Der Beitrag geothermischer Systeme zur klimaneutralen Deckung des Energiebedarfs im globalen Kontext

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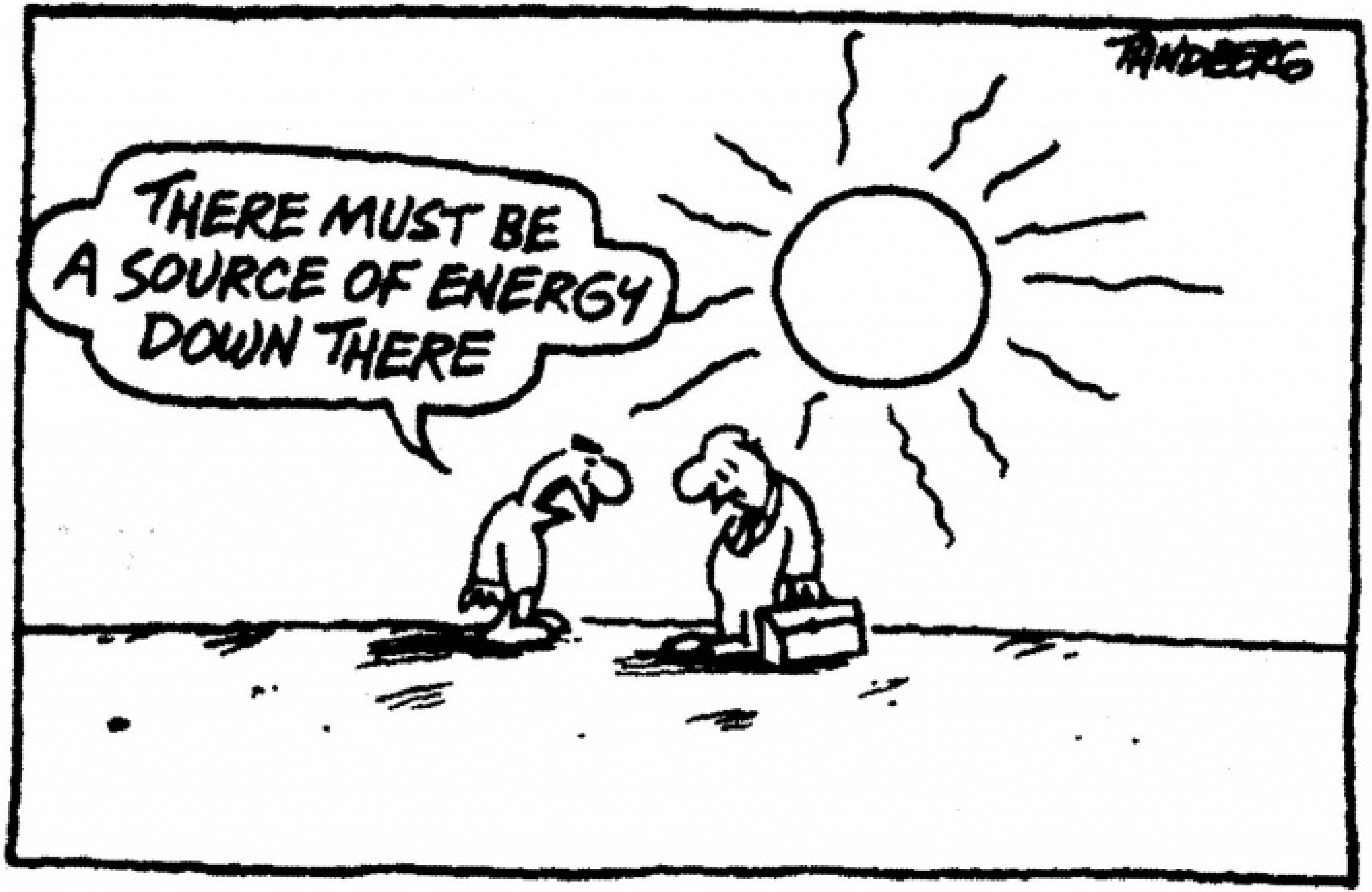

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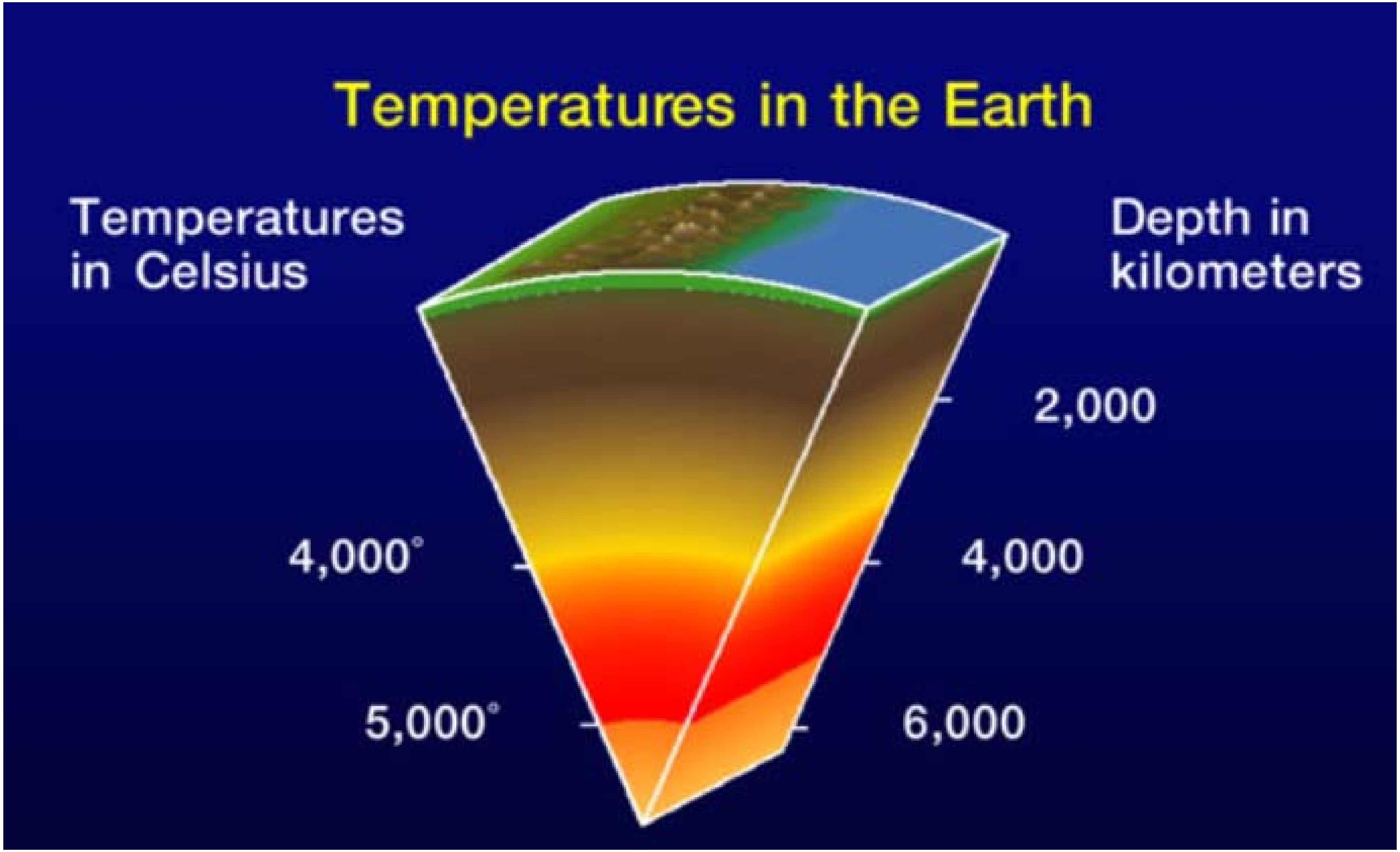
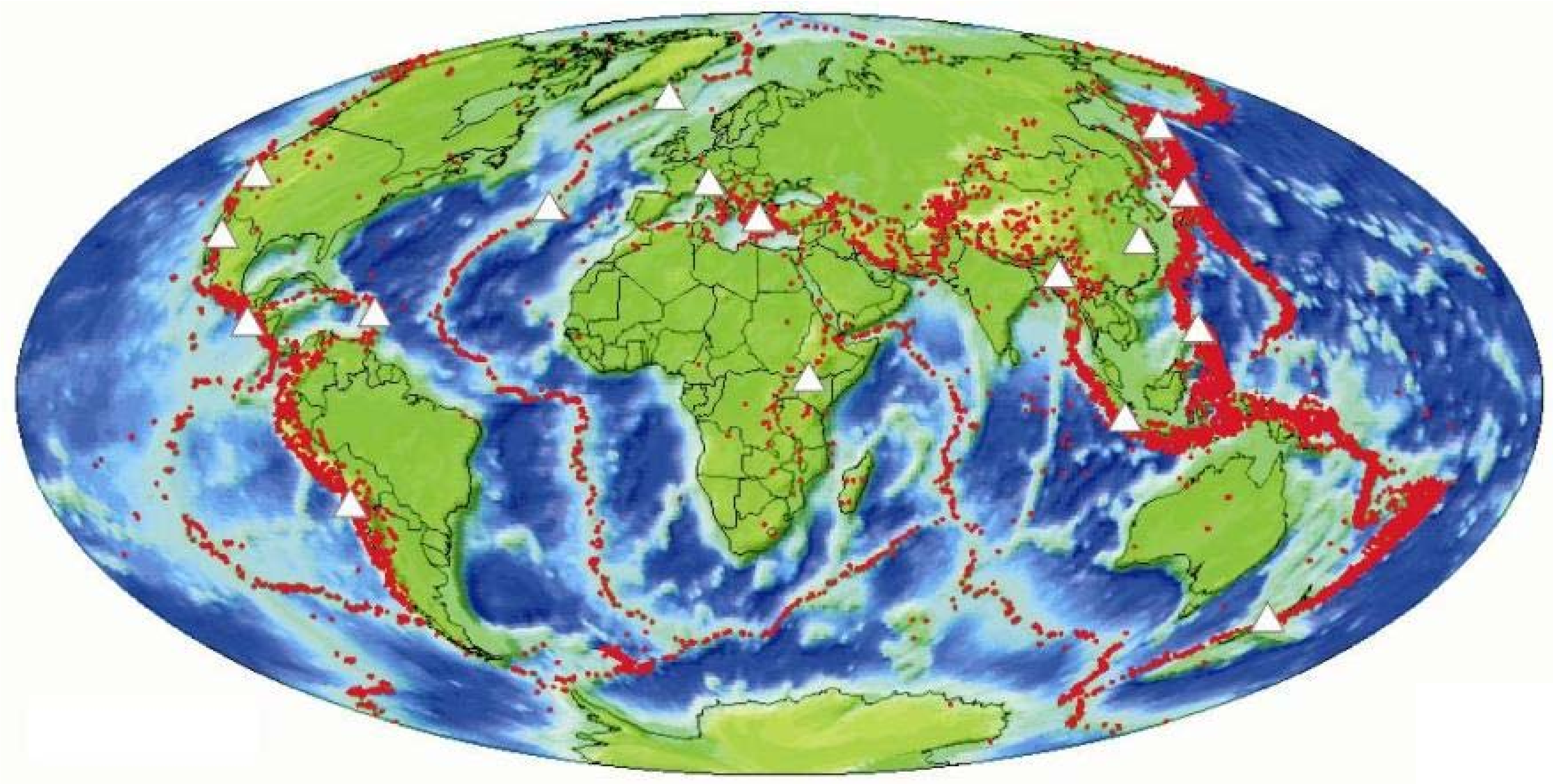


