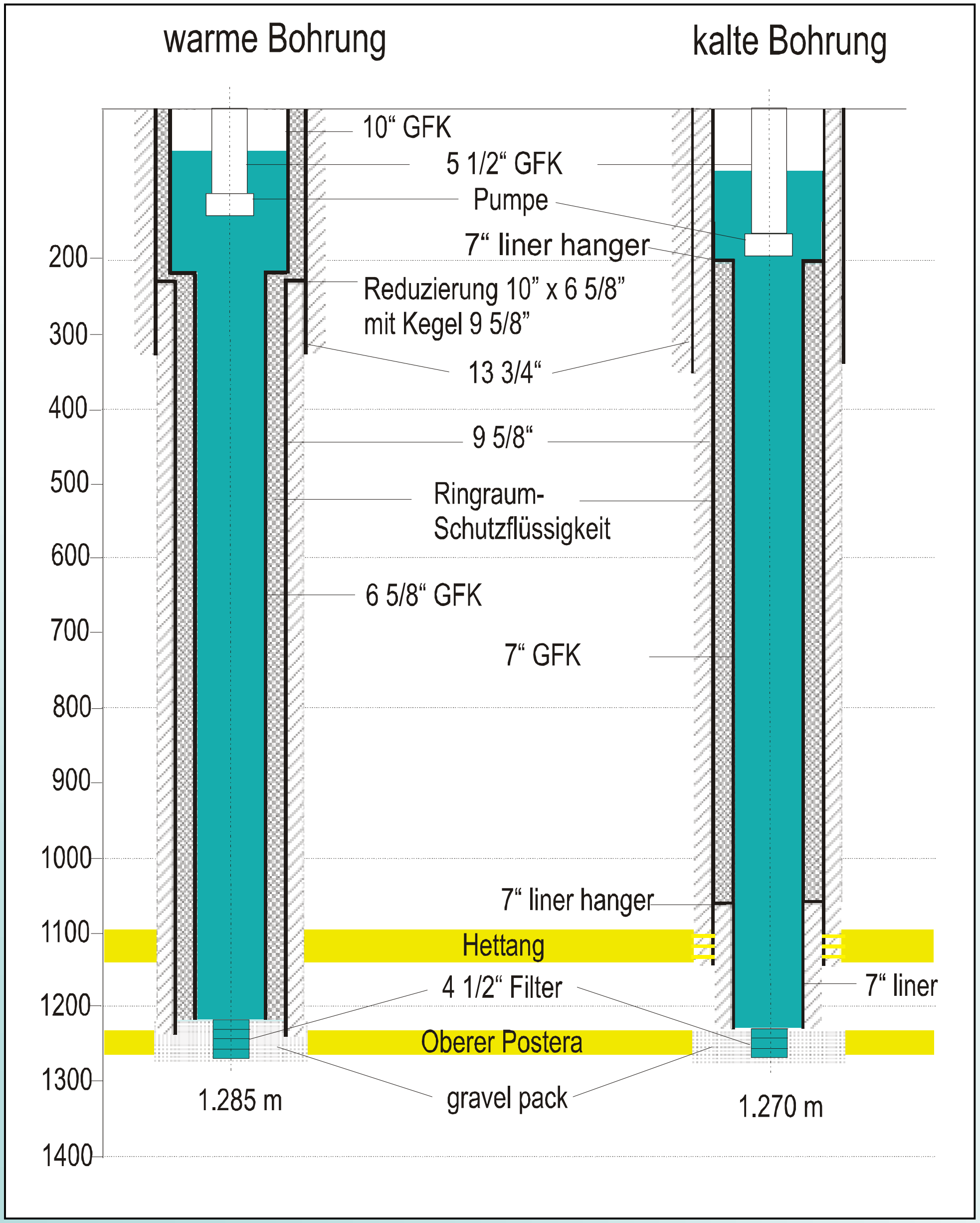
Neubrandenburg aquifer heat store



Effect of heat storage

GTN INGENIEURE & GEOLOGEN

Neubrandenburg aquifer heat store



well construction

GTN INGENIEURE & GEOLOGEN

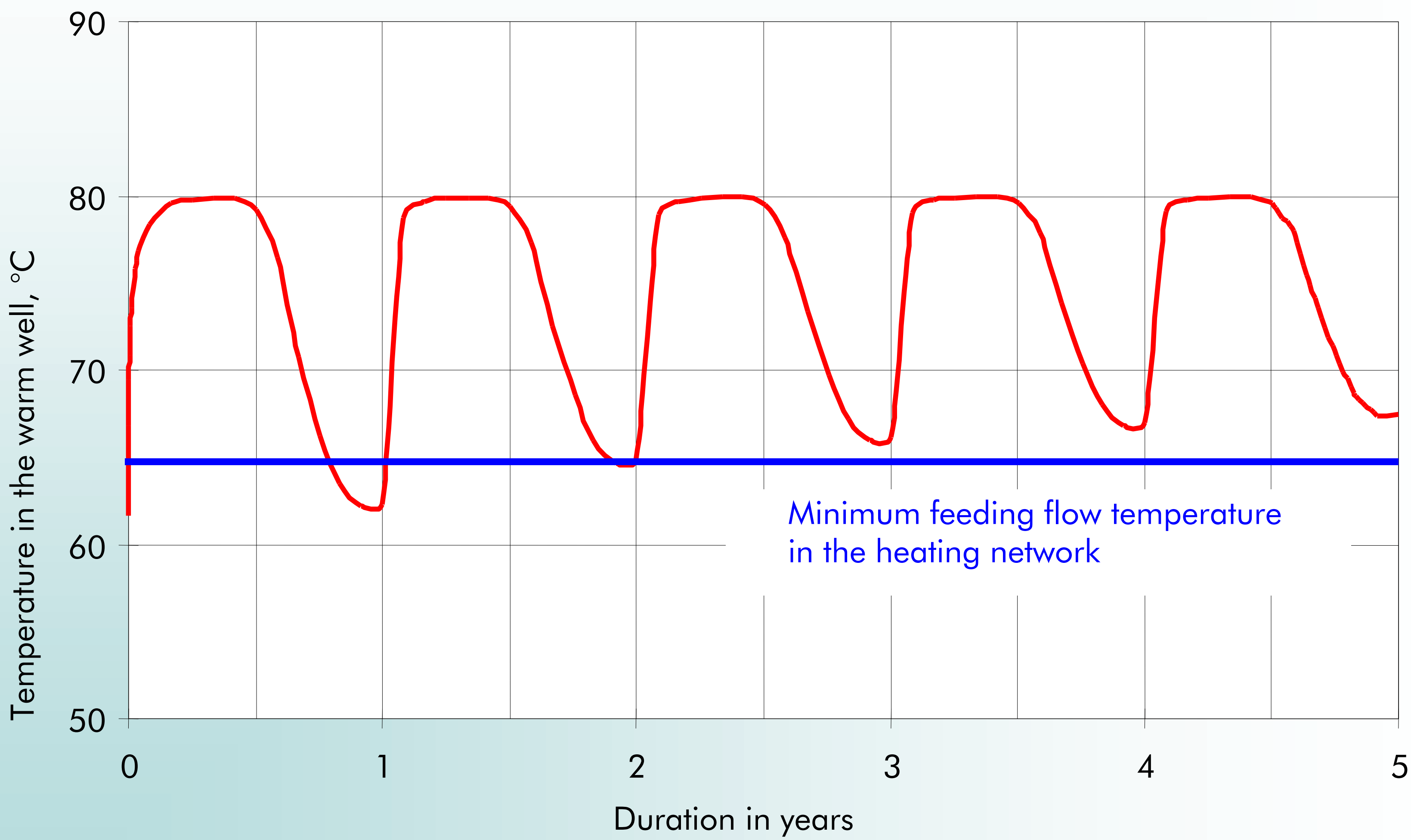
Neubrandenburg aquifer heat store

• Production horizons:	Hettangian and Upper Postera
• Depth:	1,105 m – 1,172 m 1,237 m – 1,271 m
• Flowrate:	200 m^3/h
• Production temperature:	50 °C and 54 °C
• Mineralisation:	118 g/l and 133 g/l

