(1) The VESTA research project
(2) HT-ATES in a deep carbonate aquifer

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Der Puls unserer Stadt

VESTA – Very-High Temperature Heat Aquifer Storage

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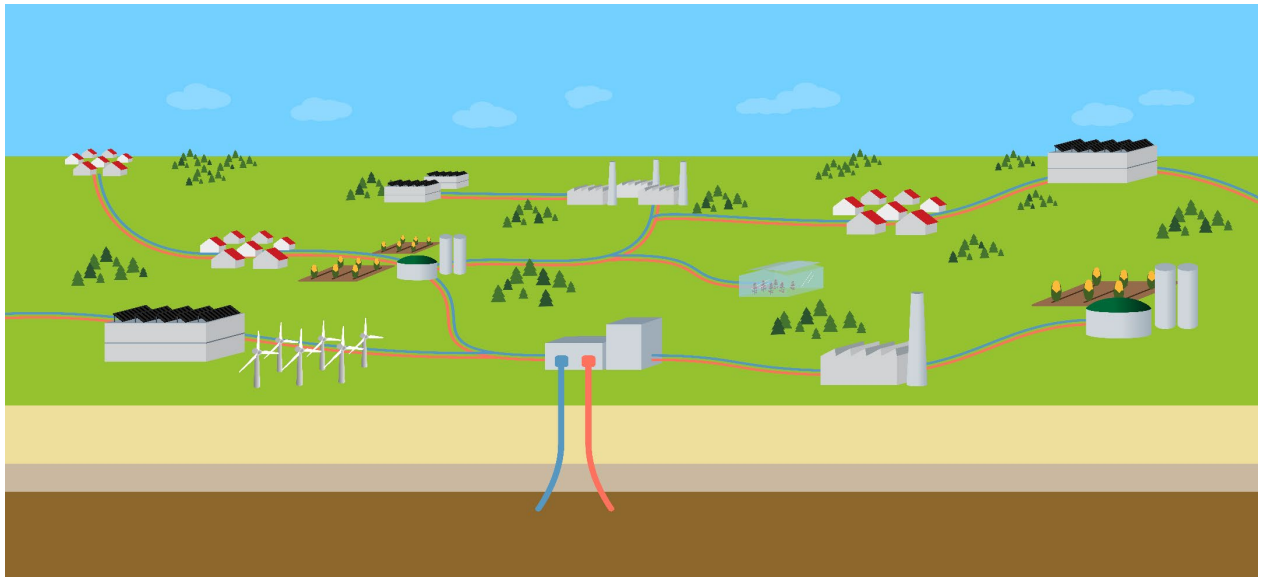
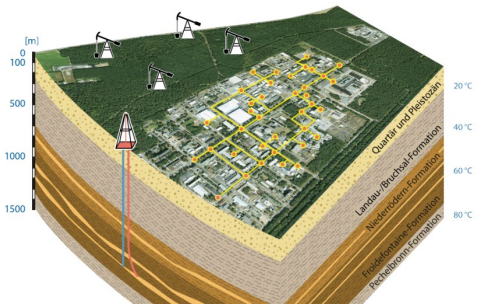
1: KIT; 2: ENBW; 3: GFZ; 4: IEG; 5: SWM; 6: GES; 7: INL; 8: LBNL

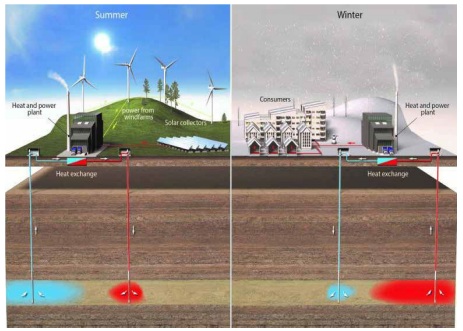


VESTA – Very-High Temperature Heat Aquifer Storage

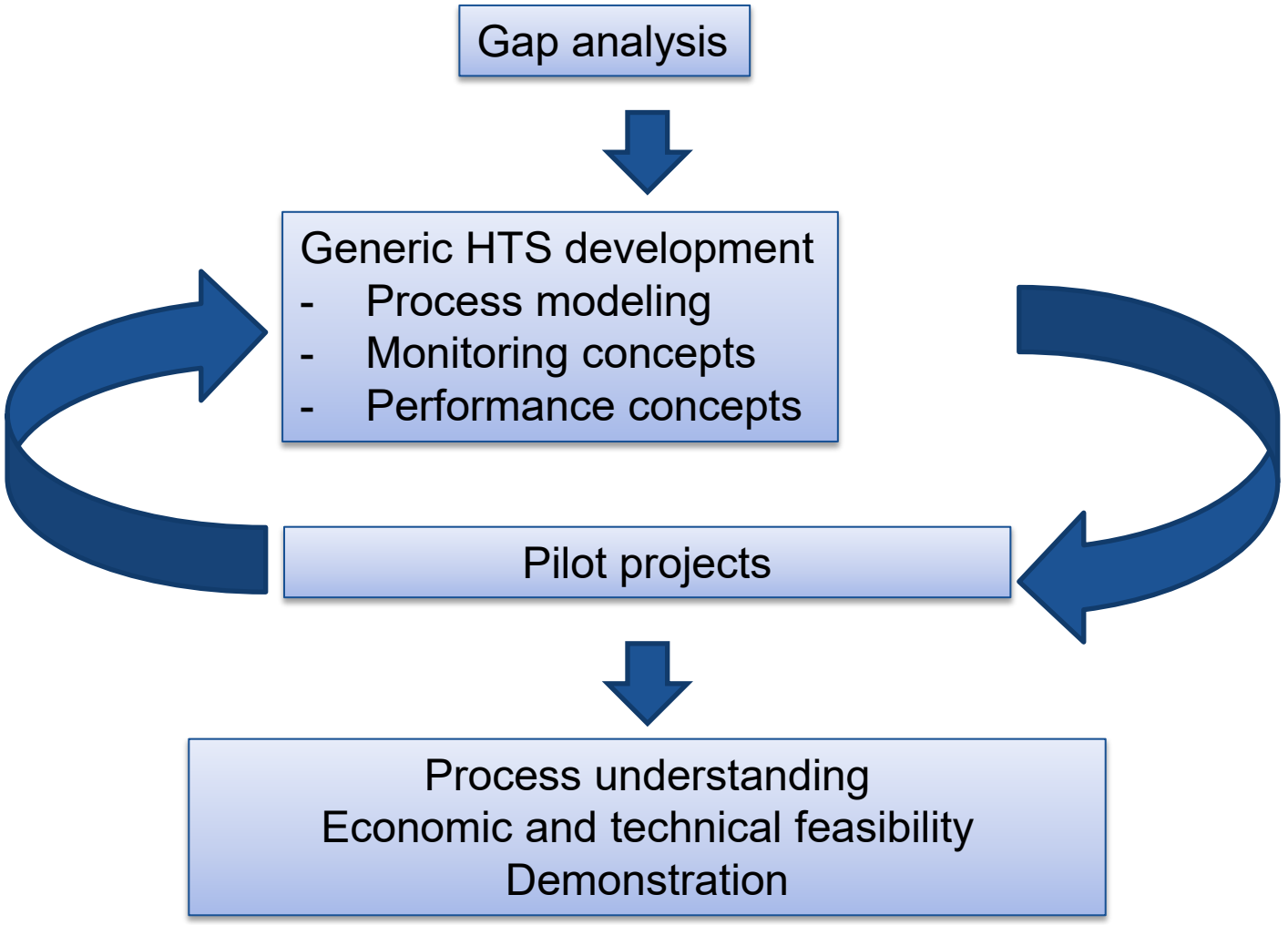
- **Focus:**
  - Scientific investigations on high-temperature underground storage (HTS)
  - Data from demonstration projects
- **Joint project by 8 partners**
  - Germany
    - Karlsruhe Institute of Technology (KIT) (Coordination)
    - GFZ German Research Centre for Geosciences
    - Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG
    - Stadtwerke München GmBH (SWM)
    - EnBW Energie Baden-Württemberg AG
  - Switzerland
    - Geo-Energie Suisse AG
  - USA
    - Lawrence Berkeley National Laboratory
    - Idaho National Laboratory

- Four pilot sites
  - DeepStor at KIT
  - Concept study Munich
  - Geospeicher Forsthaus Bern
  - Concept study Bochum