Geothermal Education Office

Locations of conventional geothermal power

The ring of fire – areas of geological plate boundaries, increased volcanic and earthquake activity



Geothermal Power stations (white triangles)

Locations of intense seismic activity (red)

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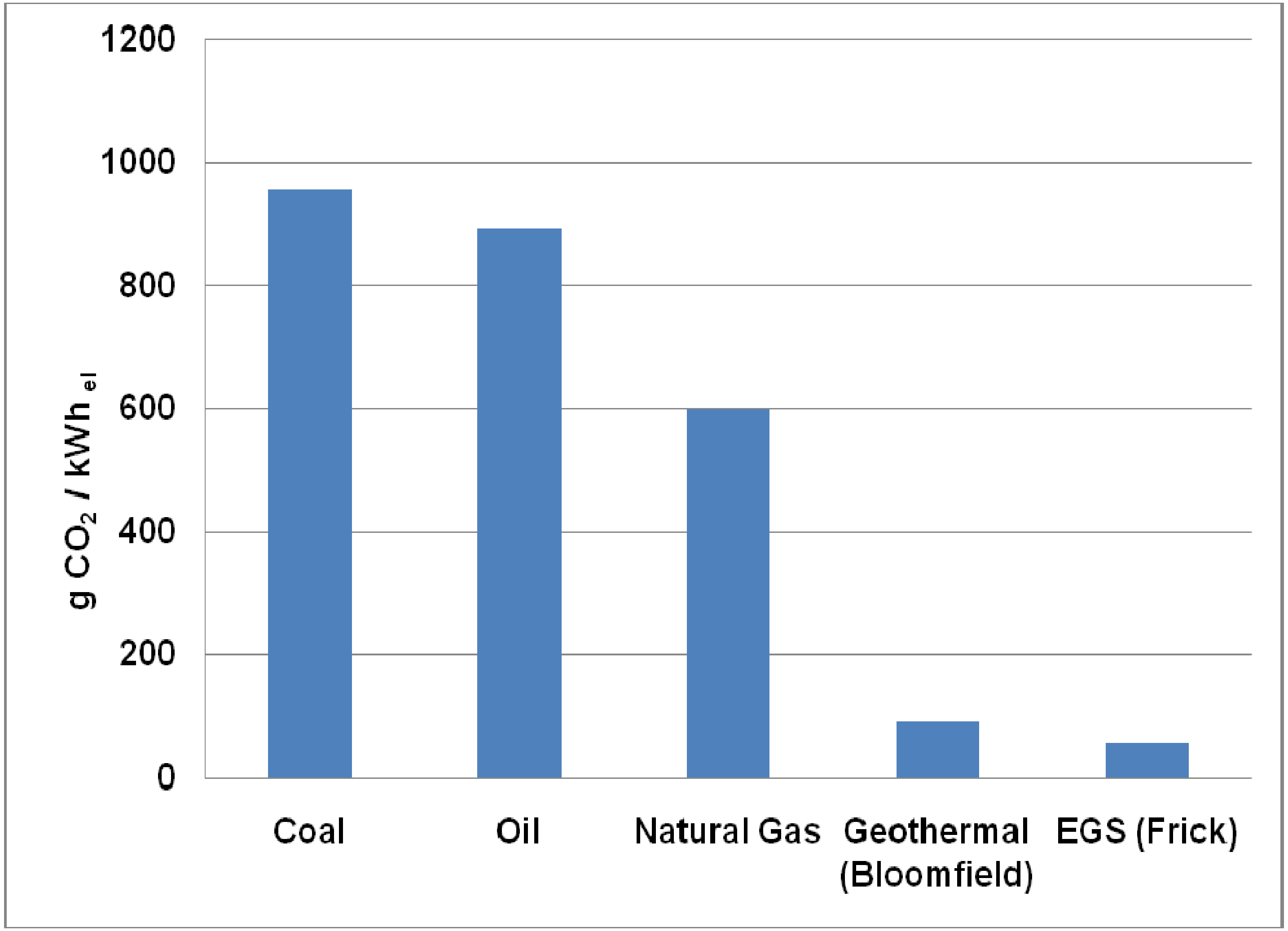
CO2 footprint



Geothermal: plants in USA -open cycles
Coal, oil, gas: DOE, Bloomfield et al. (2003)

EGS-LCA
Frick et al. (2010)

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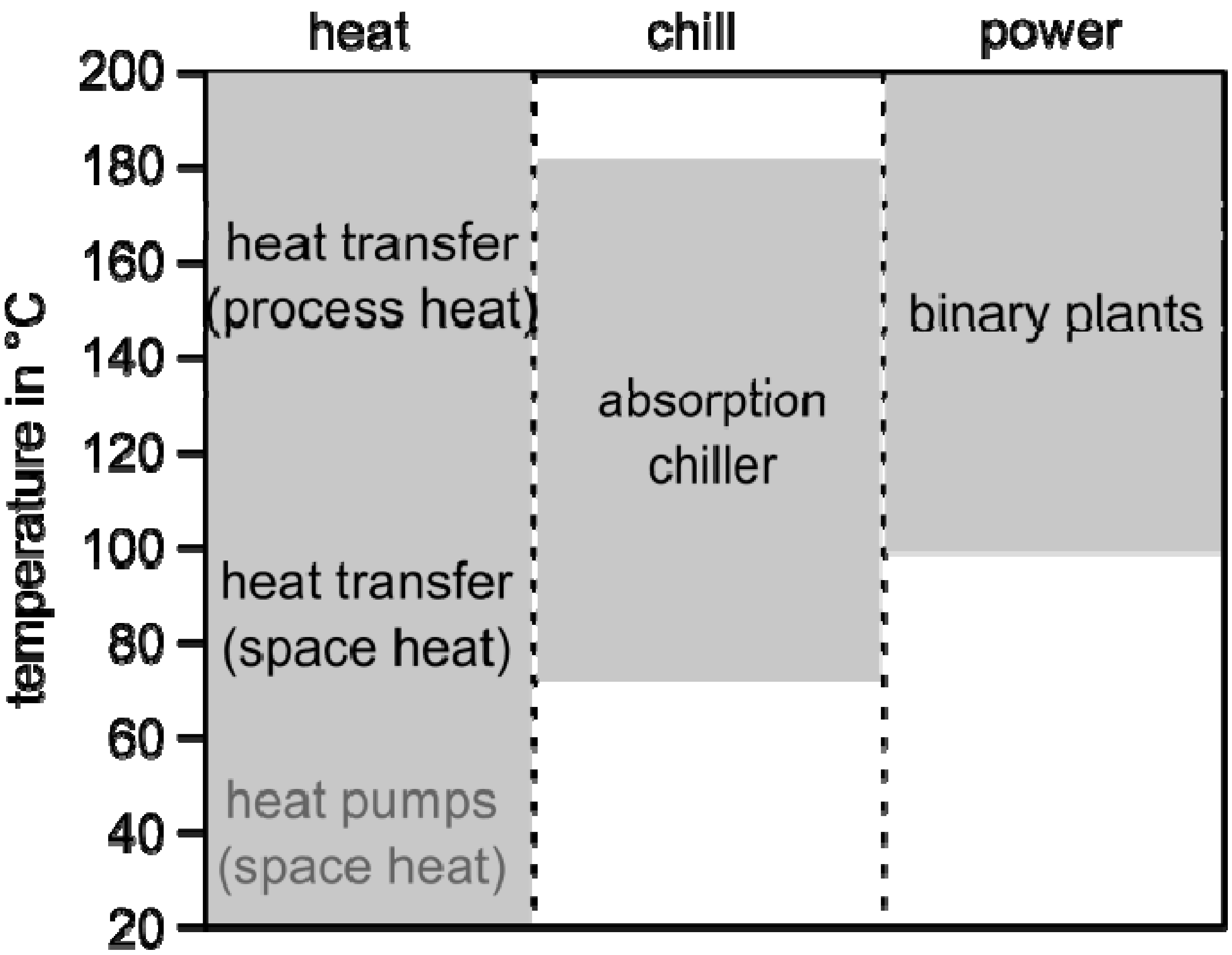
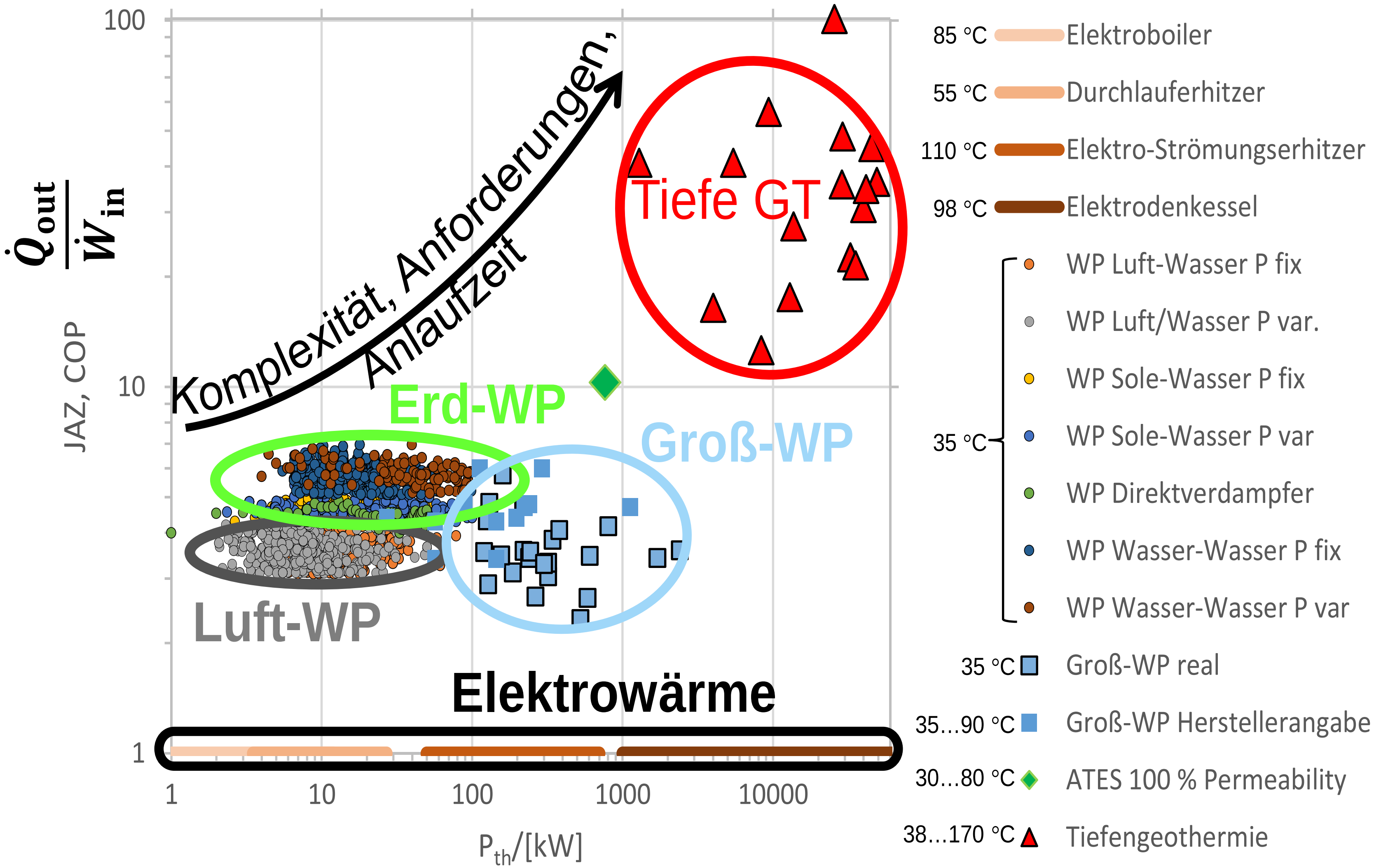
Energy provision options and correlating temperature levels