Parameters of the geothermal resource

GTN INGENIEURE & GEOLOGEN

Neubrandenburg aquifer heat store



GTN INGENIEURE & GEOLOGEN

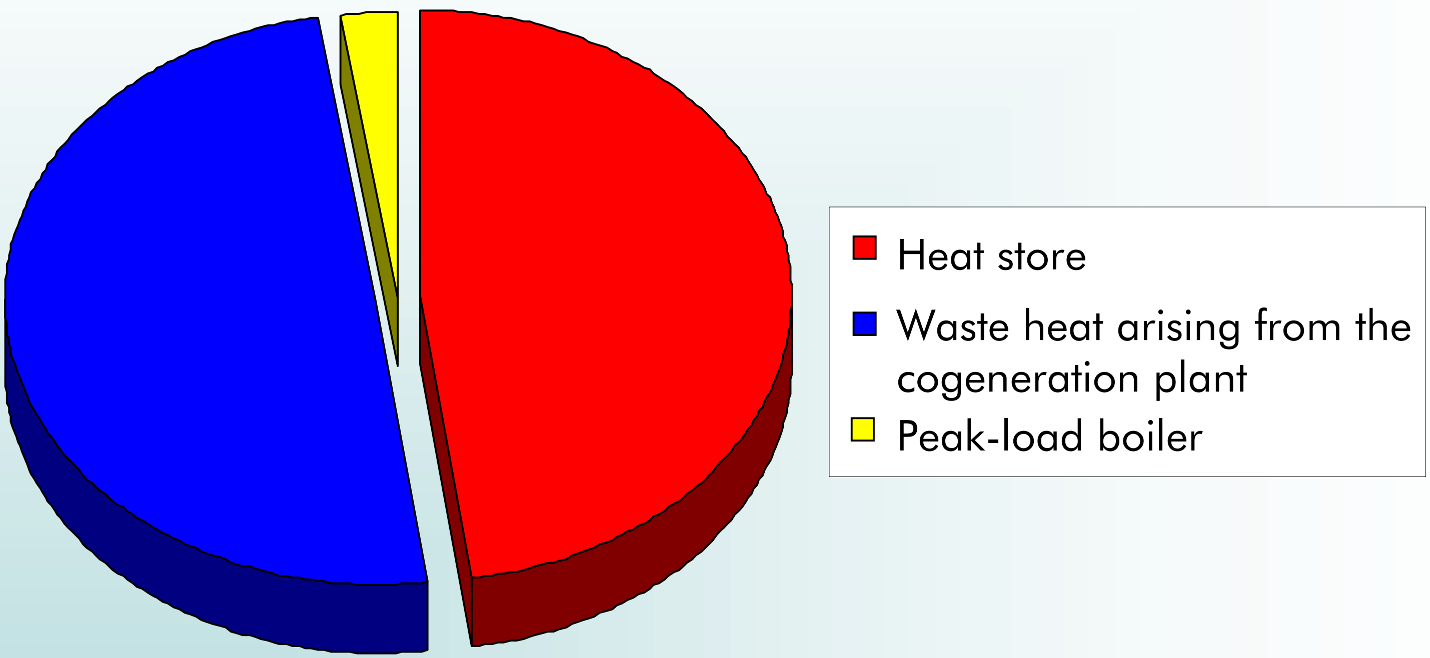
Behaviour of the temperature when discharging

Neubrandenburg aquifer heat store

Working on the well Gt N 4/86 in 2002

GTN INGENIEURE & GEOLOGEN

Neubrandenburg aquifer heat store



Balance of generation in the district heat supply network „Rostock Street“

Neubrandenburg aquifer heat store

Installation of the submersible pump in the well Gt N 4/86 in 2002

GTN
INGENIEURE
& GEOLOGEN

Neubrandenburg aquifer heat store

Gt N 4/86 well head

GTN
INGENIEURE
& GEOLOGEN

Neubrandenburg aquifer heat store

Gt N 4/86 well head

Neubrandenburg aquifer heat store

Heat exchanger for heat discharge

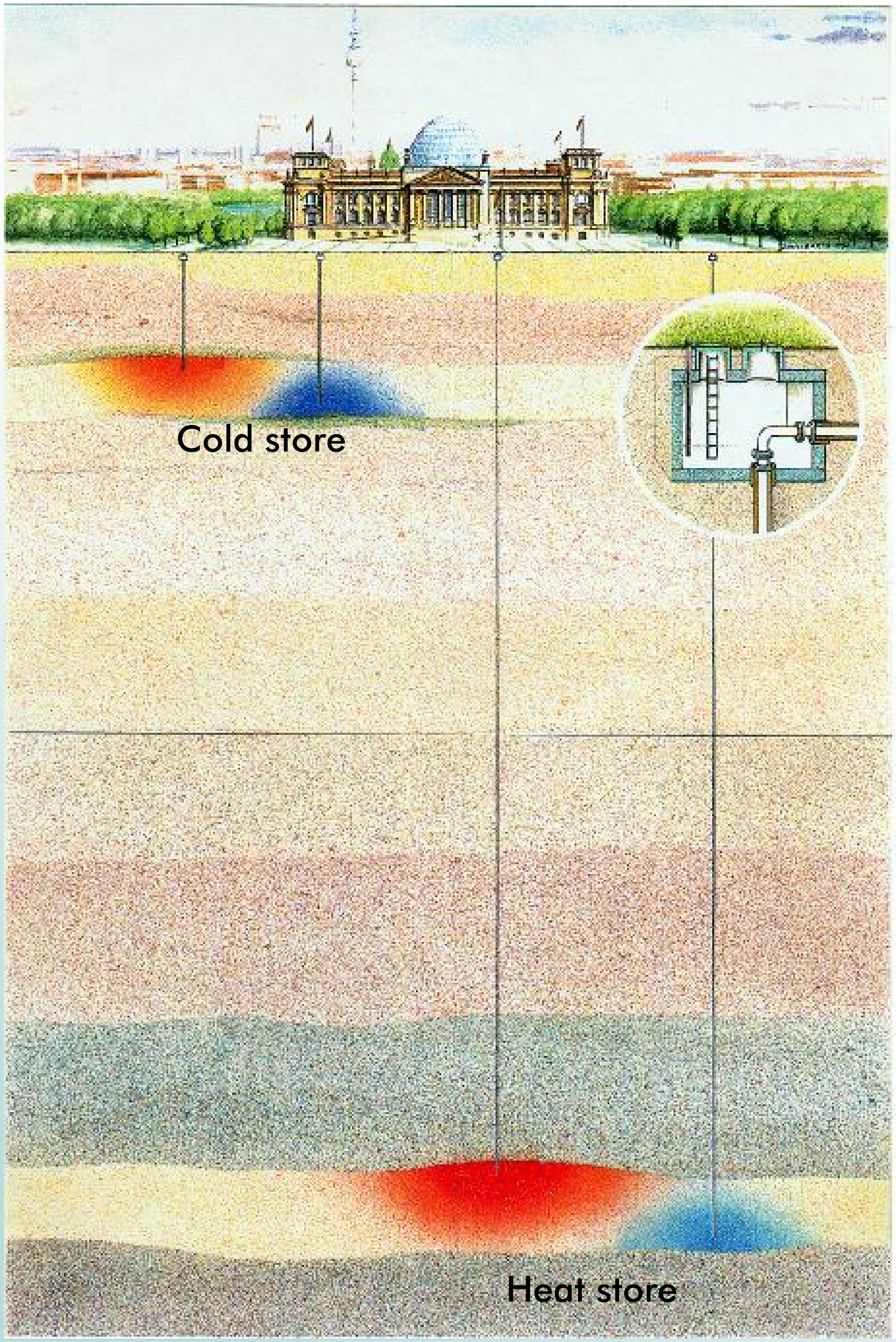
GTN INGENIEURE & GEOLOGEN

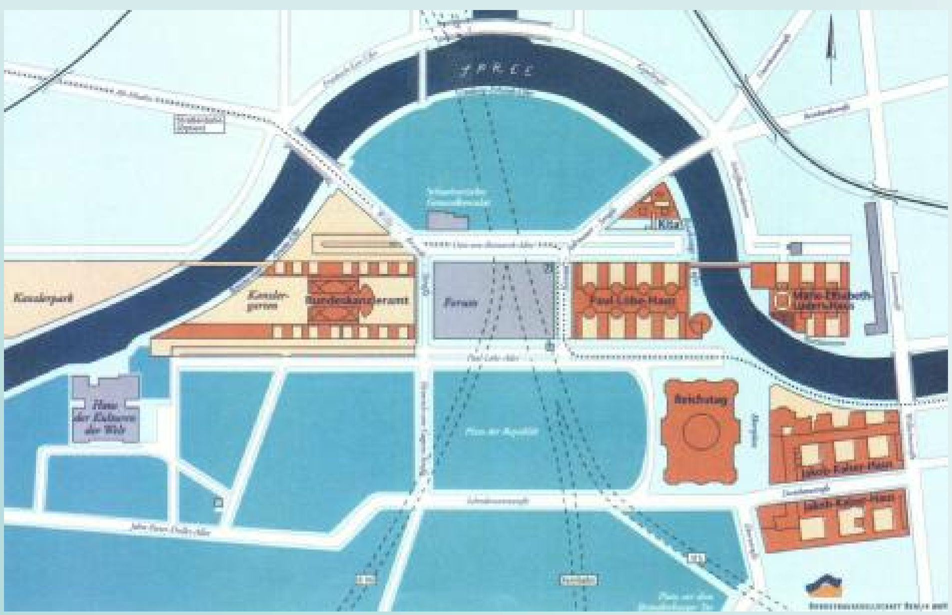
Neubrandenburg aquifer heat store

Coarse filtration of the thermal water at the cold well

GTN INGENIEURE & GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)





Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

Parliament buildings supplied by ATES

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

Drilling fields

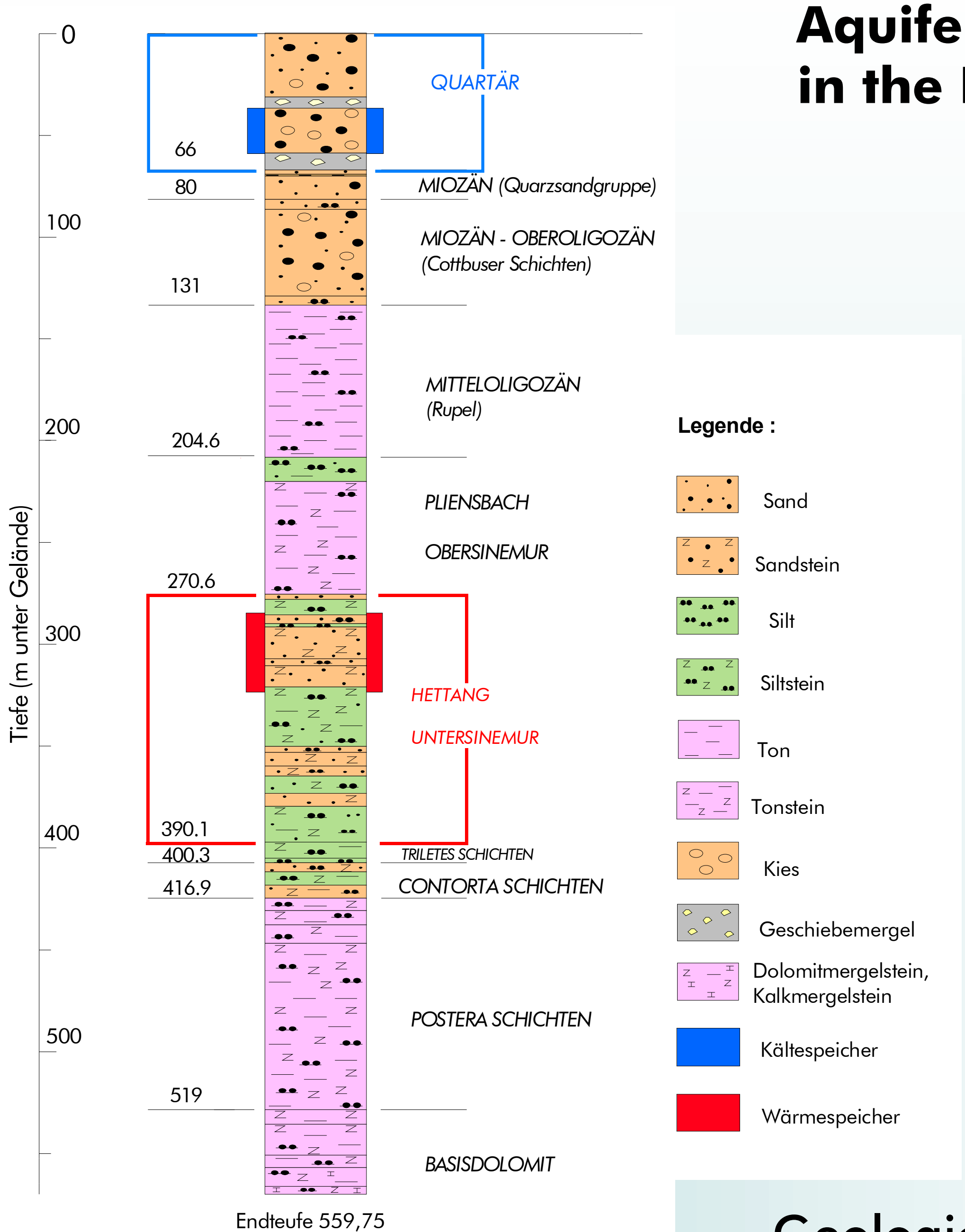
GTN INGENIEURE & GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

Drilling of a heat store well

GTN INGENIEURE & GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)



Geological cross-section

GTN INGENIEURE & GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

• Geological formation:	Hettangian
• Depth:	285 m- 315 m
• Store temperature:	19 °C
• Mineralisation:	29 g/l
• Porosity:	30.4 %
• Permeability:	2.8- 4.2 μm^2
• Number of wells:	2
• Internal distance:	400 m
• Production/injection flowrate:	100 m^3/h
• Injection temperature:	70 °C

Heat store parameters

GTN INGENIEURE & GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

• Geological formation:	Quaternary
• Depth:	30 m- 60 m
• Store temperature:	10 °C
• Porosity:	~30 %
• Permeability:	>1 μm^2
• Number of wells:	12 in 2 groups
• Internal distance:	400 m
• Production / injection flowrate:	300 m^3/h
• Injection temperature:	
in winter	5 °C
in summer	28 °C

Cold store parameters

GTN INGENIEURE & GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

Installation of the twin pipes in a heat store well

GTN INGENIEURE & GEOLOGEN

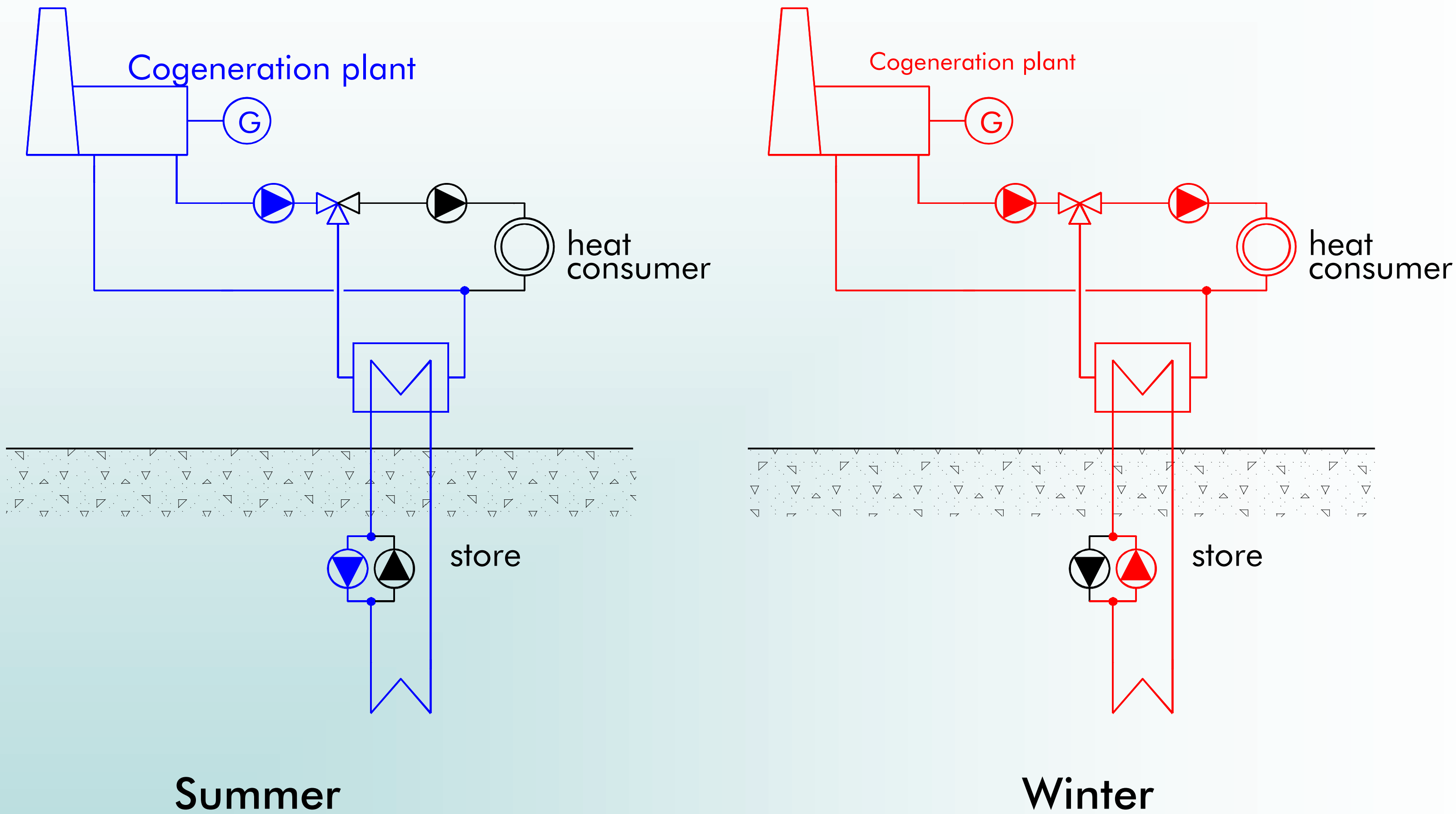
Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