VESTA – Working structure

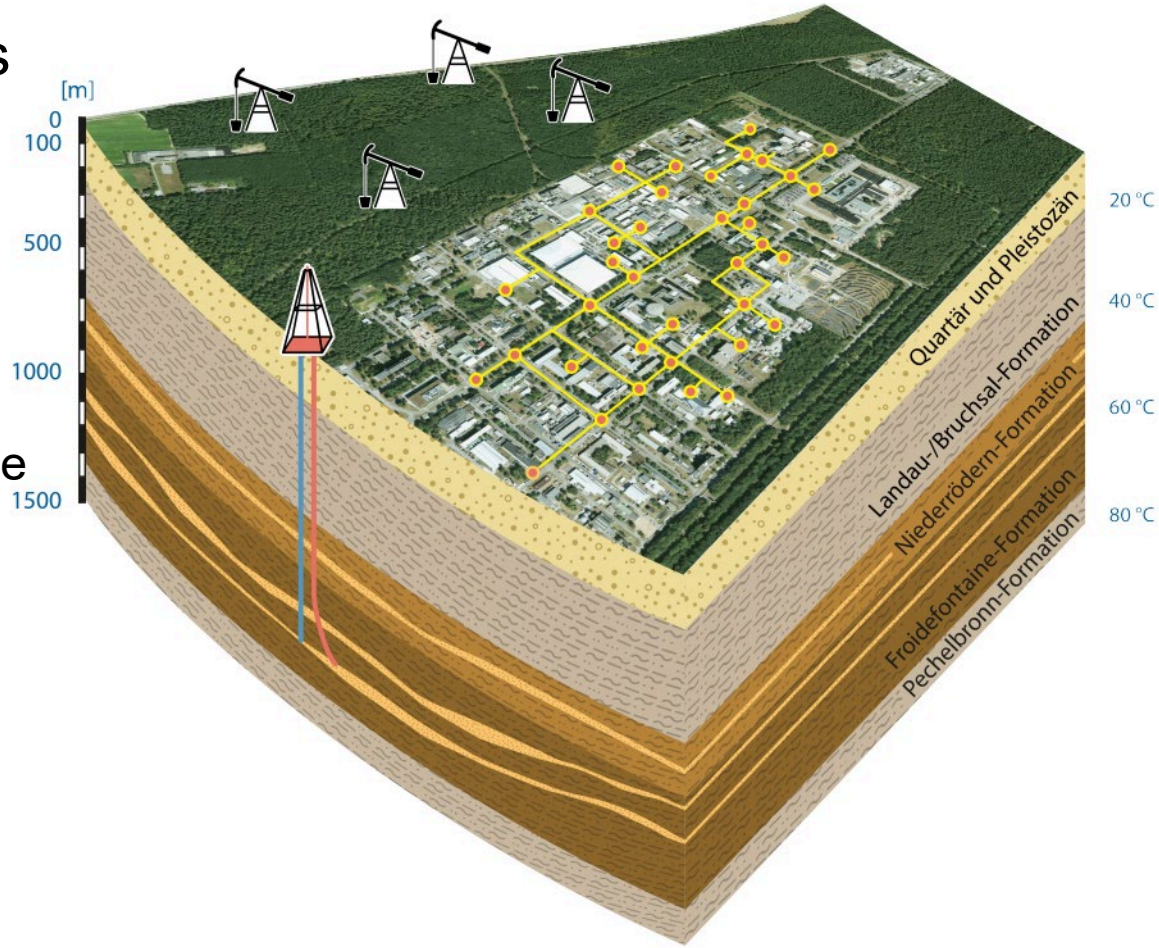


VESTA – Pilot sites
DeepStor

- Geothermal utilization of depleted oil reservoirs

  → Transition from hydrocarbon production to geothermal storage

- **Advantages**
  - High storage capacity of existing hydrocarbon wells in the Upper Rhine Graben *(Stricker et al. 2020)*
  - Well explored
  - Proven record of production
  - Huge potential worldwide
- **Research infrastructure DeepStor:**
  - Storage in water-bearing rim of depleted oil reservoir
  - Analogue model for urban setting
  - Risk sensitive approach due to highly sensitive infrastructure at Campus



HTS at KIT Campus North
location of former oil wells and existing district heating network

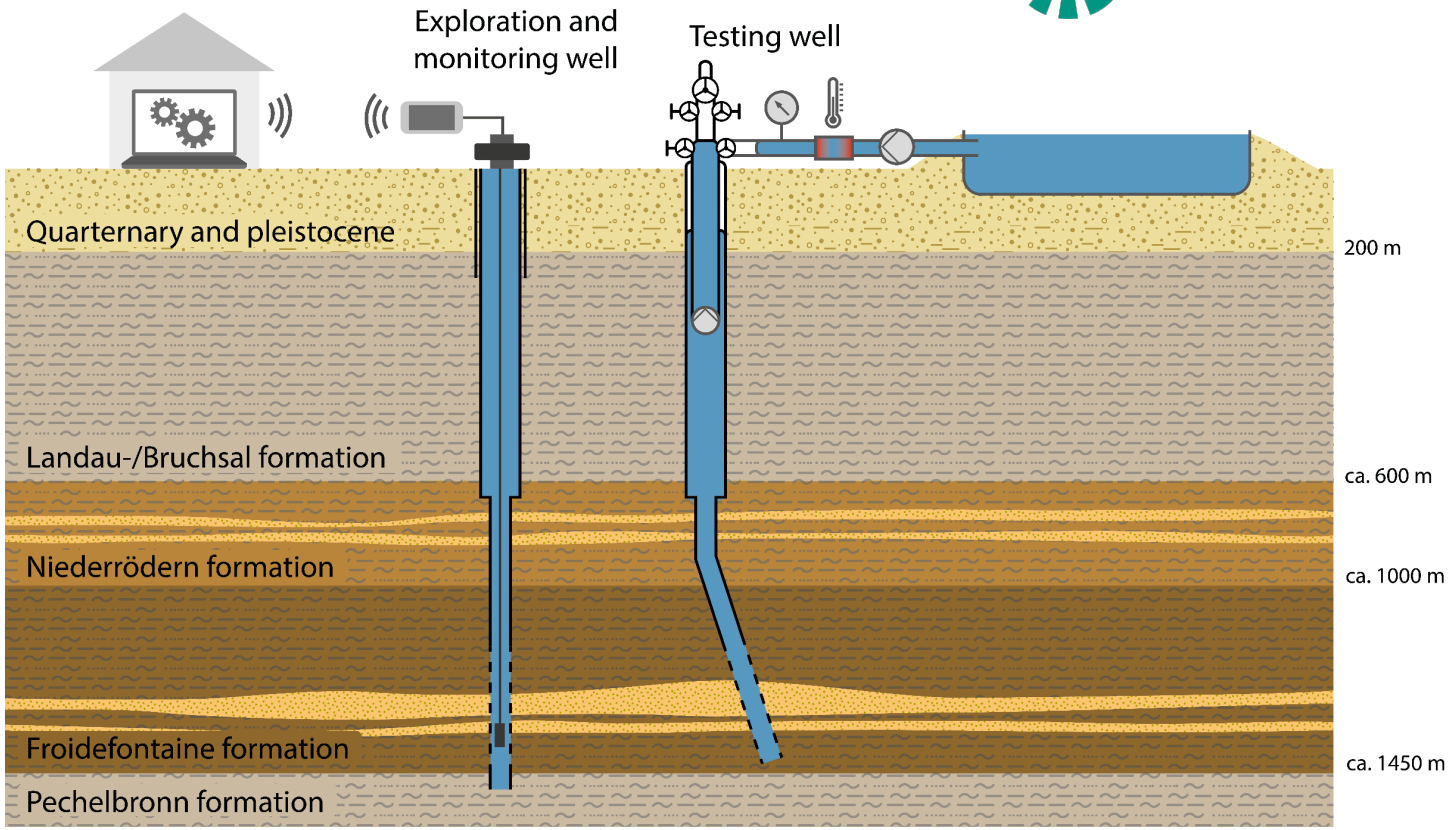
VESTA – Pilot sites
DeepStor

VESTA

- DeepStor-1:
  - Exploration (coring, logging, testing)
  - Monitoring (isolation of 3 zones, P/T/seismic sensors, fluid sampling)
- DeepStor-2:
  - Production tests (pump 1)
  - Injection tests (pump 2)
- Separation and reinjection of hydrocarbons
- Basin
  - Storage volume of 4'000 m^3
- Heat exchanger plus mobile heating