Auxilliary energy for geothermal heat supply



Francke et al. 2018

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Jigokudani hotspring, Nagano Japan

Energy transition requires heat transition

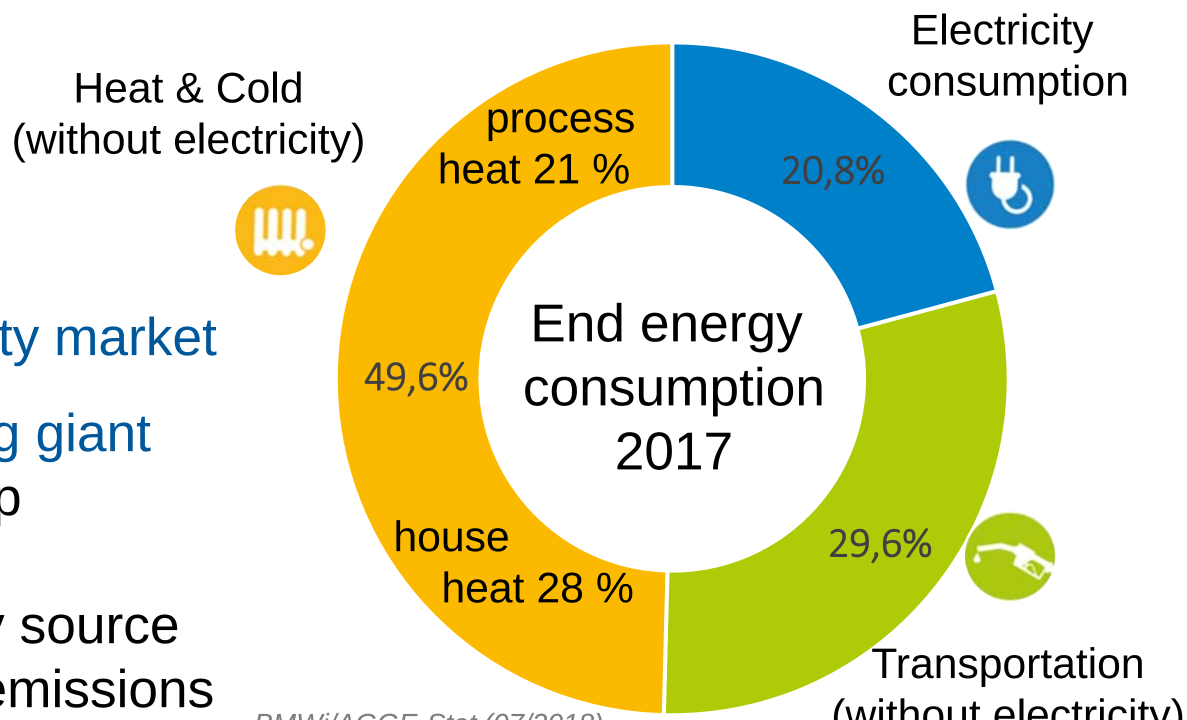
Grand challenges:

- Climate change
- Energy transition

Heat market ~ 2x electricity market

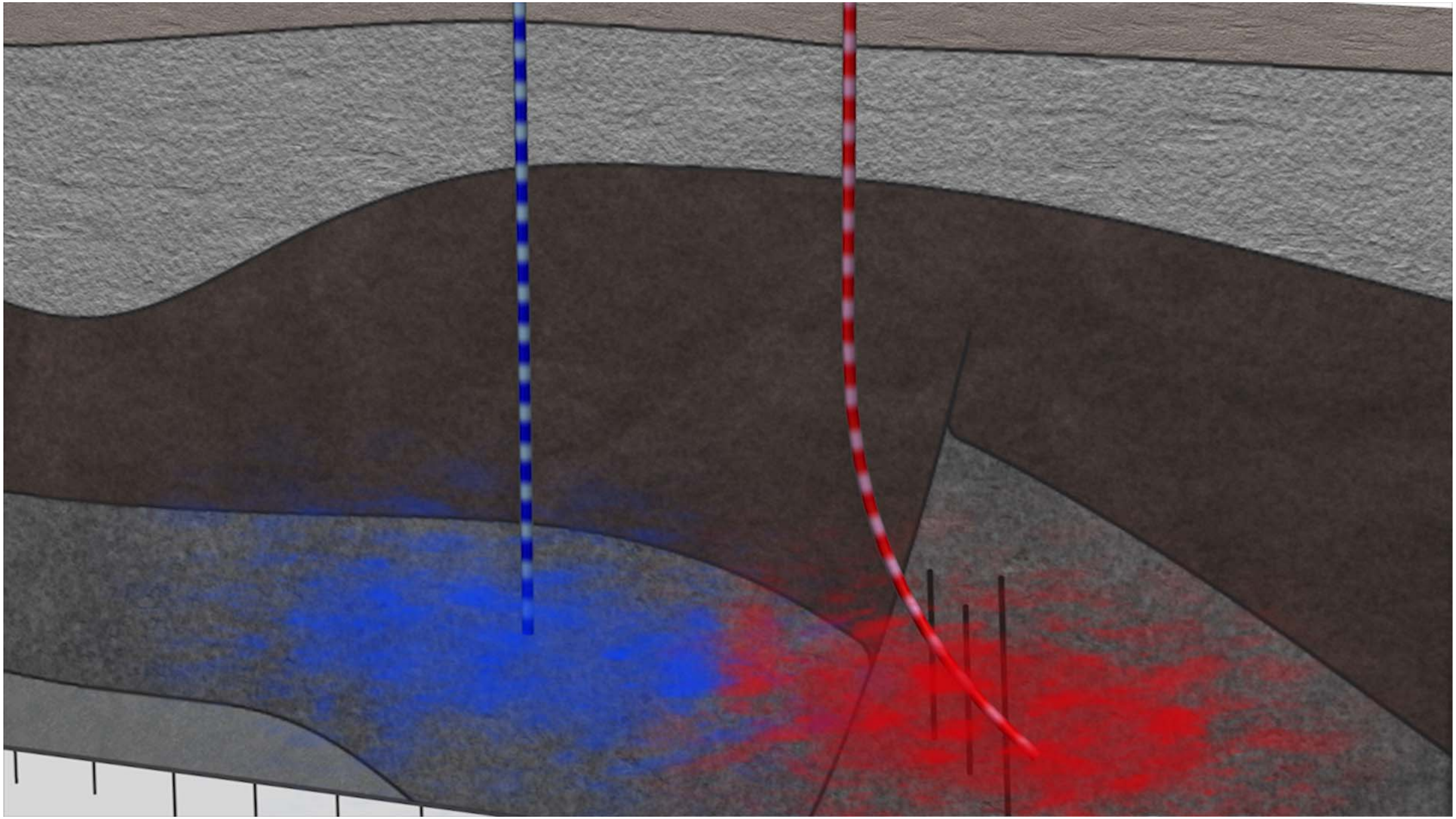
Geothermal – the sleeping giant

- Huge potential for deep geothermal
- Local baseload energy source
- Low greenhouse gas emissions

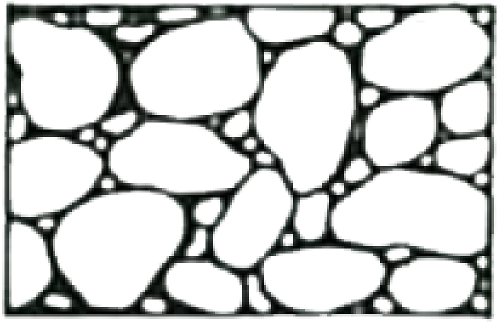


BMWi/AGGE-Stat (07/2018)