Installation of a heat store well head

Heat store well chamber

GTN INGENIEURE & GEOLOGEN

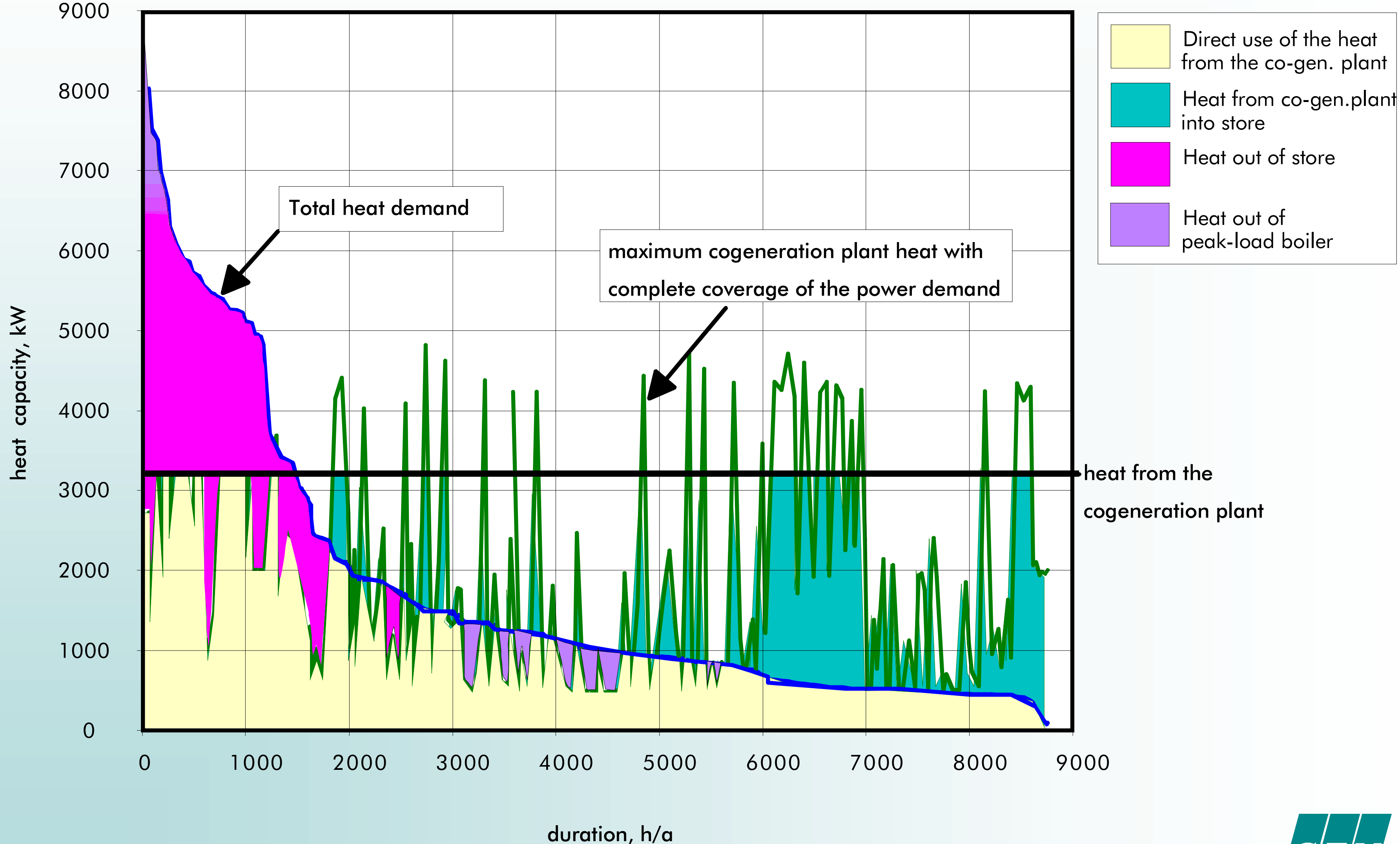
Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)



Technical concept of the storage of waste heat arising from a cogeneration plant

GTN INGENIEURE & GEOLOGEN

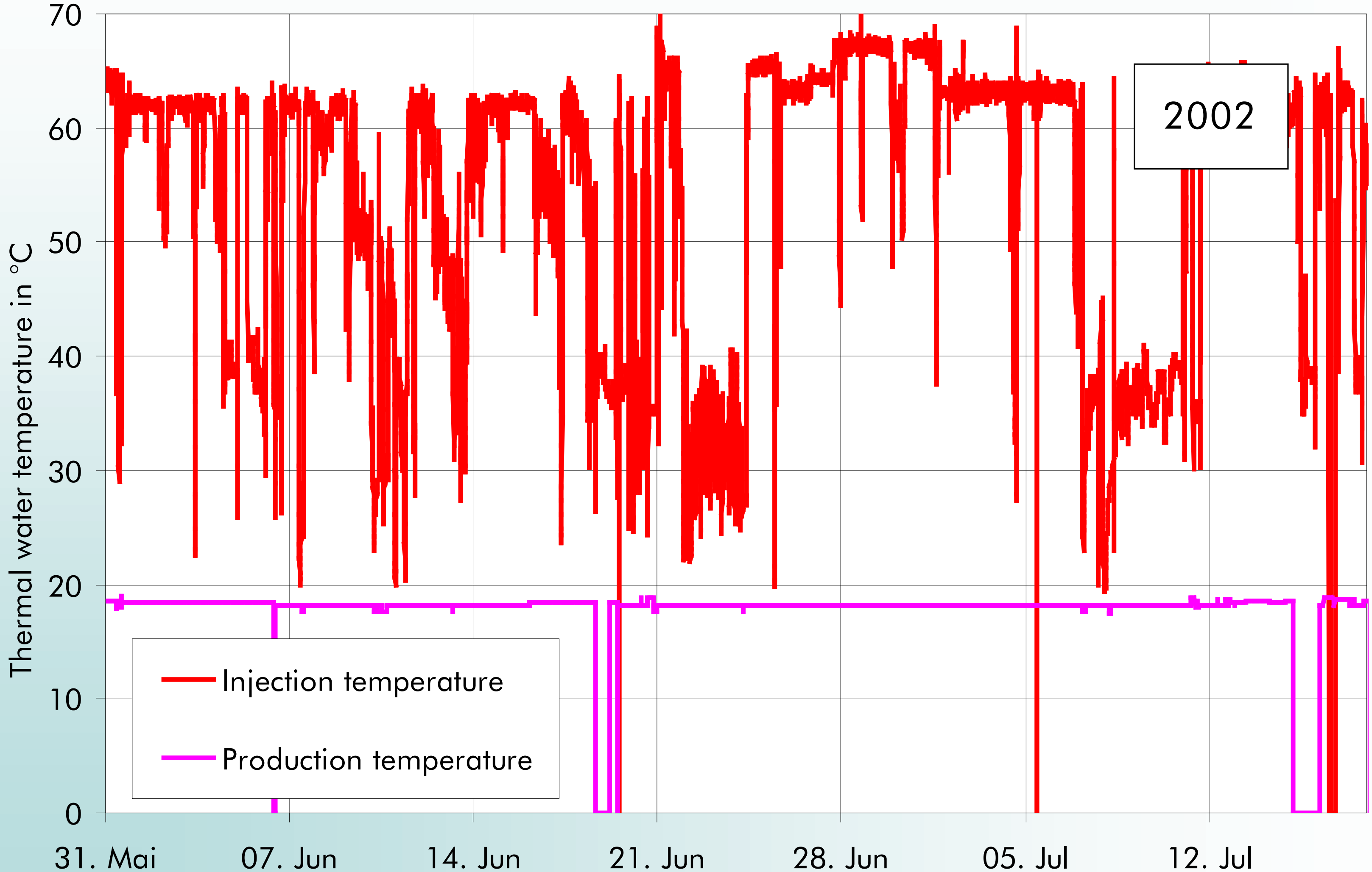
Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)