- Helmholtz Side Projects

Kadi 4Geo

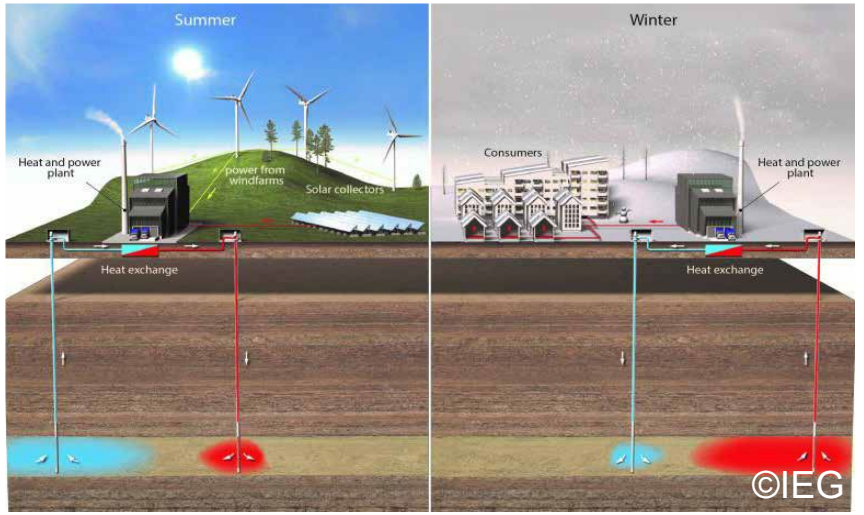


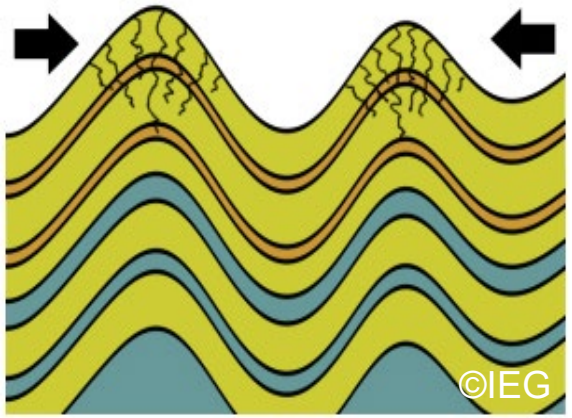
SWM

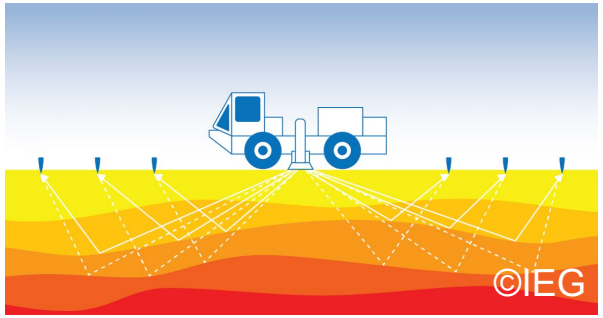
VESTA – Pilot sites
CONTRAST / IEG

- **CONTRAST – C**arb**ON**iferous Tempe**RA**ture **St**orage

- **Aims:**
  - Deep geophysical exploration for basic understanding of
    - geological situation / tectonic stress field
    - required borehole design
    - hydraulic regime
  - Investigation of Carboniferous sandstone units Kaisbergformation, Namur B
    - Depth 1'200 – 1'500 TVD
    - folding/ jointing expected
  - **2D Seismic Survey in 2023**
  - Calibration of IEG subsurface model
  - Well planing







VESTA – Pilot sites
Forsthaus Bern

- Pilot Project Geostorage Forsthaus Bern (BE)
  - Geostorage for seasonal heat storage as part of the urban district heating supply system
- Aims within VESTA cooperation:
  - Development of a general storage concept with VESTA partners
  - Logging with borehole simulations

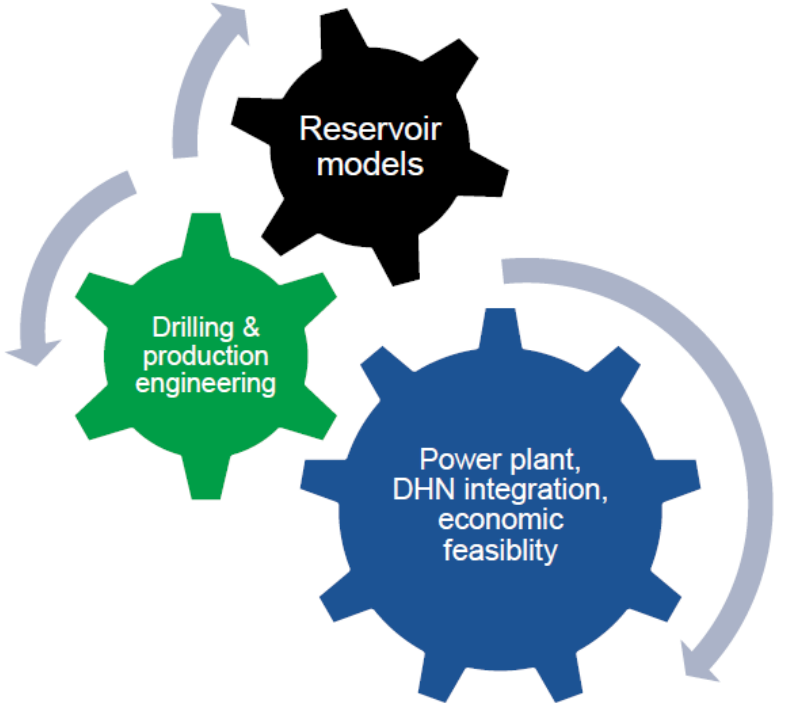
see presentation by Peter Maier

The "Geospeicher Forsthaus" is being built on the site of the Forsthaus energy center.

Drilling site in March 2022

VESTA – Pilot sites
Stadtwerke München

- **Overarching goal:**
  - Heat supply for the city of Munich 100% CO_2-neutral in 2040
  - High-temperature heat storage to secure supply in periods with high heat demand
- **Goal of VESTA Concept study:**
  - Requirements of a high-temperature storage at a site
  - Hydraulic-thermal, hydrochemical and geomechanical conditions
  - Reliable monitoring methods
  - Logging with borehole simulations
  - Heat management
  - Regulatory frameworks