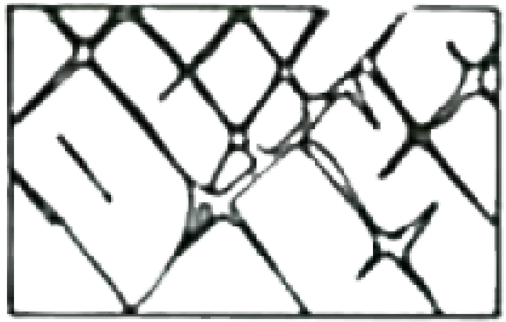
Recovery of geothermal heat



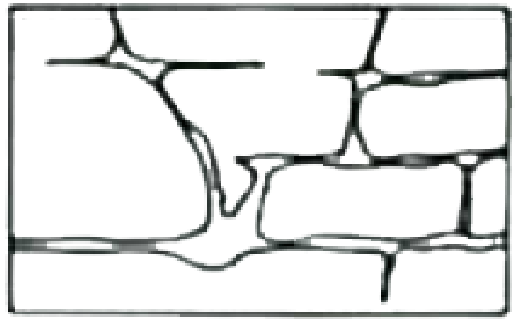
Porous rocks and fracture zones



porous media

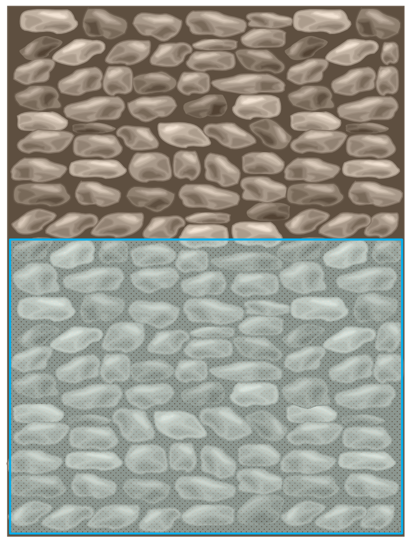


fractured media



karst aquifer

geothermal fluids (gas + liquids)



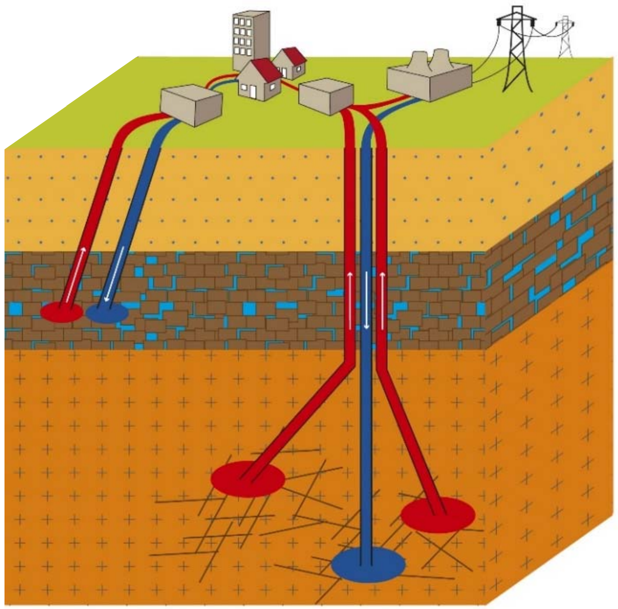
Deep geothermal energy utilization

Challenges:

- Easily exploitable reservoirs limited (hydrothermal systems)
- Most rocks require engineering (petrothermal systems)

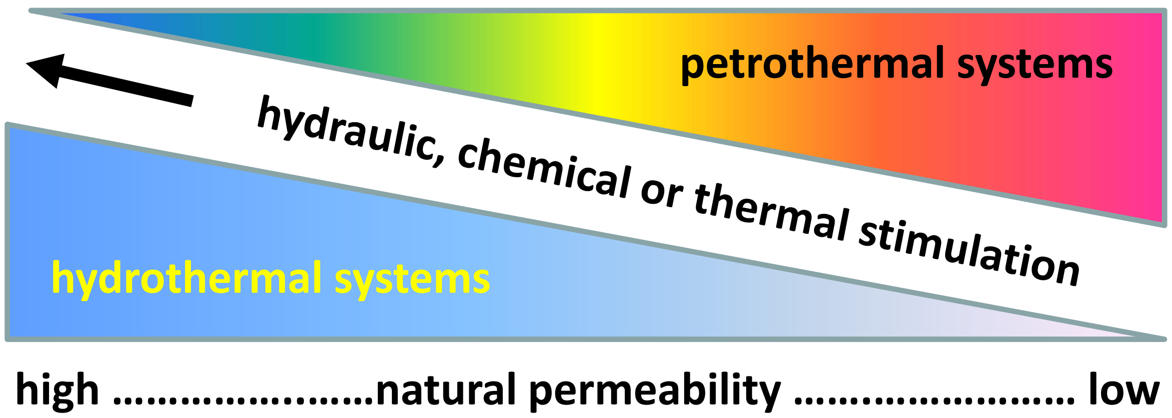
Tasks:

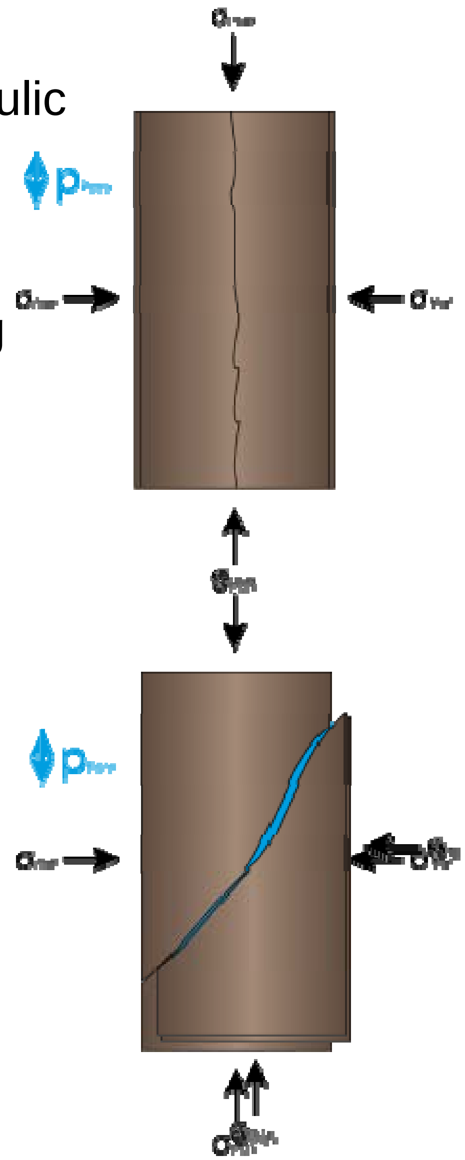
- Increase productivity (economics) → Stimulation
- Reduce seismicity (environmental impact) → Soft stimulation



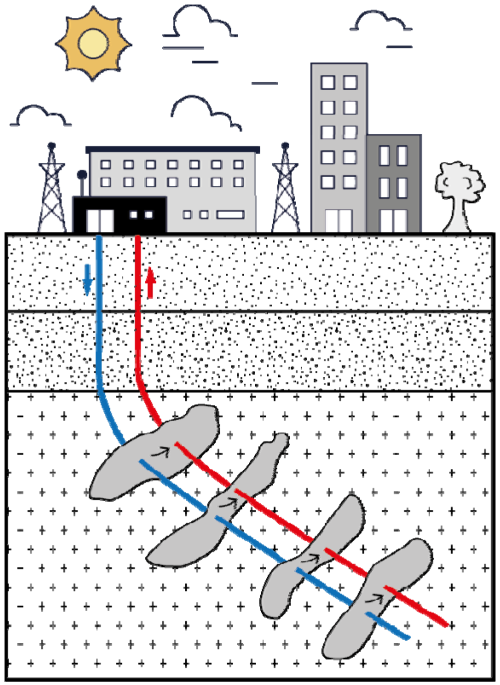
Enhanced geothermal systems (EGS)

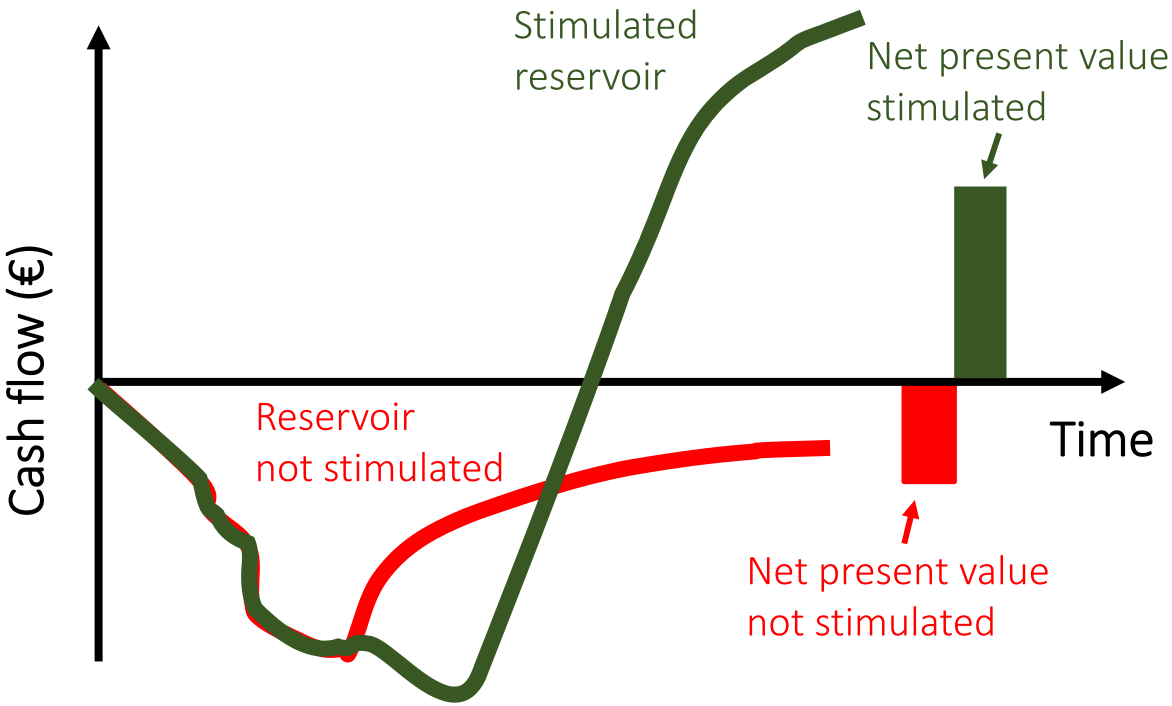
- The EGS concept includes artificial improvement of the hydraulic performance of a reservoir with the goal to use it for an economical provision of heat or electric energy
- The enhancement challenge is based on several non-conventional methods for exploring, developing and exploiting geothermal resources that are not economically viable by conventional methods
- Enhanced vs Engineered