Energetic benefit from a heat store

GTN INGENIEURE & GEOLOGEN

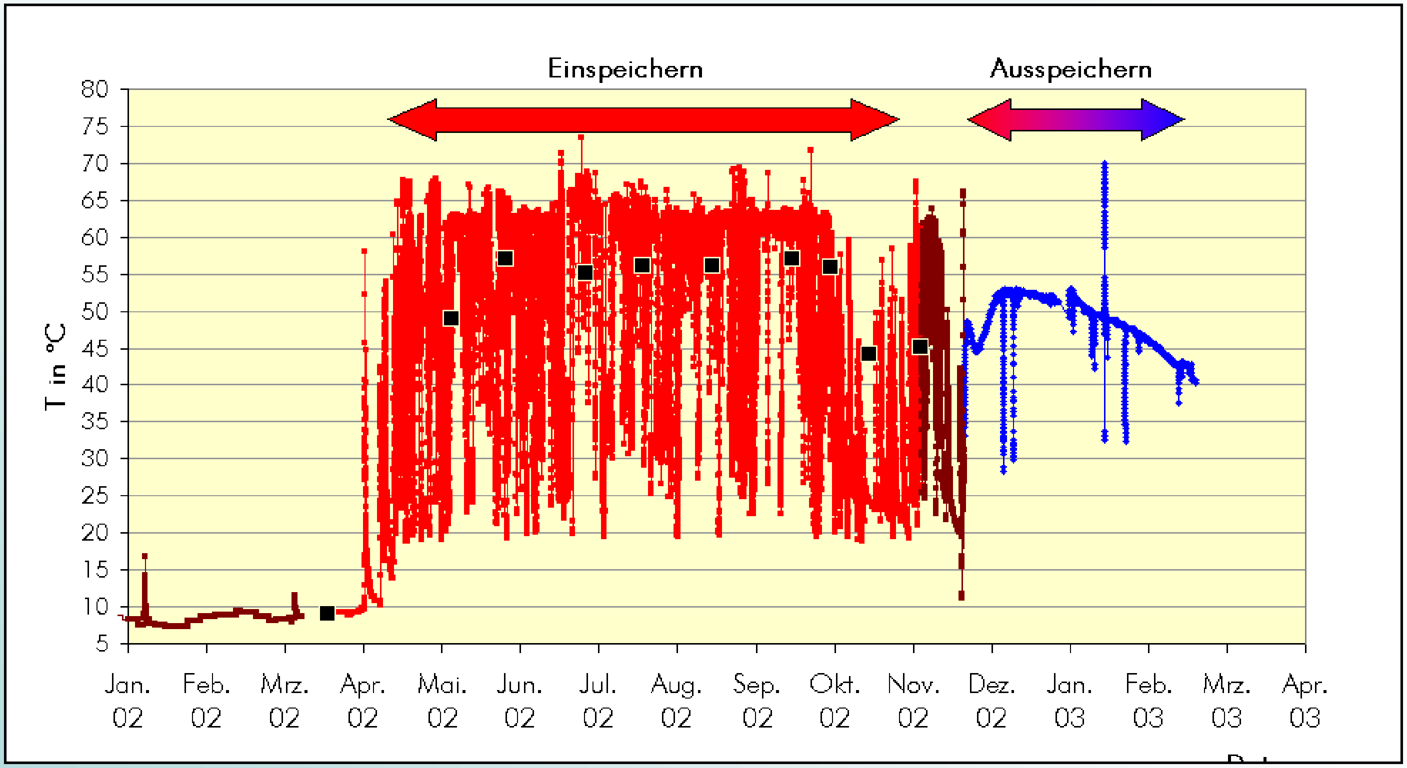
Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)



Heat store – parameters of heat charging

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

- Until autumn 2002: Charging only
- First regular annual cycle: Completed by discharging in winter 2002/2003