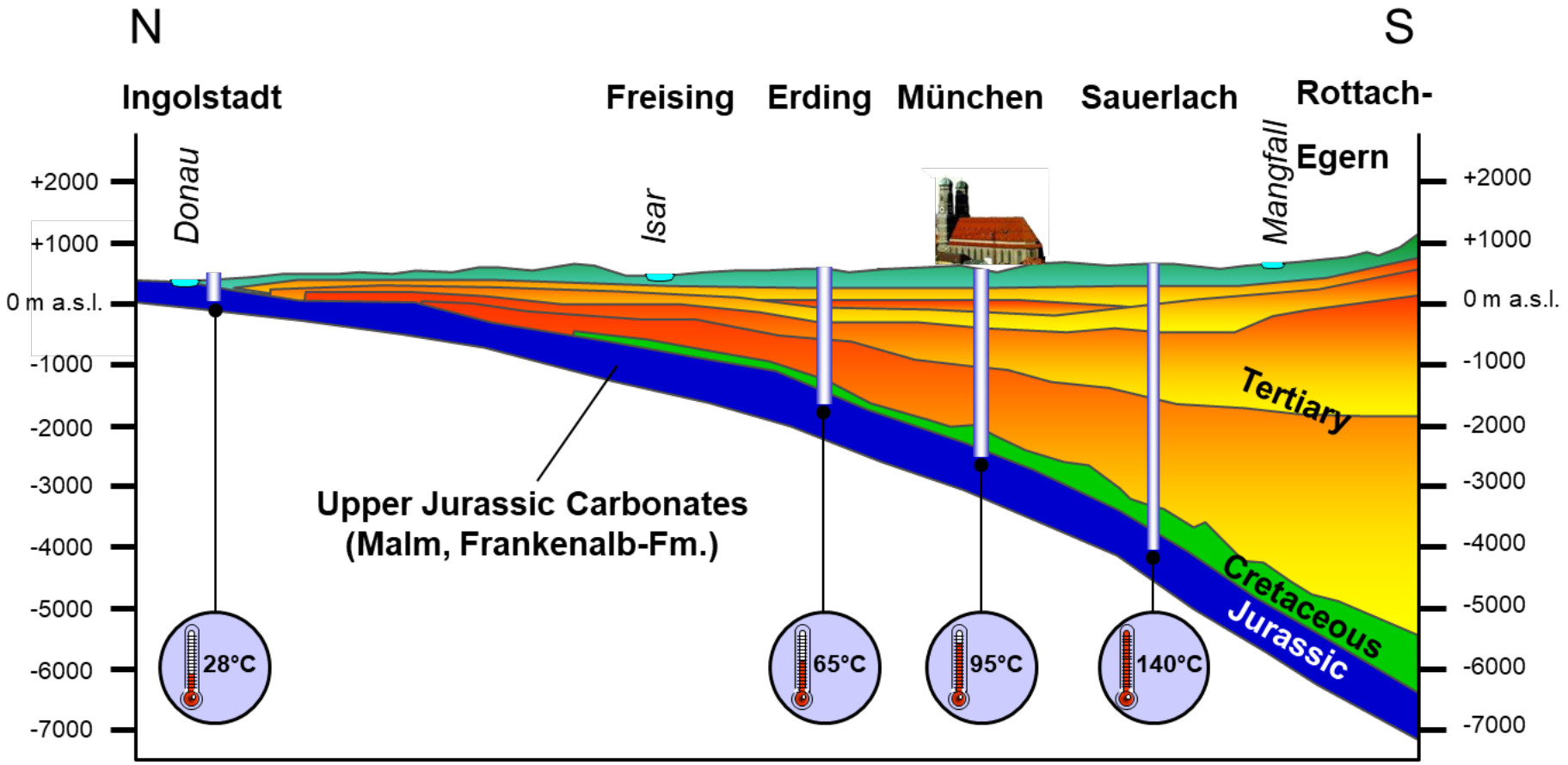
Holistic approach by SWM

Renewable heat generation: Germany's largest geothermal plant

ATES in Munich

1	Strategic overview
2	Heat source availability
3	Technichal challenges
4	Economic modelling

Geology


N
S
Ingolstadt
Freising
Erding
München
Sauerlach
Rottach-
Egern
Donau
Isar
Mangfall
+2000
+1000
0 m a.s.l.
-1000
-2000
-3000
-4000
-5000
-6000
-7000
Tertiary
Cretaceous
Jurassic
Upper Jurassic Carbonates
(Malm, Frankenalb-Fm.)
28°C
65°C
95°C
140°C