Economic impact of reservoir stimulation





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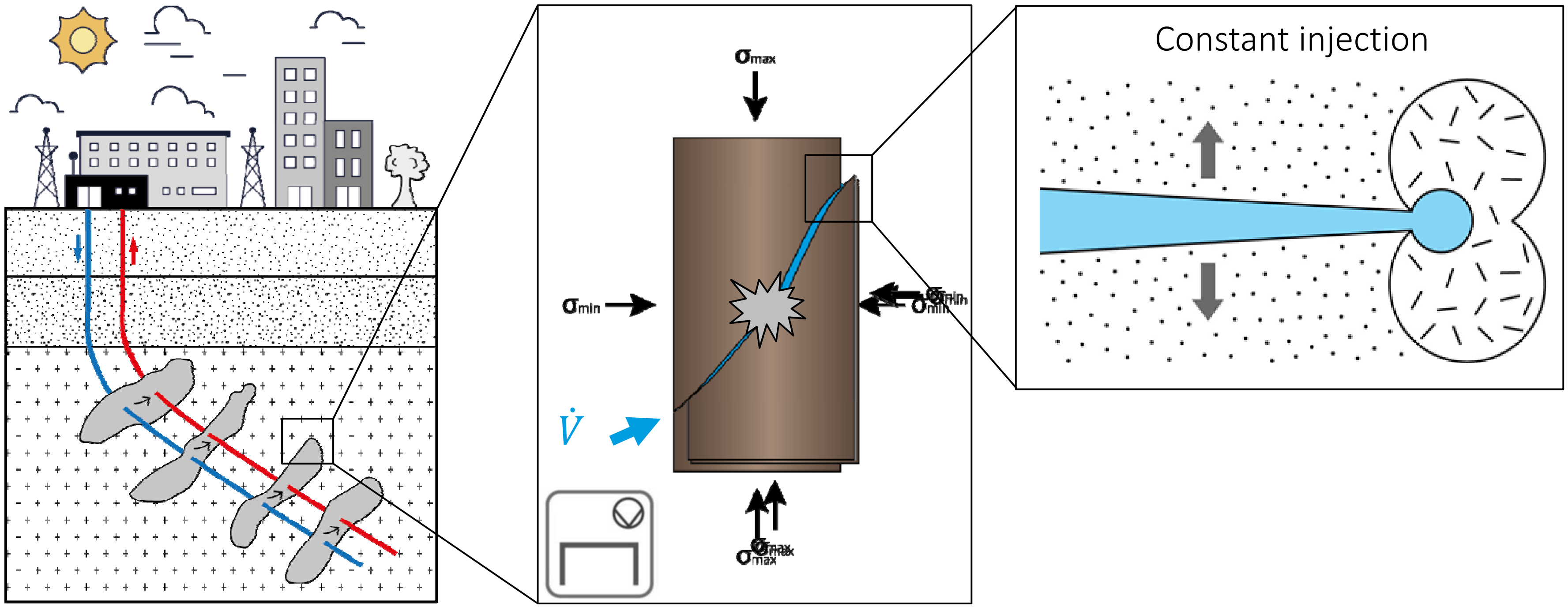
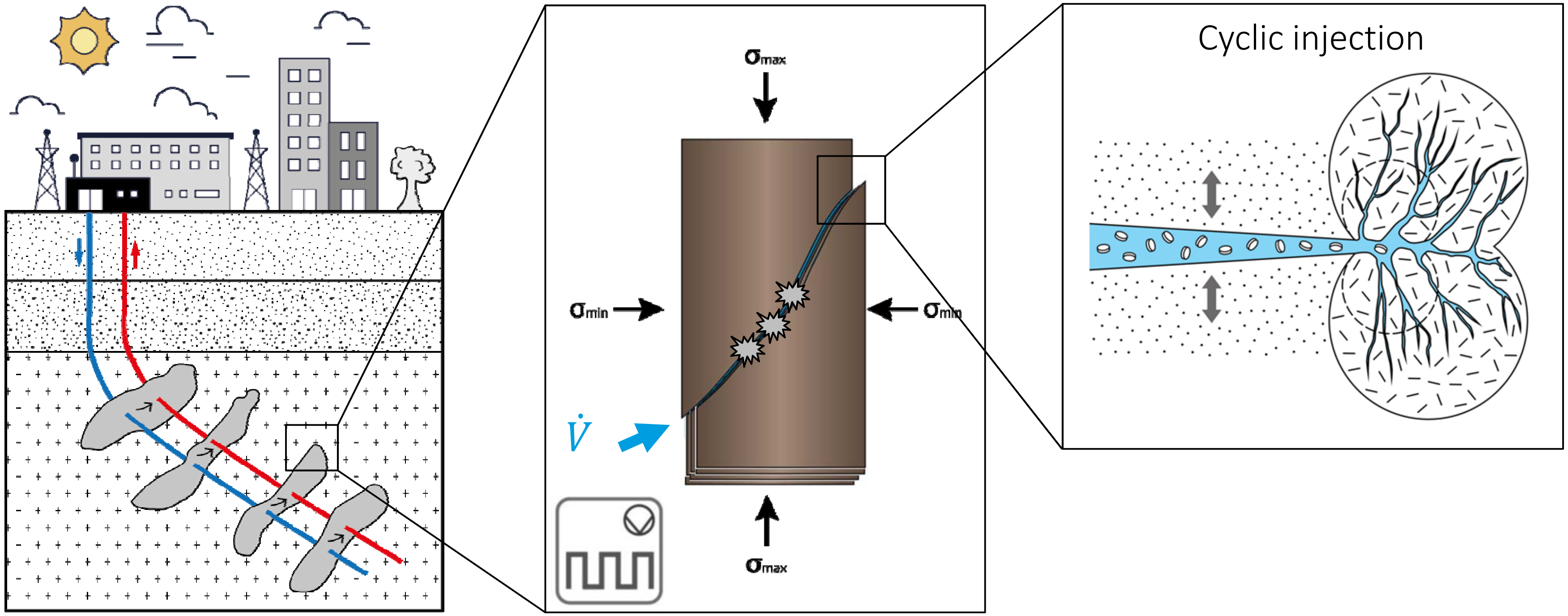
Conventional hydraulic stimulation process



Objective: Validation of „Cyclic Soft Stimulation“ Concept

(Hofmann et al. 2018, 2019)



Field experiment in Reykjavik, Iceland

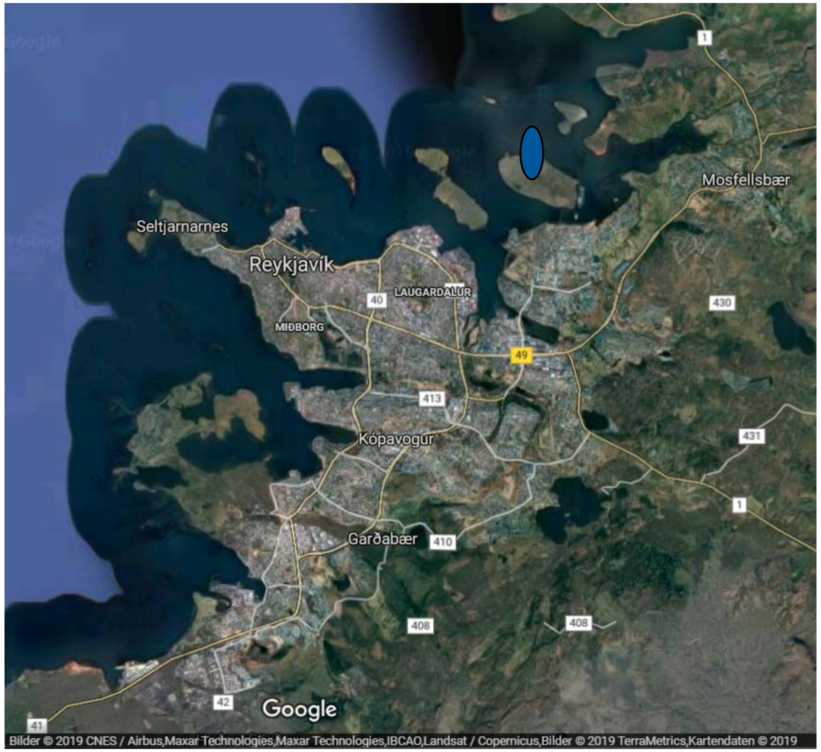
7 October – 1 November 2019

DESTRESS

Purpose: Growing heat demand of Reykjavik

Approach: Demonstration of soft stimulation

Budget: 1.200.000 € (EU H2020 „DESTRESS“)



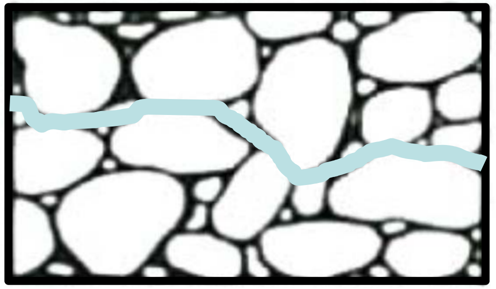
Partners & contractors:

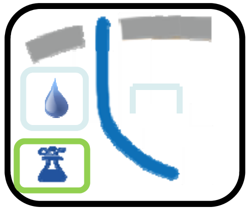
GFZ Helmholtz Centre Potsdam, Iceland Drilling, Veðurstofa Íslands, ETH zürich, ÍSOR, TNO, OR Reykjavík Energy

Conceptual Chemical Stimulation

Porous rocks

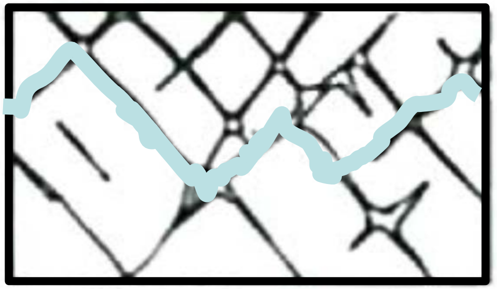
Acidisation to remove obstacles in pores (e.g. carbonates and fines) (Mezöberény, Hungary January 2020)