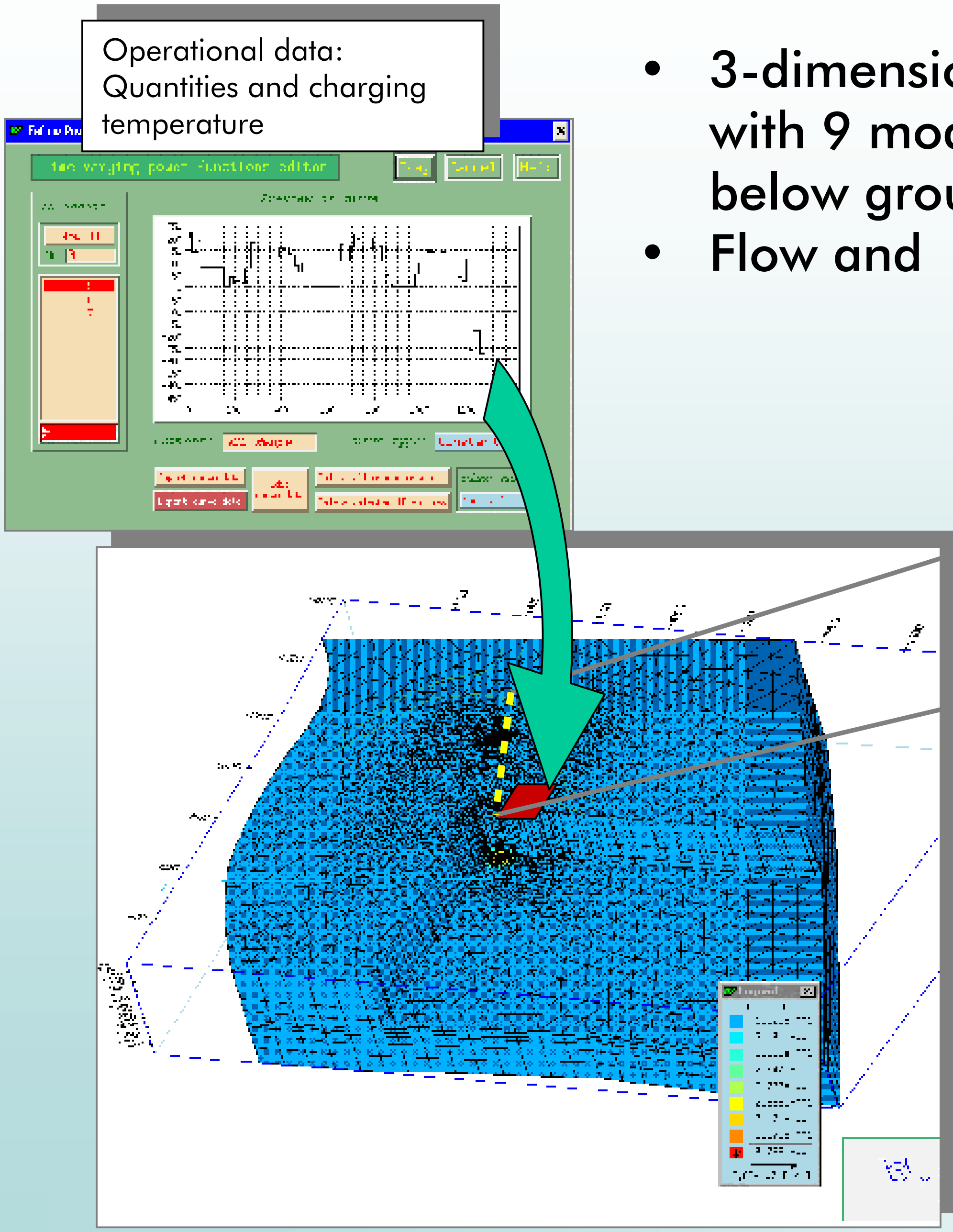


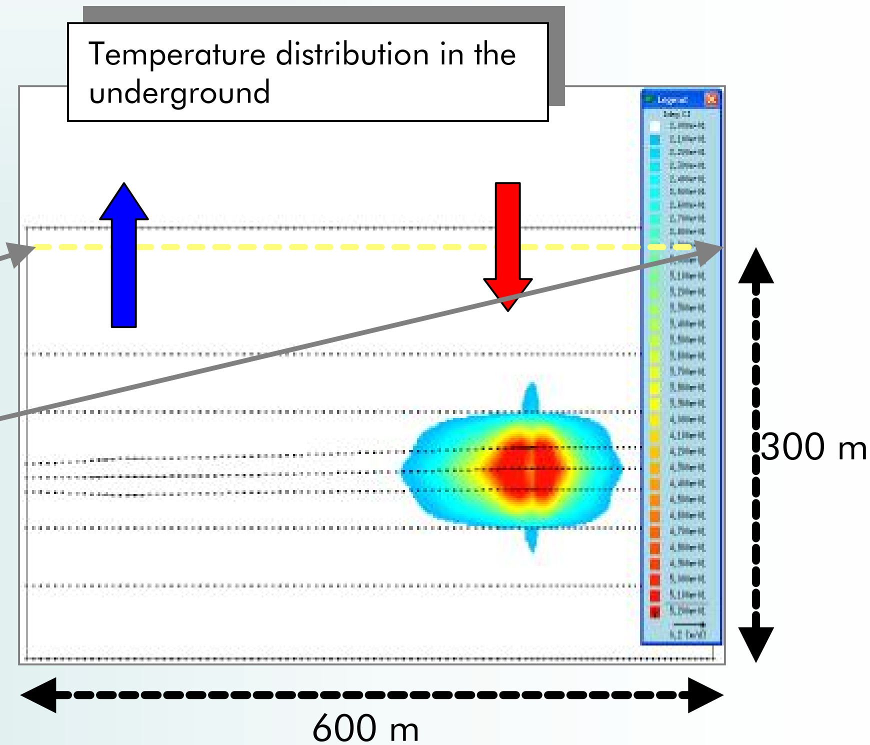
Charging the heat store: Annual curve

GTN INGENIEURE & GEOLOGEN

Numerical model of the heat store: Structure

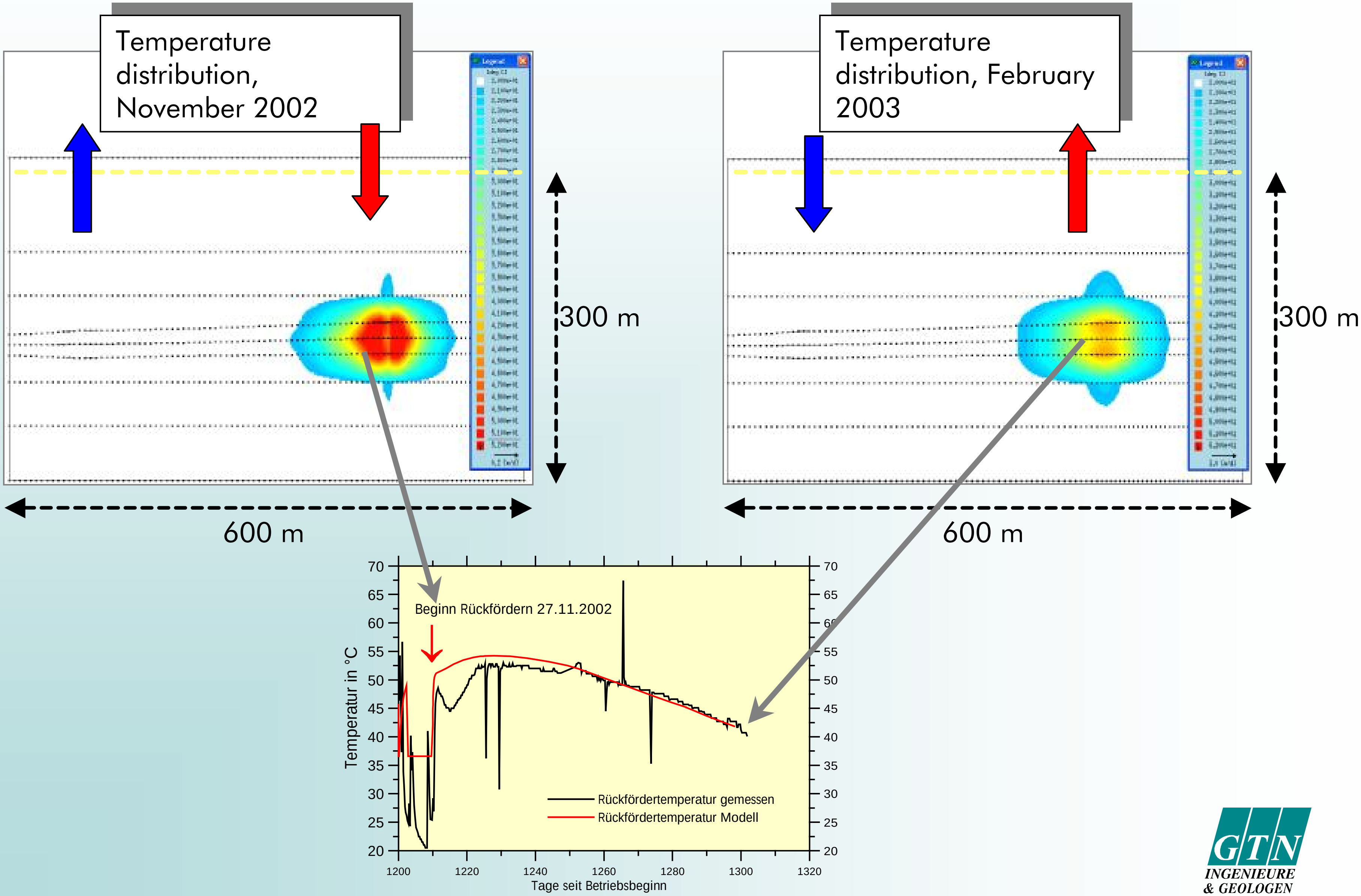
- 3-dimensional Finite-Element model grid with 9 model layers from 100 m to 400 m below ground
- Flow and propagation of the heat front





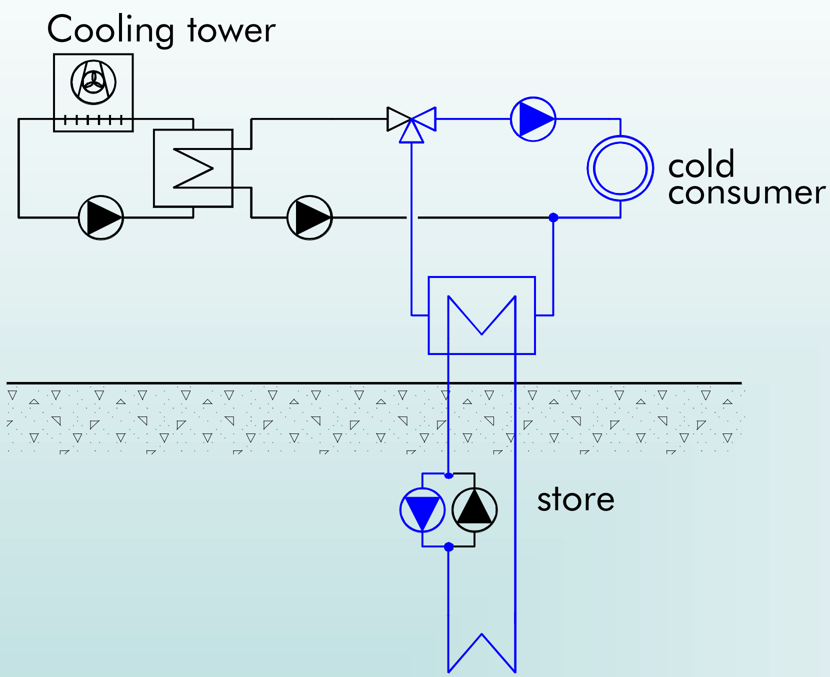
GTN
INGENIEURE
& GEOLOGEN

Numerical model of the heat store: Validation

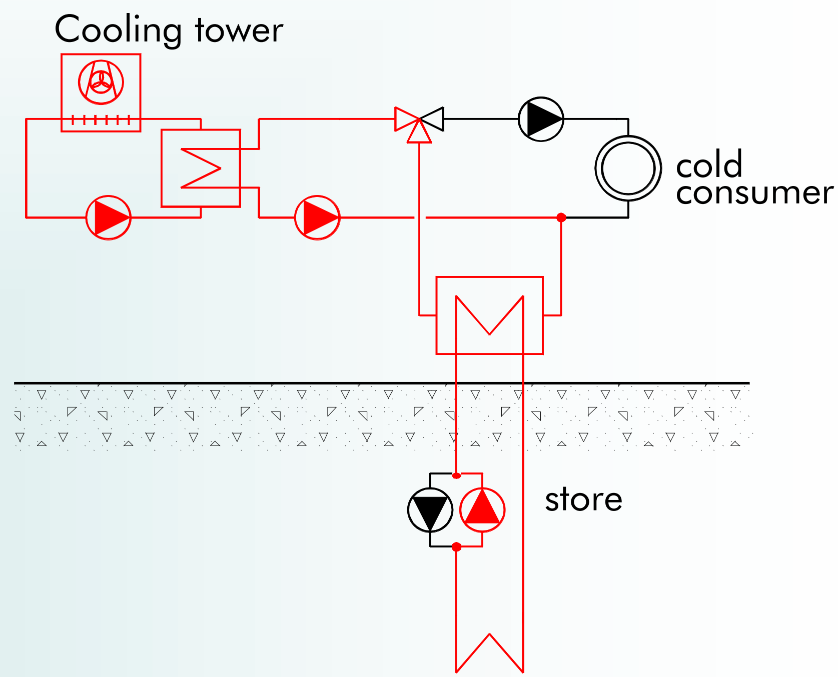


GTN
INGENIEURE
& GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)