SWM's deep geothermal development strategy

Today
- 8 „Doublets“
- ~ 80 MW_{th} / 15 MW_{el}
- ~ 550 GWh_{th} / year

1 **Riem** 2004

1 **Sauerlach** 2013

1 **Freiham** 2016

1 1 **Dürrnhaar Kirchstockach** Aquisition in 2017

3 **HKW Süd** In test operation

Expansion Kirch-stockach

3/4 **Michaelibad**

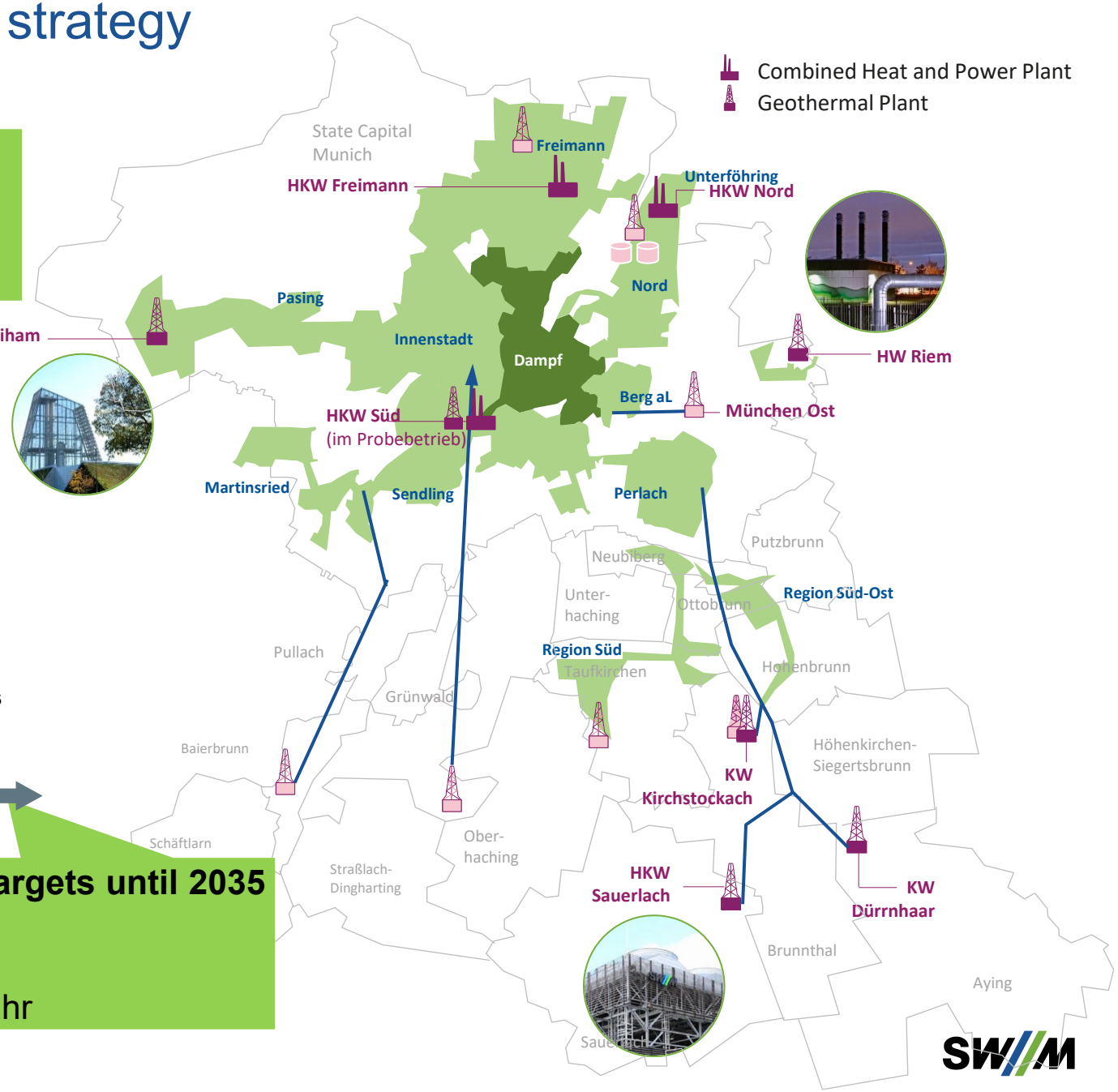
3-7 **Cooperation County**

mind. 3 Connection to **Dürrnhaar, Kirchstockach & Sauerlach**

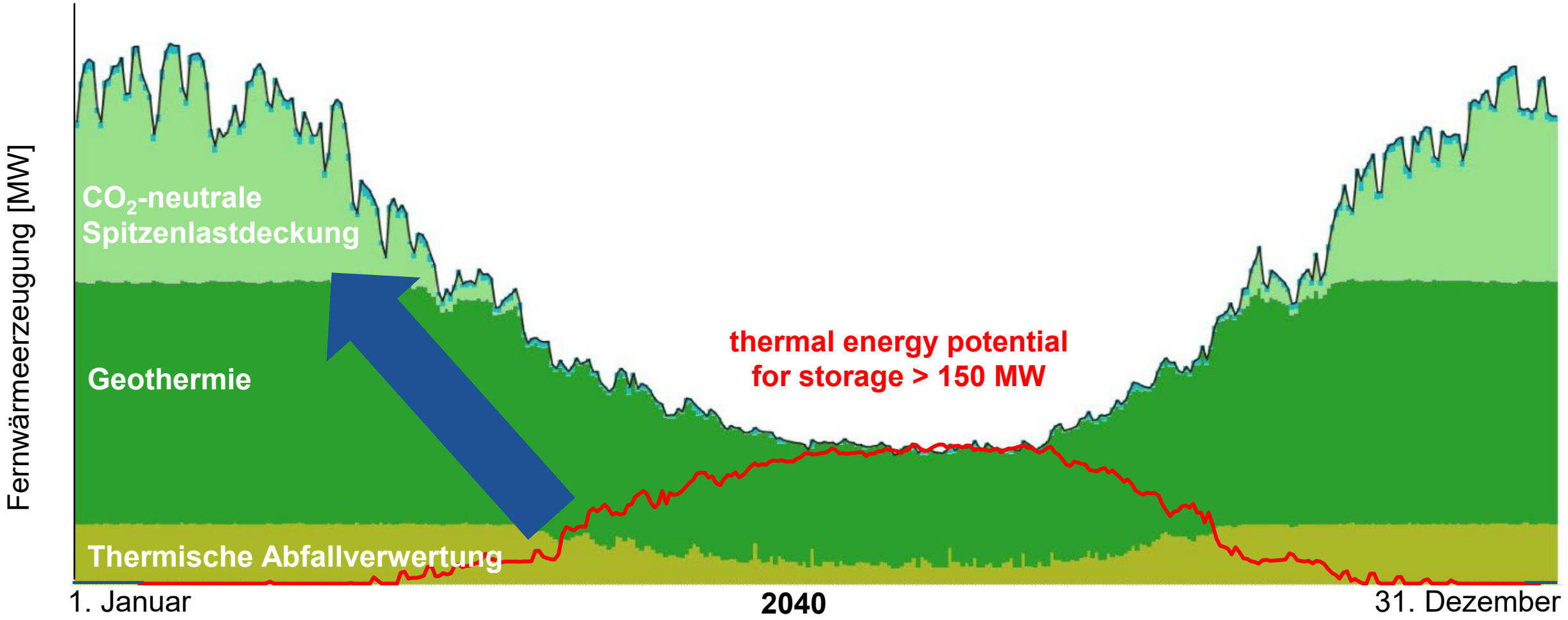
Further Options being explored

Current minimum Targets until 2035
- ~ 17 „Doublets“
- ~ 375 MW_{th}
- ~ 2.500 GWh_{th} / Jahr

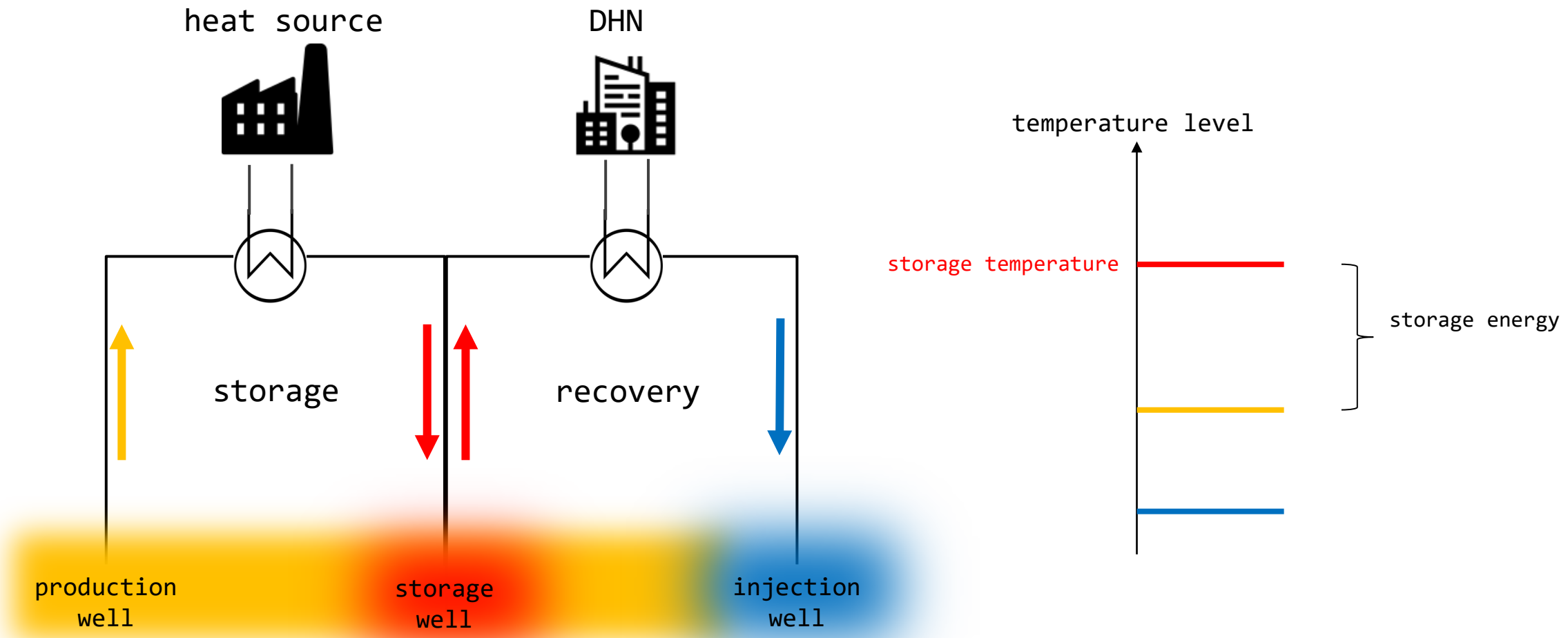
1 Number of „Doublets“



Seasonal heat storage



ATES configuration (triplet)

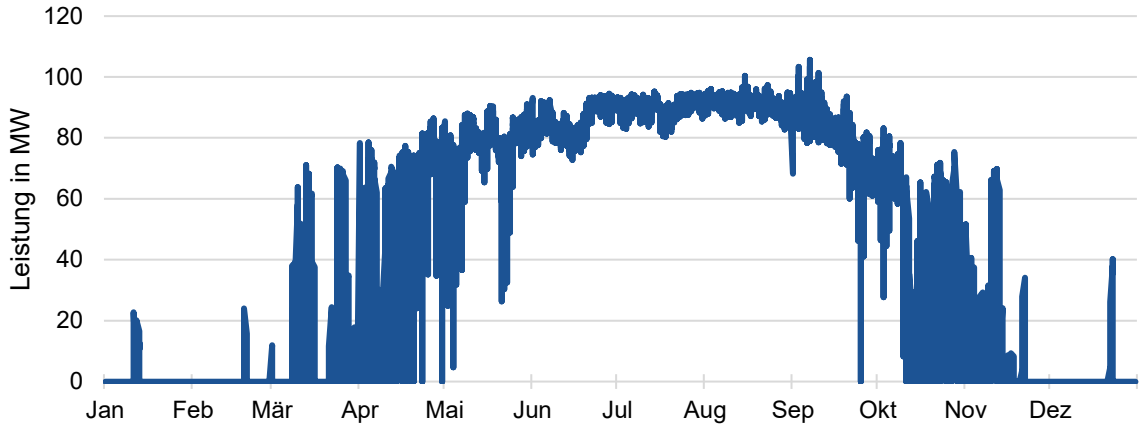


Topics

1	Strategic overview
2	Heat source availability
3	Technichal challenges
4	Economic modelling

Thermal storage potential: Example target Area 1 – ATES North-East

- CO2-neutral & low-cost storage potential
  = residual load Block 1/3 (Waste-to-Energy)
- **Heat source**: steam at approx. 4 bar (= 144°C)
- **Storage potential**: ca. 60 - 80 MW over ca. 5 months