Fractured rocks

Acidisation to weaken strength of particles (e.g. barite) in contractions (Soultz, France November 2019)



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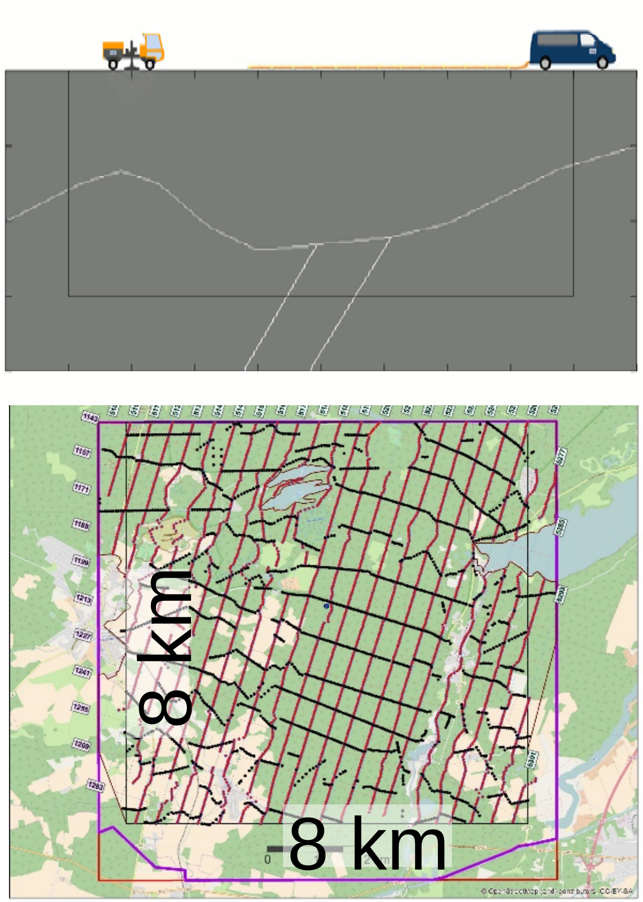
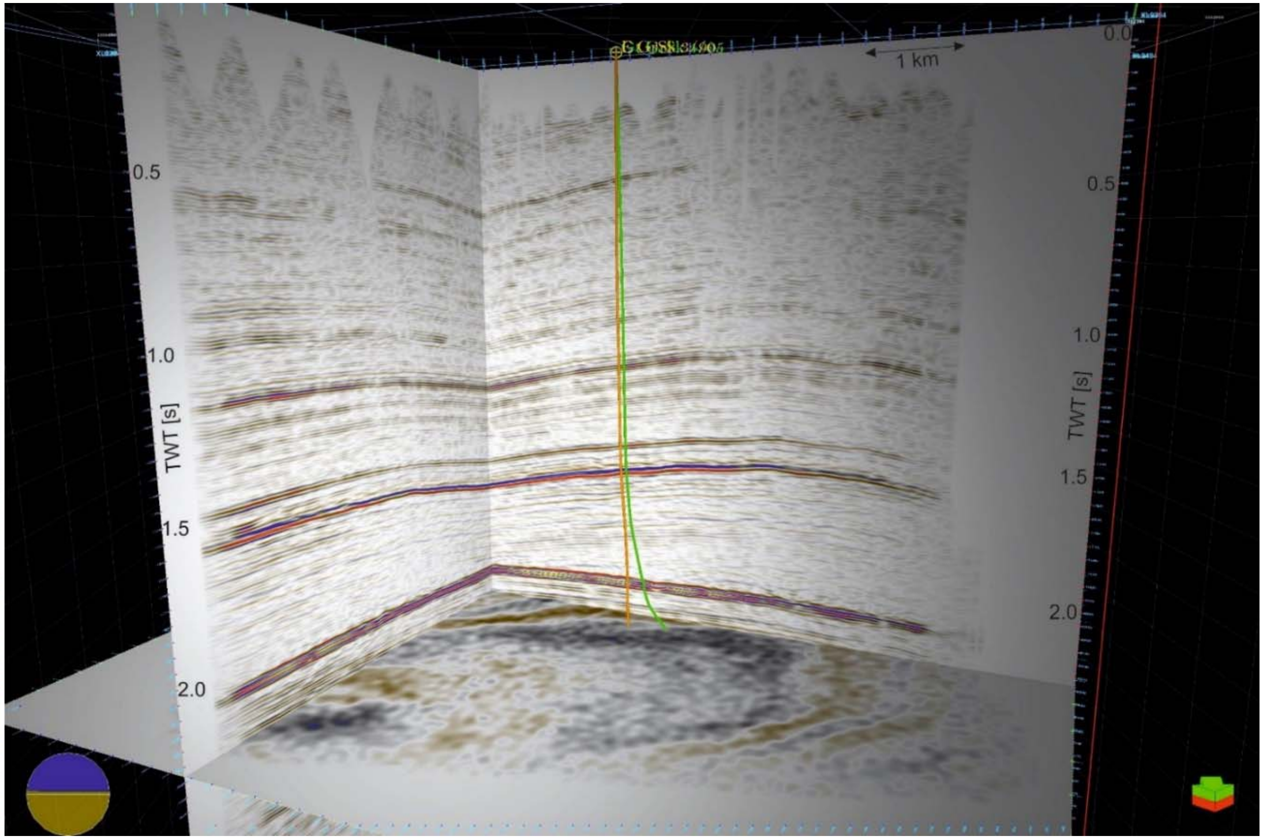
Explore geothermal systems

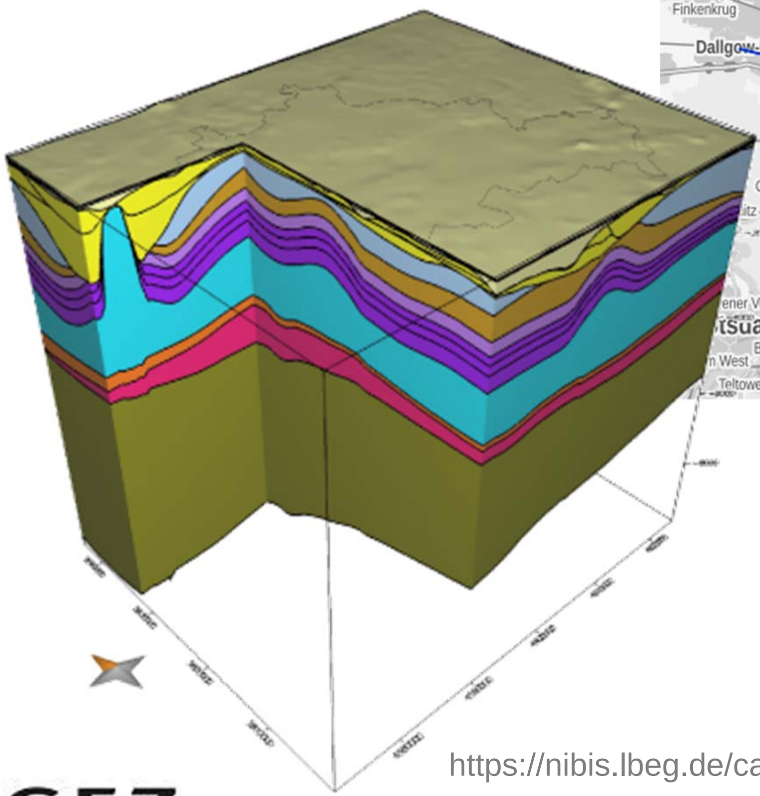
Seismic campaign in Groß Schönebeck 2017



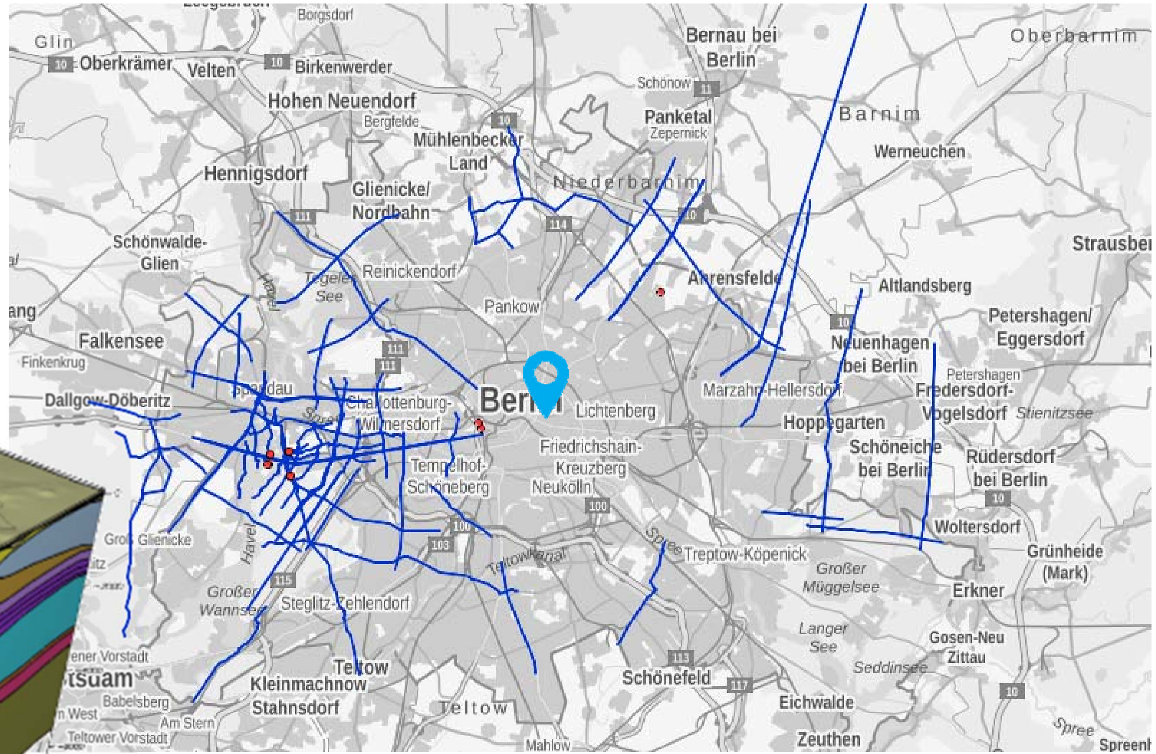


(Stiller et al., 2018)