Summer



Winter

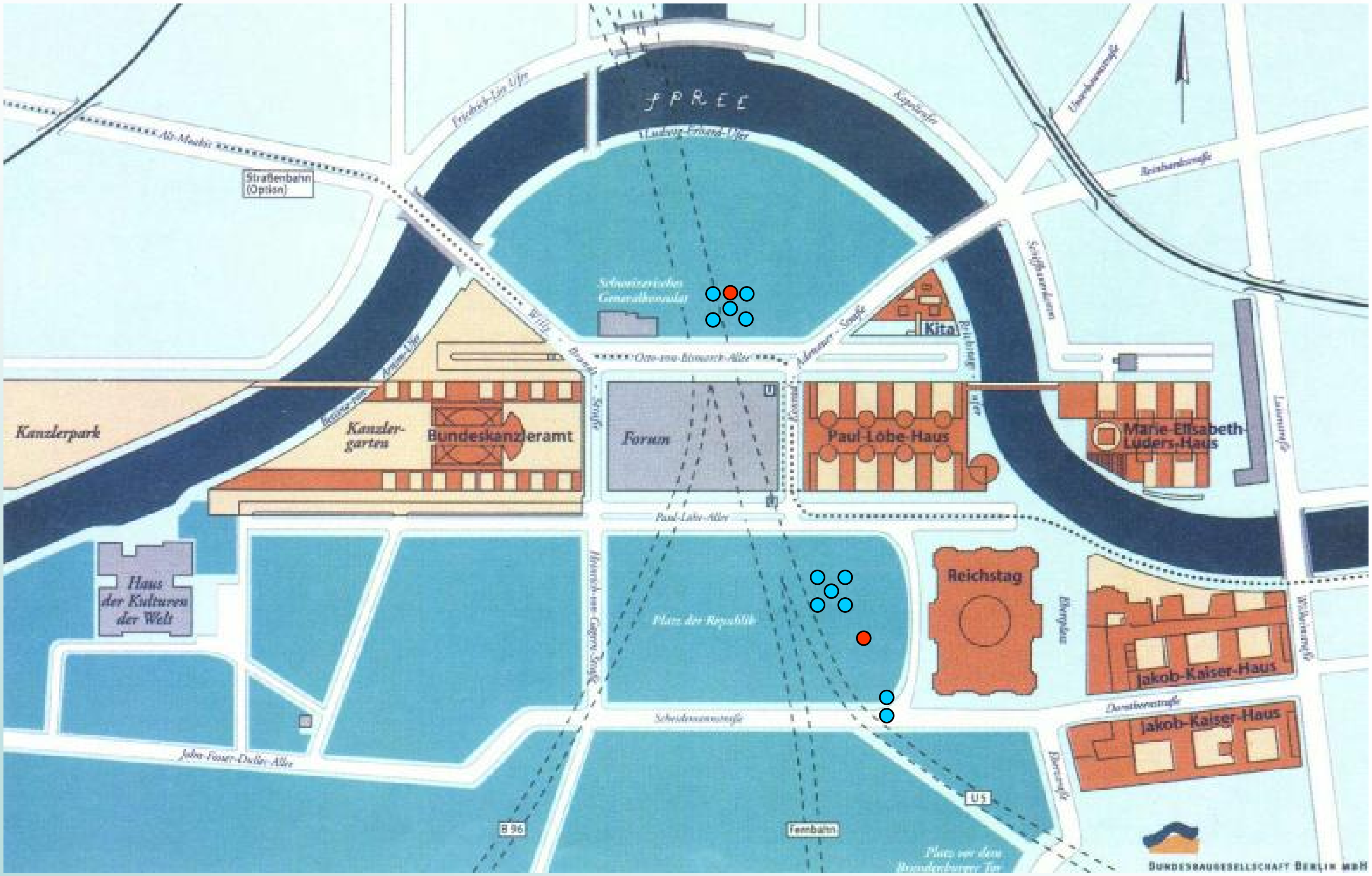
Technical concept of the storage of ambient cold

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

Borehole grid in the Spree river curve

GTN
INGENIEURE
& GEOLOGEN

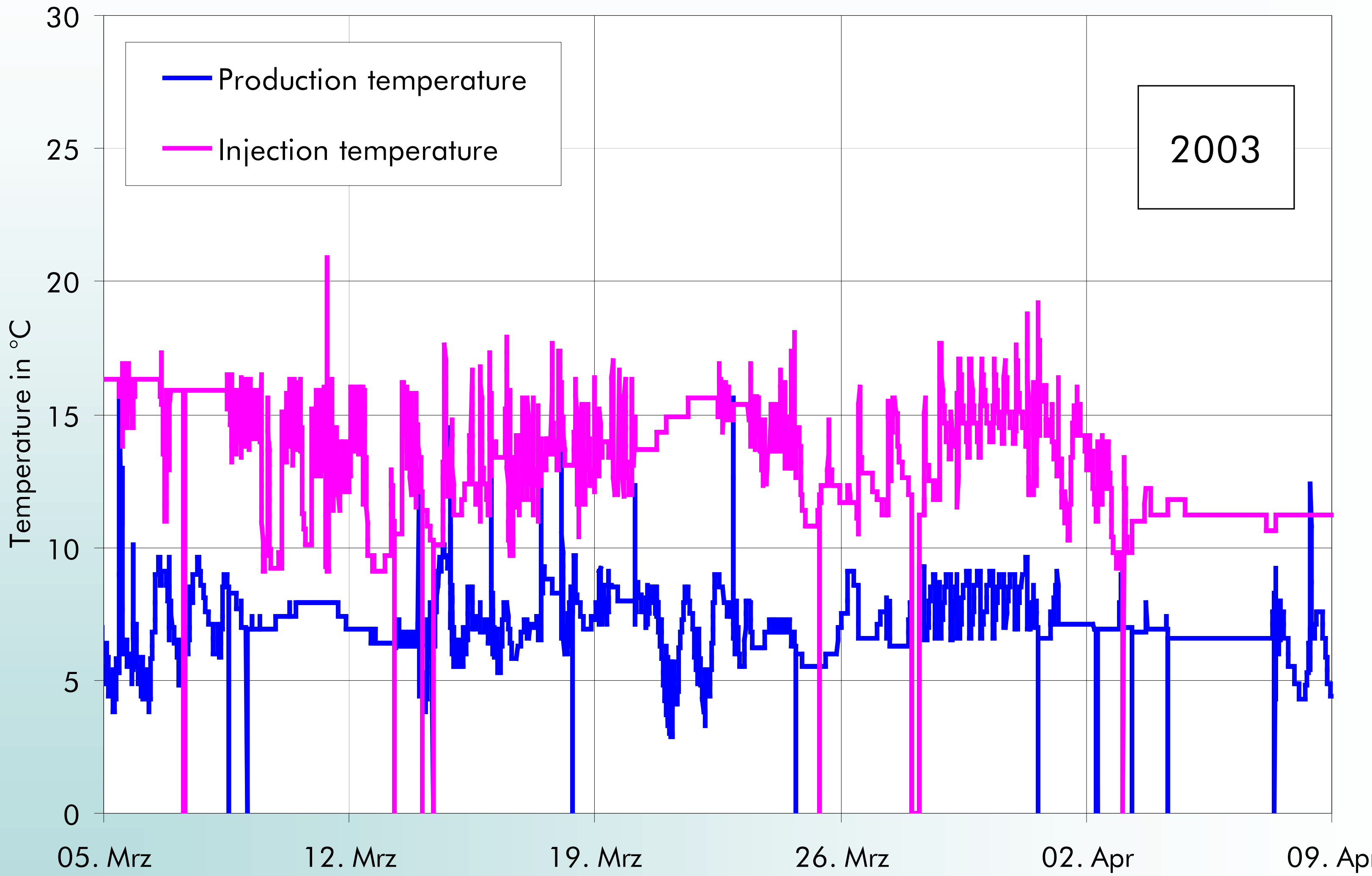
Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)



- Cold store
- Heat store

Siting of the wells

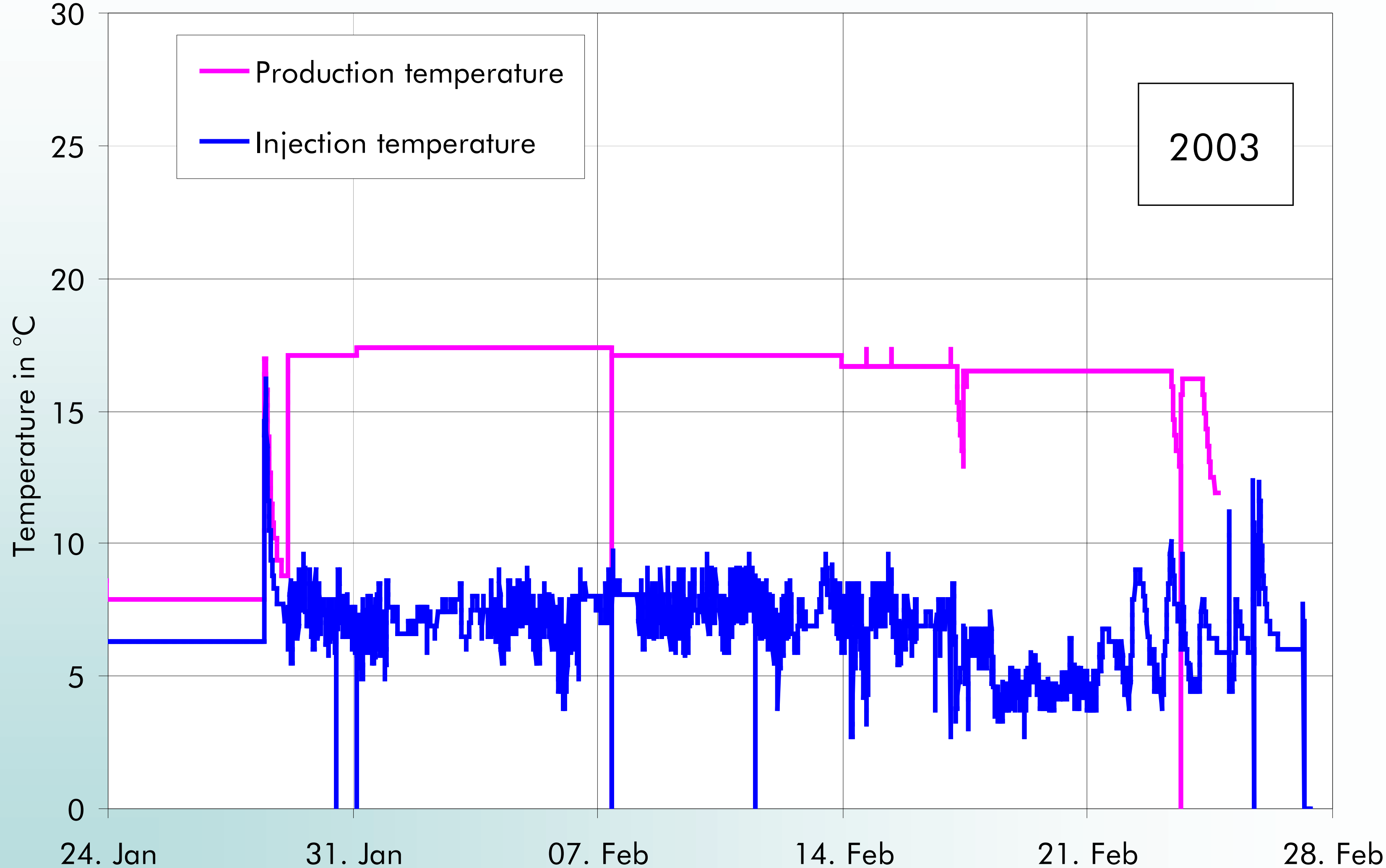
Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)