Topics

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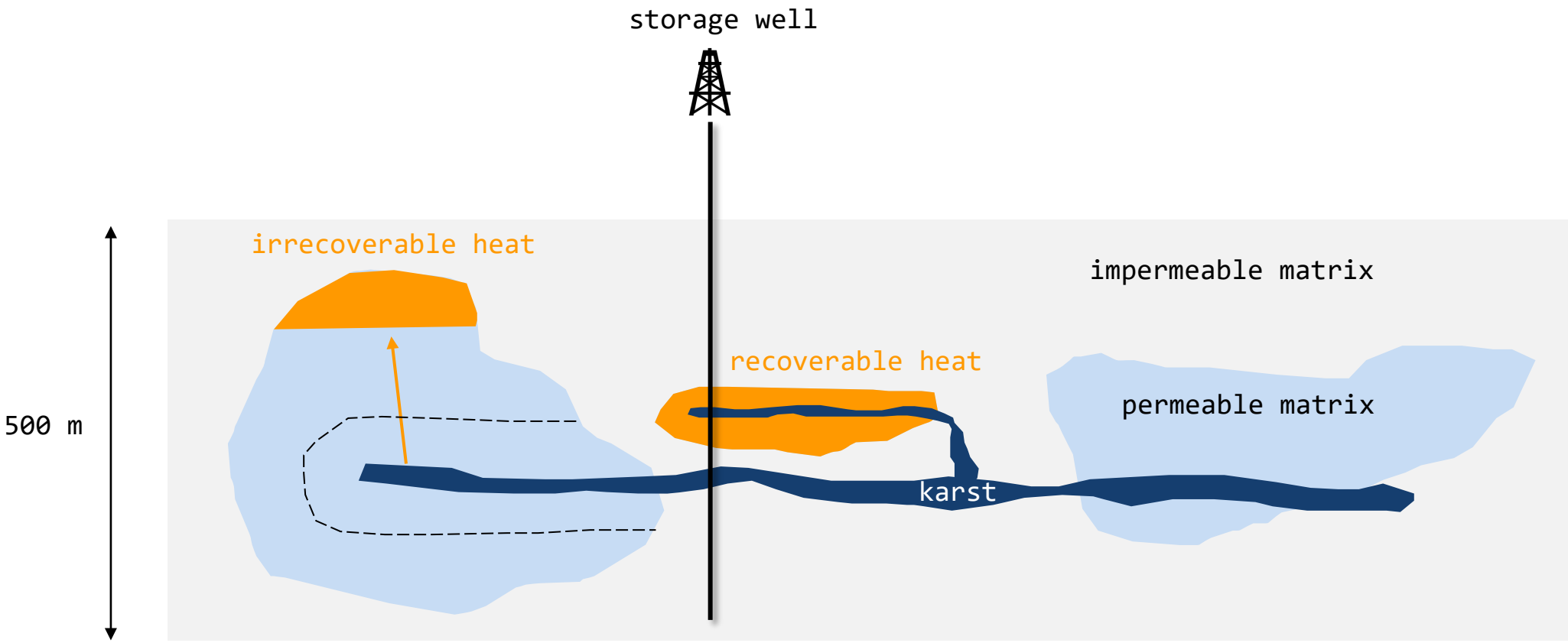
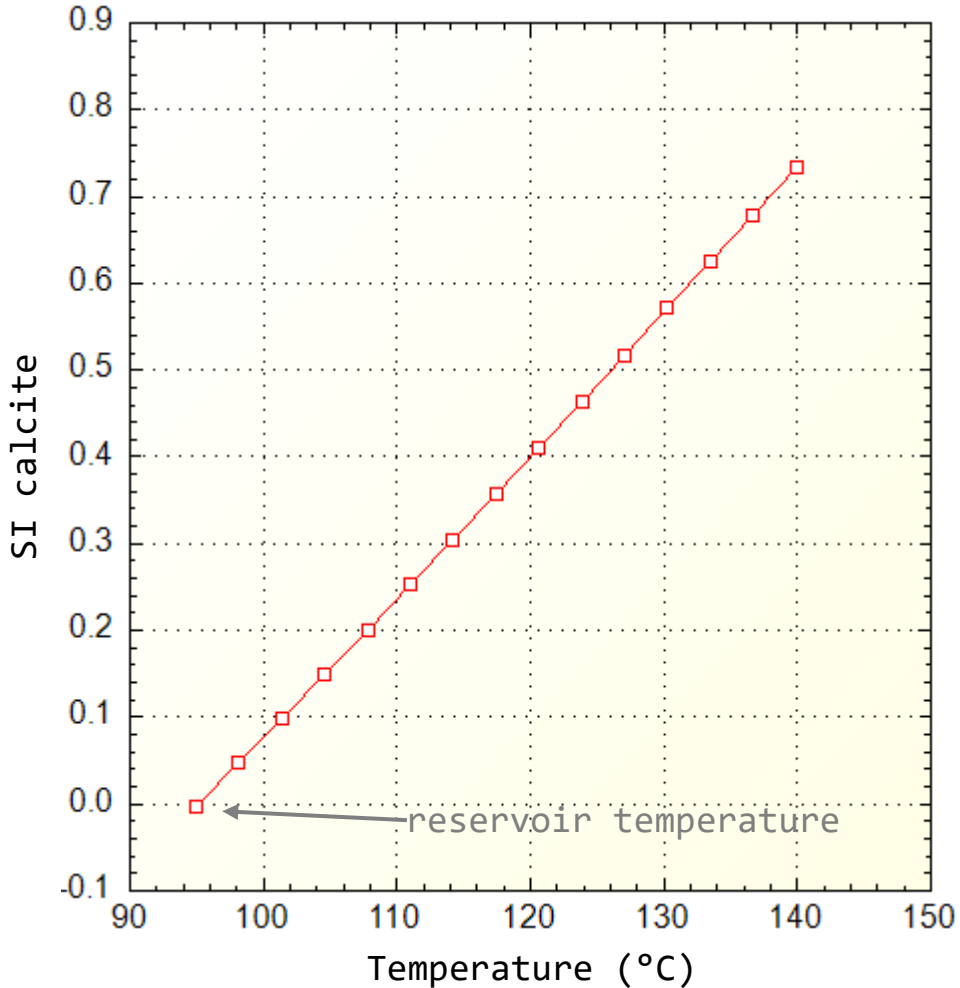
Reservoir heterogeneity & heat recovery



Scaling and Corrosion

- Successful testing of 2 different inhibition methods
  - CO2
  - Threshold inhibitor (polymere)

- Currently no corrosion issues
- Potential addition of CO2 poses corrosion risk due to high supersaturation