Exploration in Berlin



https://nibis.lbeg.de/cardomap3/



https://nibis.lbeg.de/cardomap3/

Reduce uncertainity

Depth – structure - properties

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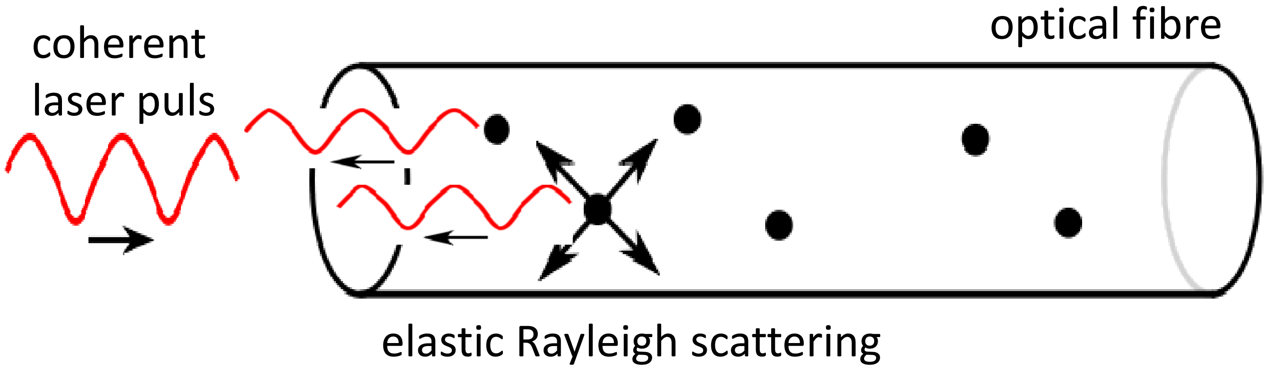
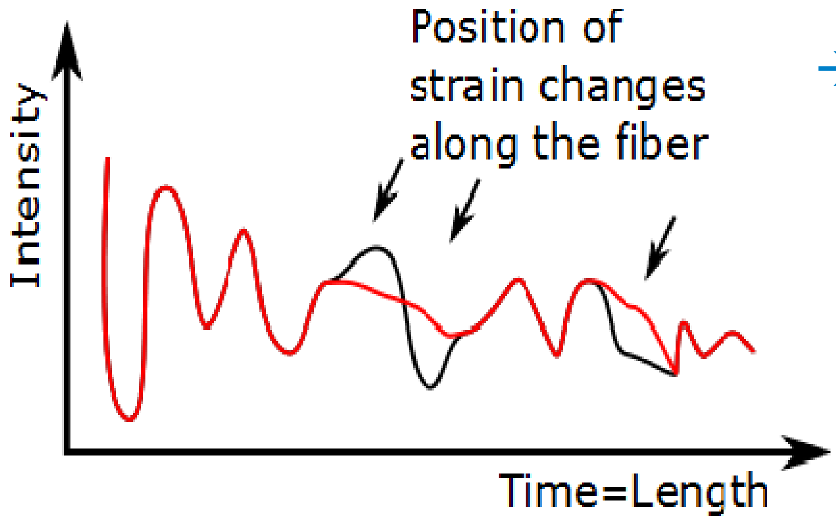
Distributed Optical Fibre Sensors (DOFS)

Distributed Strain Sensing (DSS)

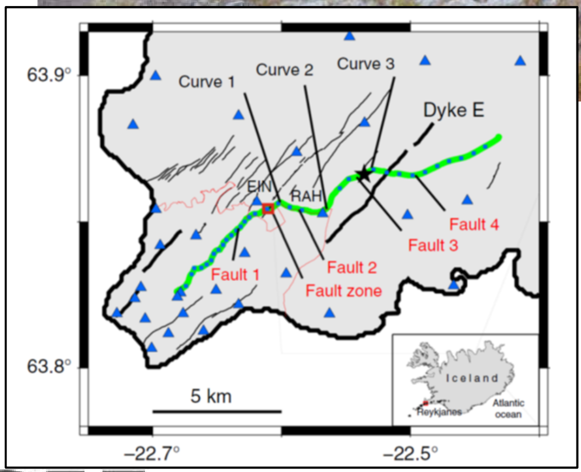


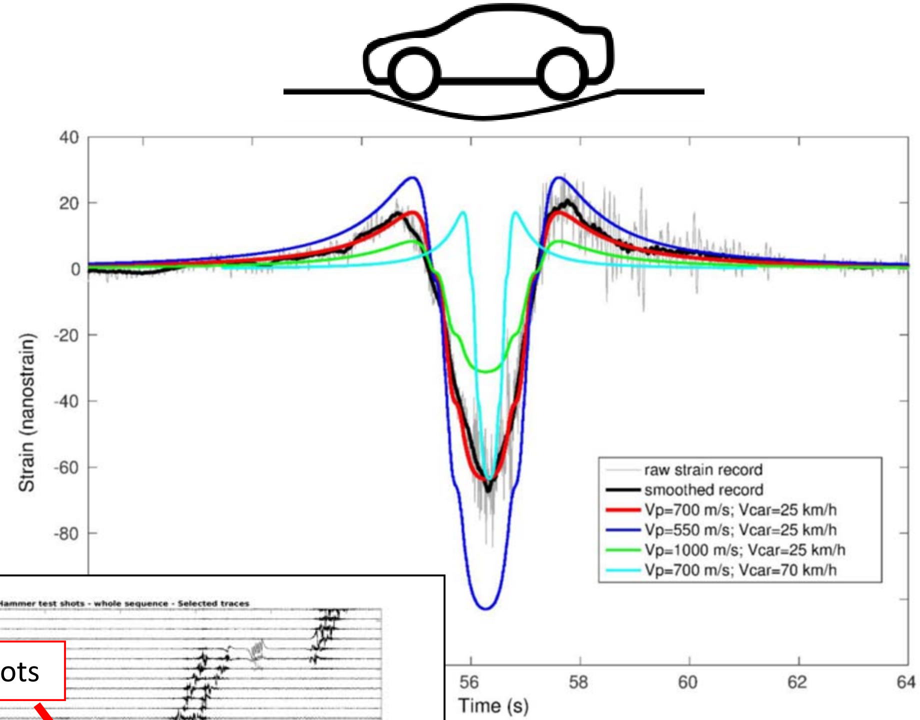


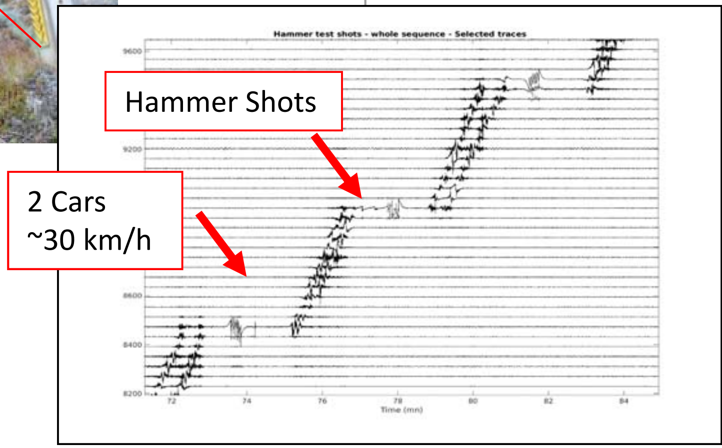
→ Intensity change
= deformation (time)