Cold store, doublet KS5/KS6 – parameters in cooling operation

GTN INGENIEURE & GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

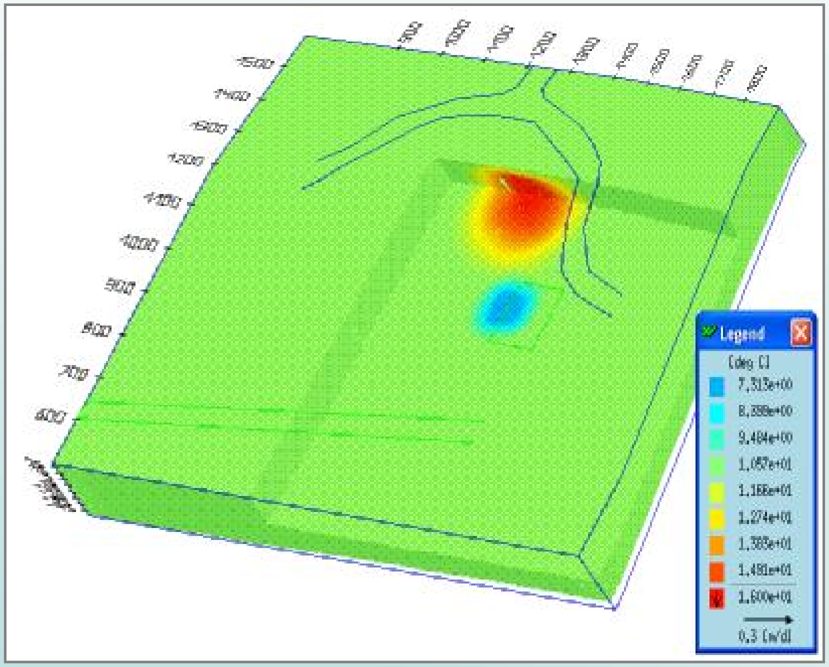


Cold store, doublet KS2/KS3 - parameters during regeneration

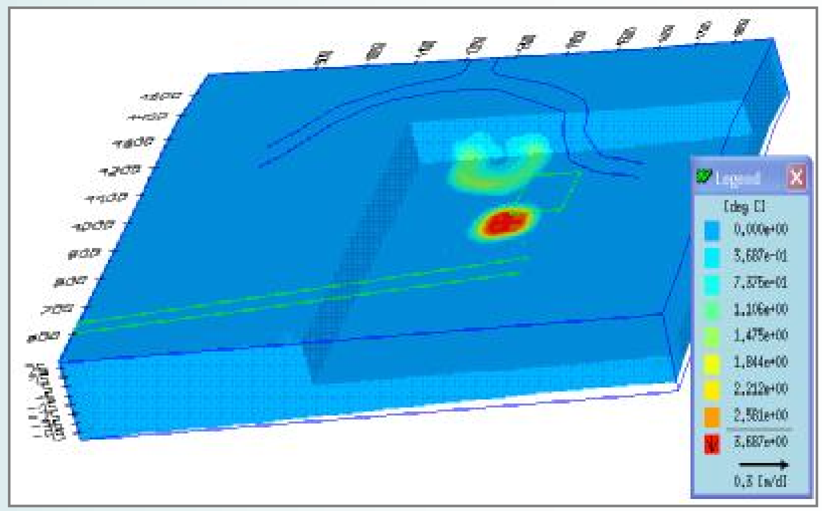
GTN INGENIEURE & GEOLOGEN

Numerical model of the heat store

Simulated temperature distribution, March 2003



Simulated cooling-down since March 2002



GTN INGENIEURE & GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

Cold store well head

Heat store well head

GTN INGENIEURE & GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

Surface loop of the cold store

Surface loop of the heat store

GTN INGENIEURE & GEOLOGEN

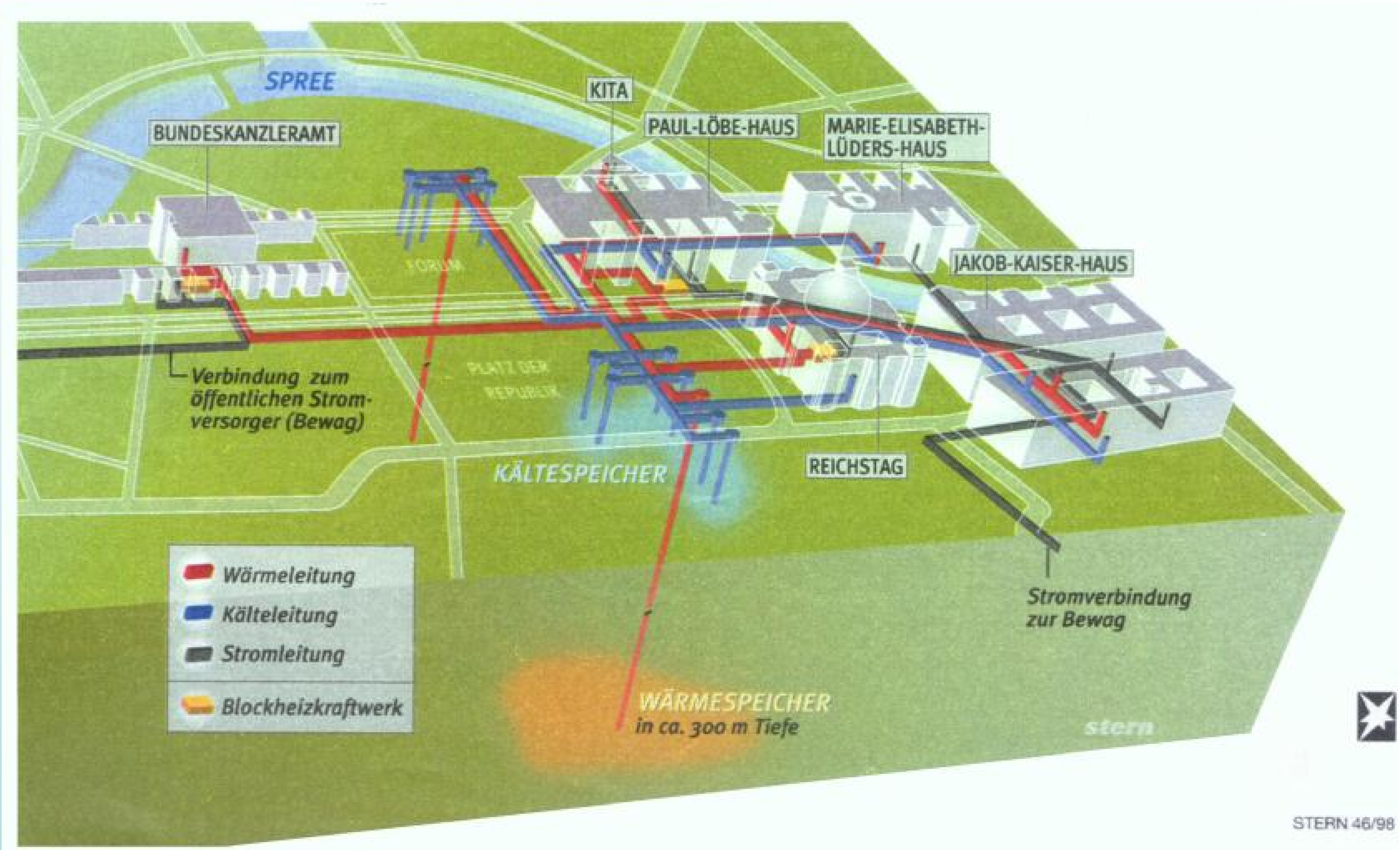
Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

Filter in the cold store loop

Heat exchanger in the cold store loop

GTN INGENIEURE & GEOLOGEN

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)



Arrangement of the technical units

Aquifer thermal energy stores in the Berlin Spree river curve (Parliament District)

GTN INGENIEURE & GEOLOGEN