Topics

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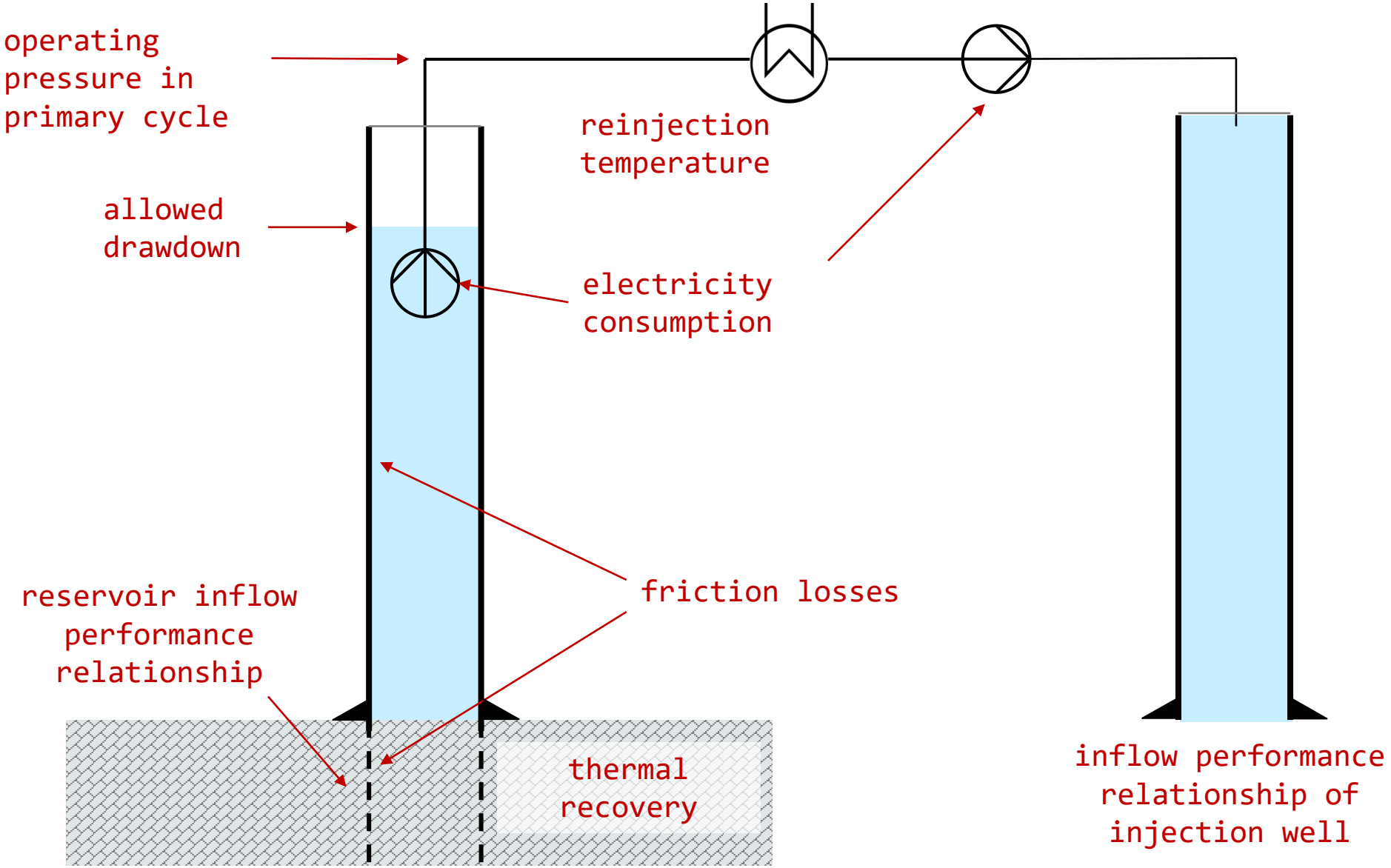
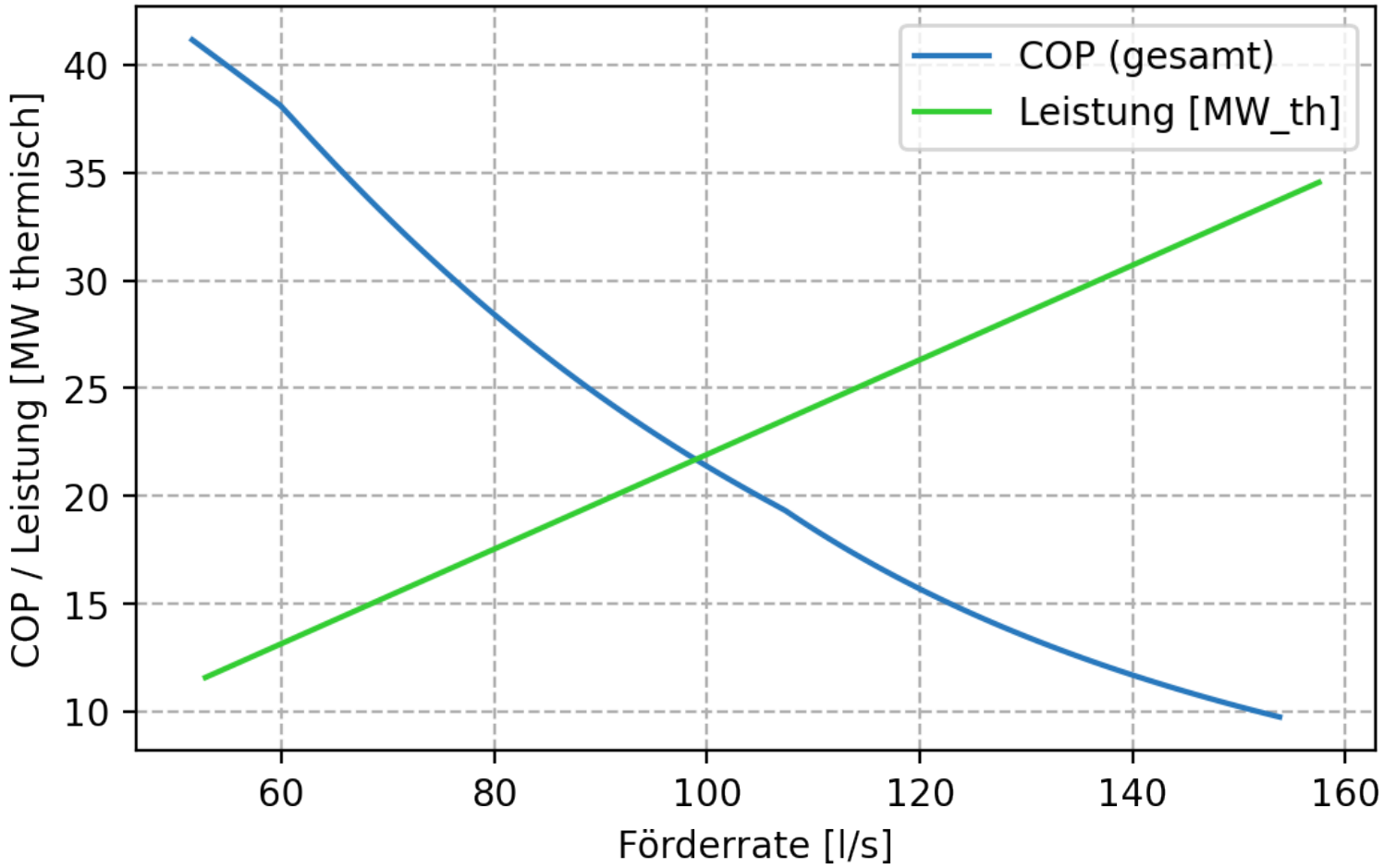
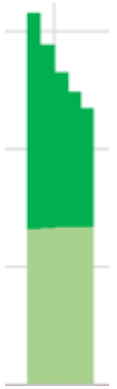
Digital twin of the geothermal production system



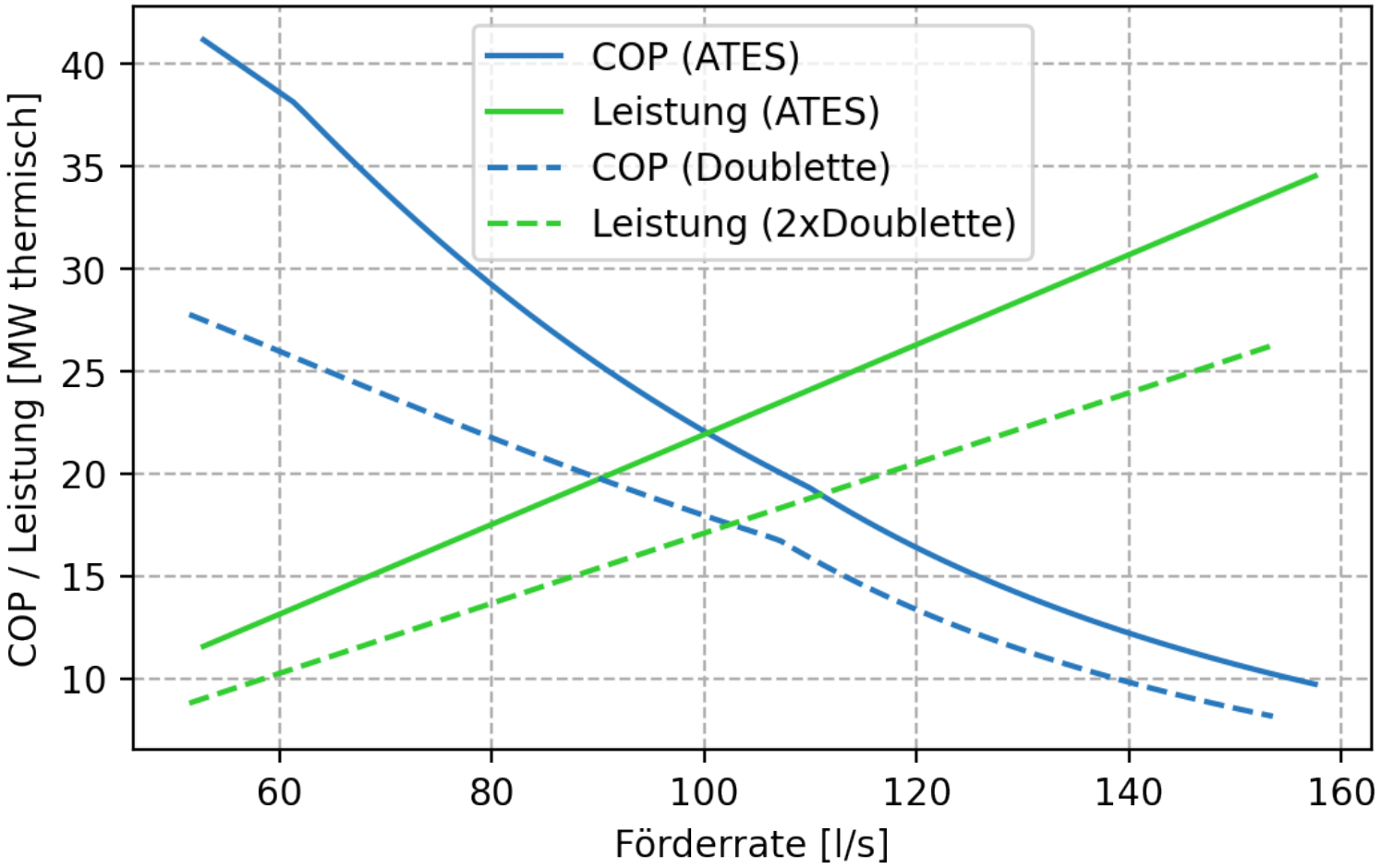
ATES (recovery & storage)

$$COP_{tot} = \frac{E_{th}}{(E_{TKP} + E_{IP})_{rec} + (E_{TKP} + E_{IP})_{store}}$$

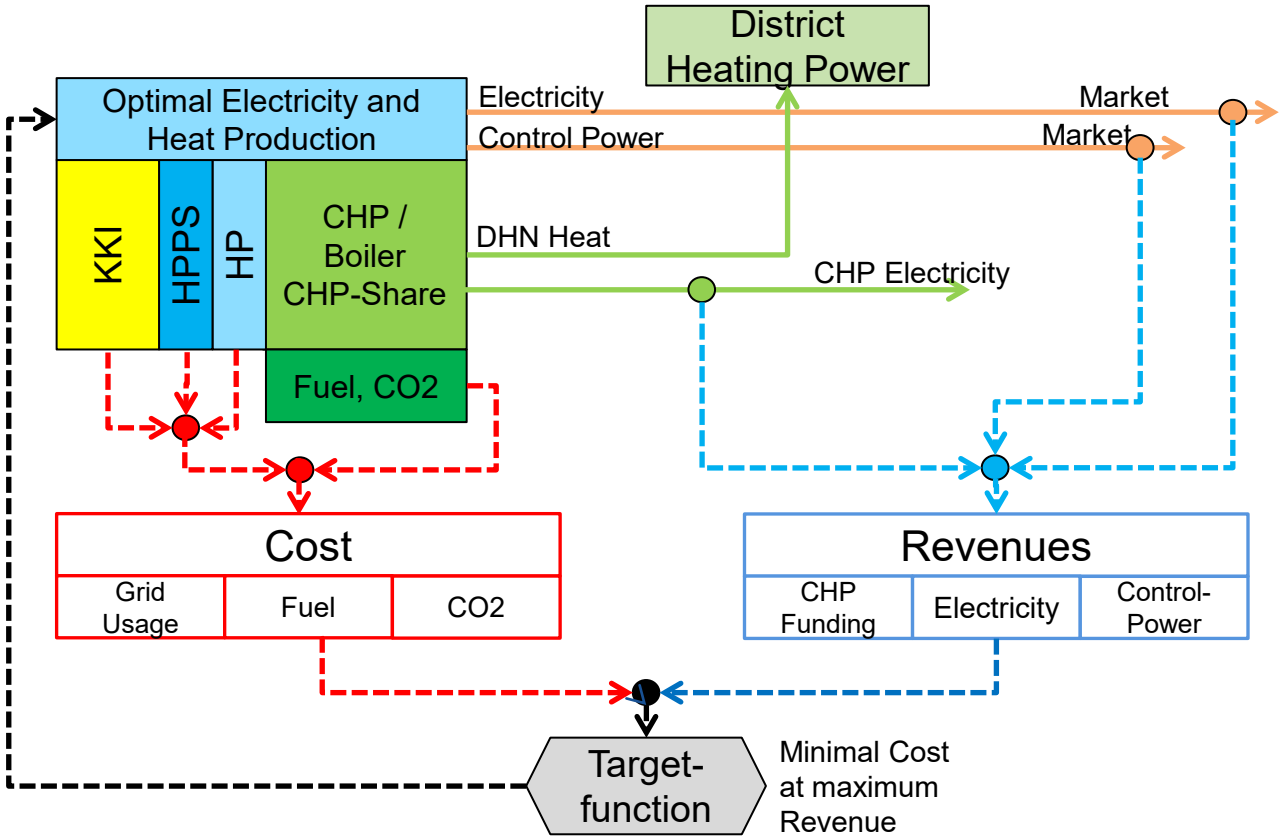




Comparison ATES with 2 conventional geothermal doublets



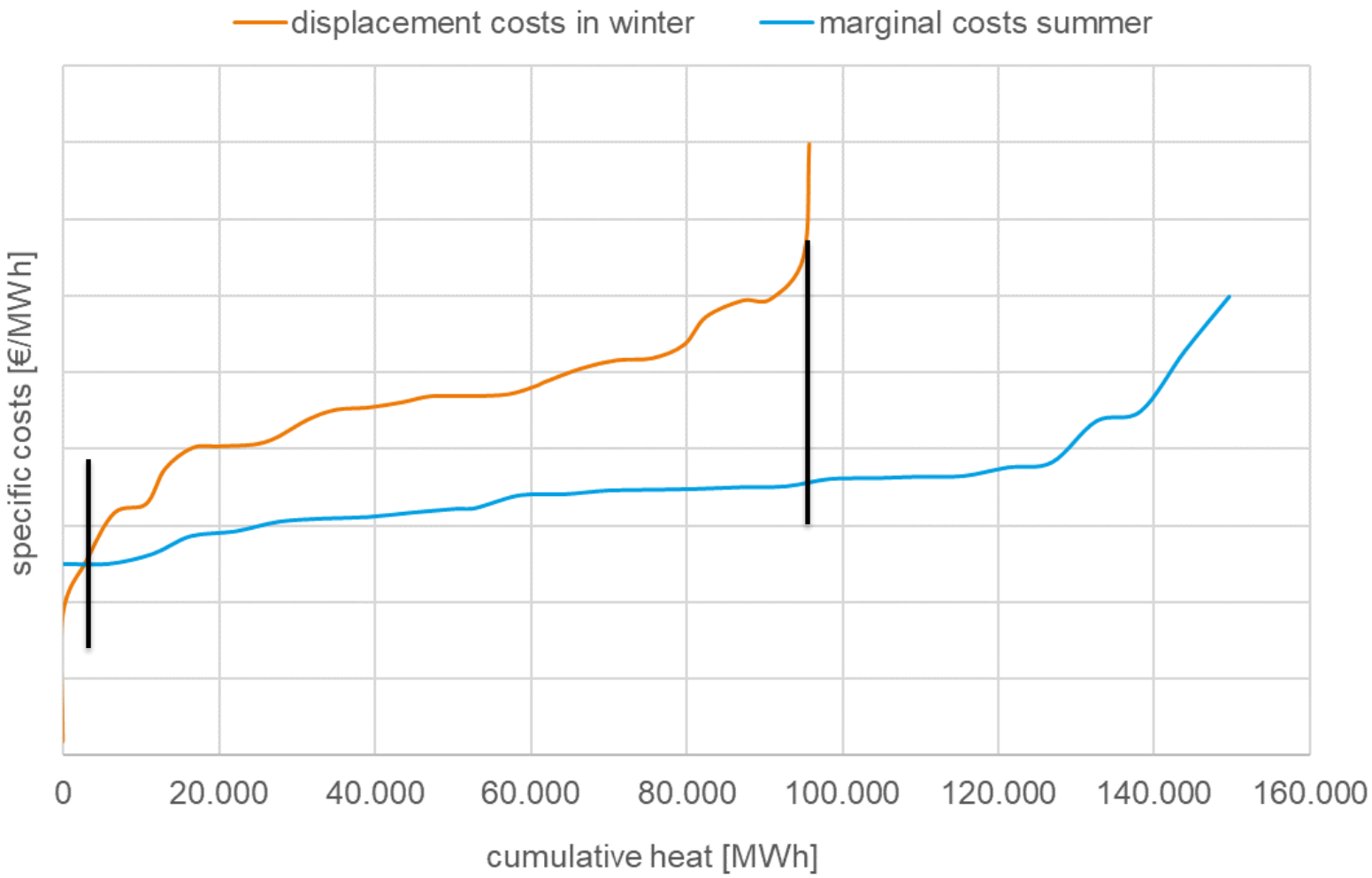
Modeling & Simulation of ATES in future SWM power plant portfolio using BoFiT



Longterm Simulations (time horizon: 2025 … 2050)

- Evolution of SWM plant fleet (incl. new plants, decommissioning, refurbishing...)
- Strategic considerations (commodity prices, CO2 price etc.)
- Long-term supply concept

Arbitrage in seasonal heat price

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