Application: Monitoring

deformation-monitoring







Jousset, Reinsch et al.,
Nature Comm. 2018

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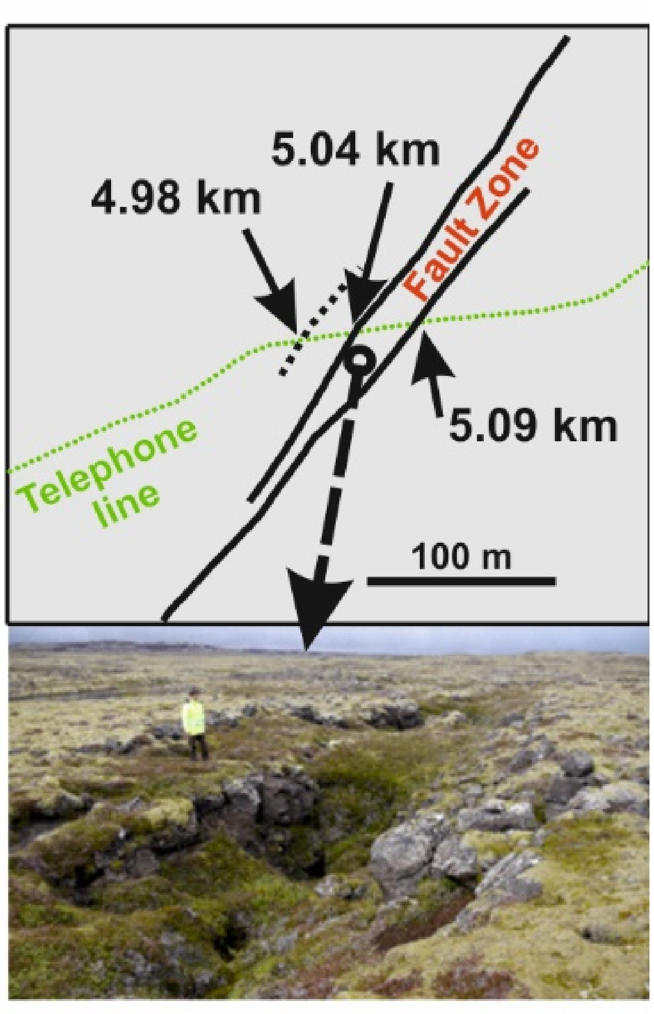
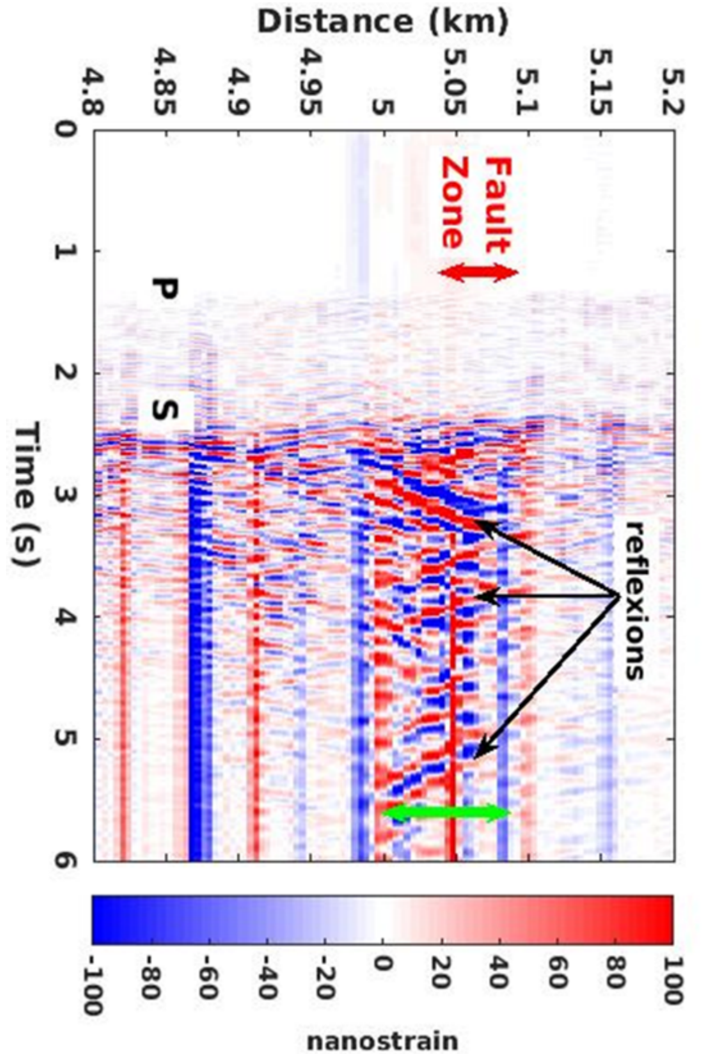
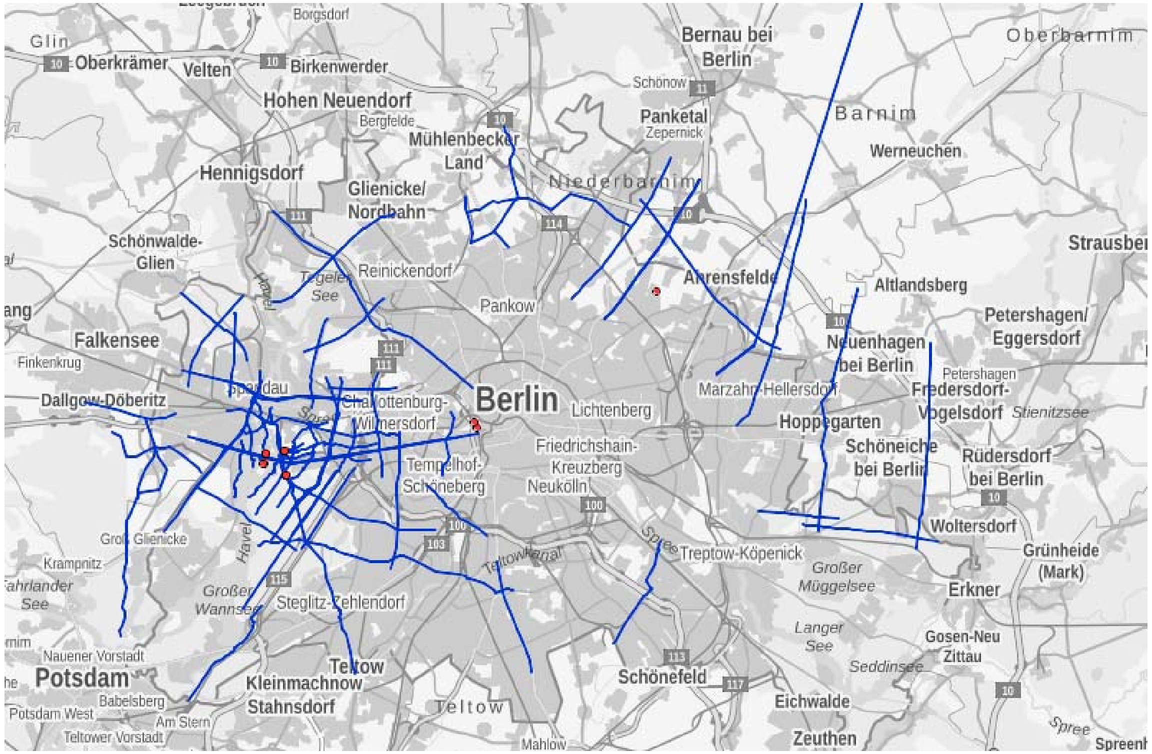
Application: exploration of structures

geological faults systems



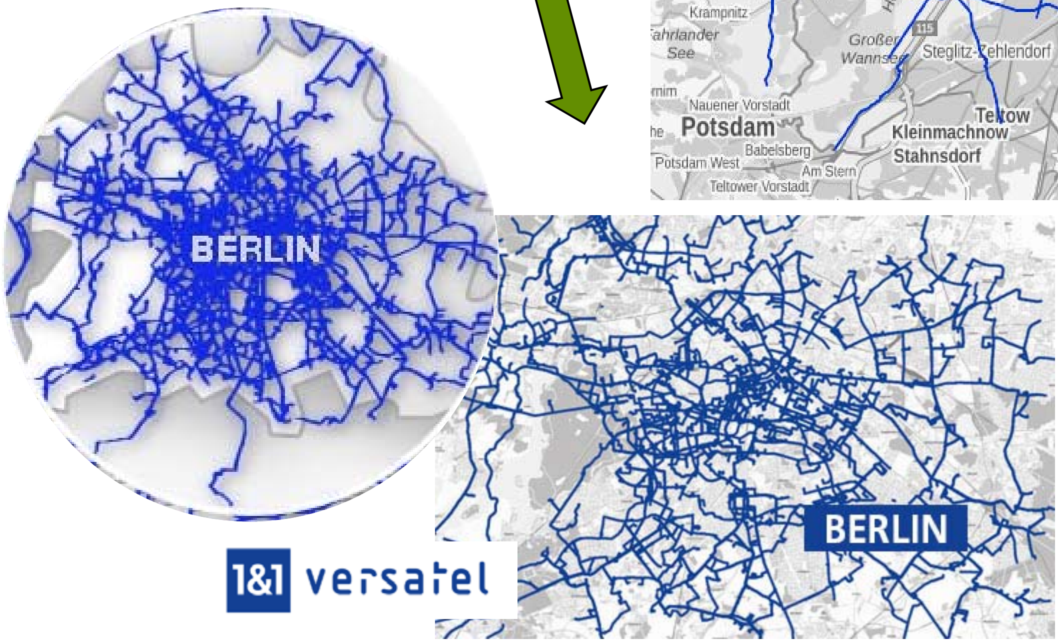


Seismic lines so far



https://nibis.lbeg.de/cardomap3/

fibre cables



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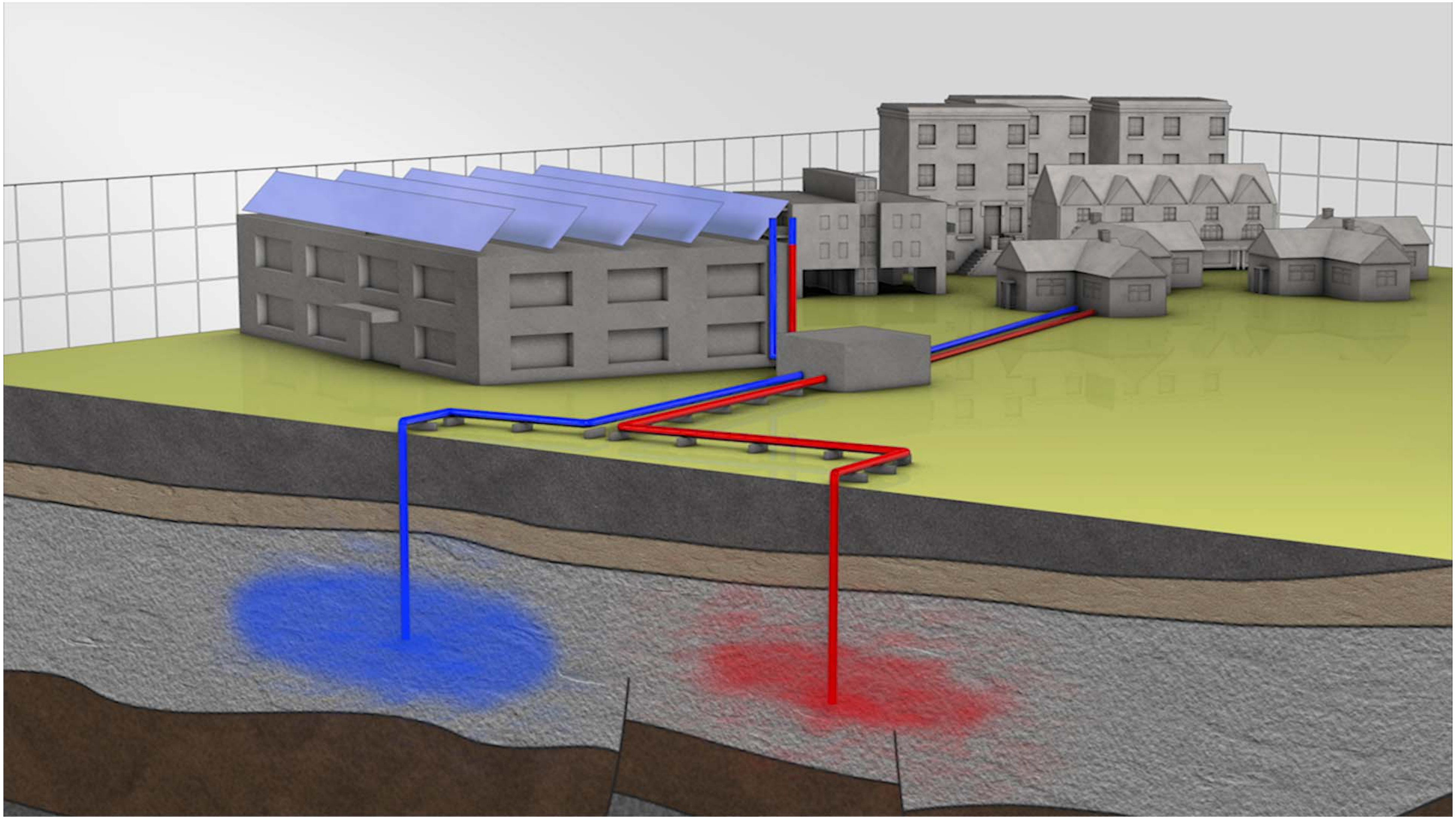
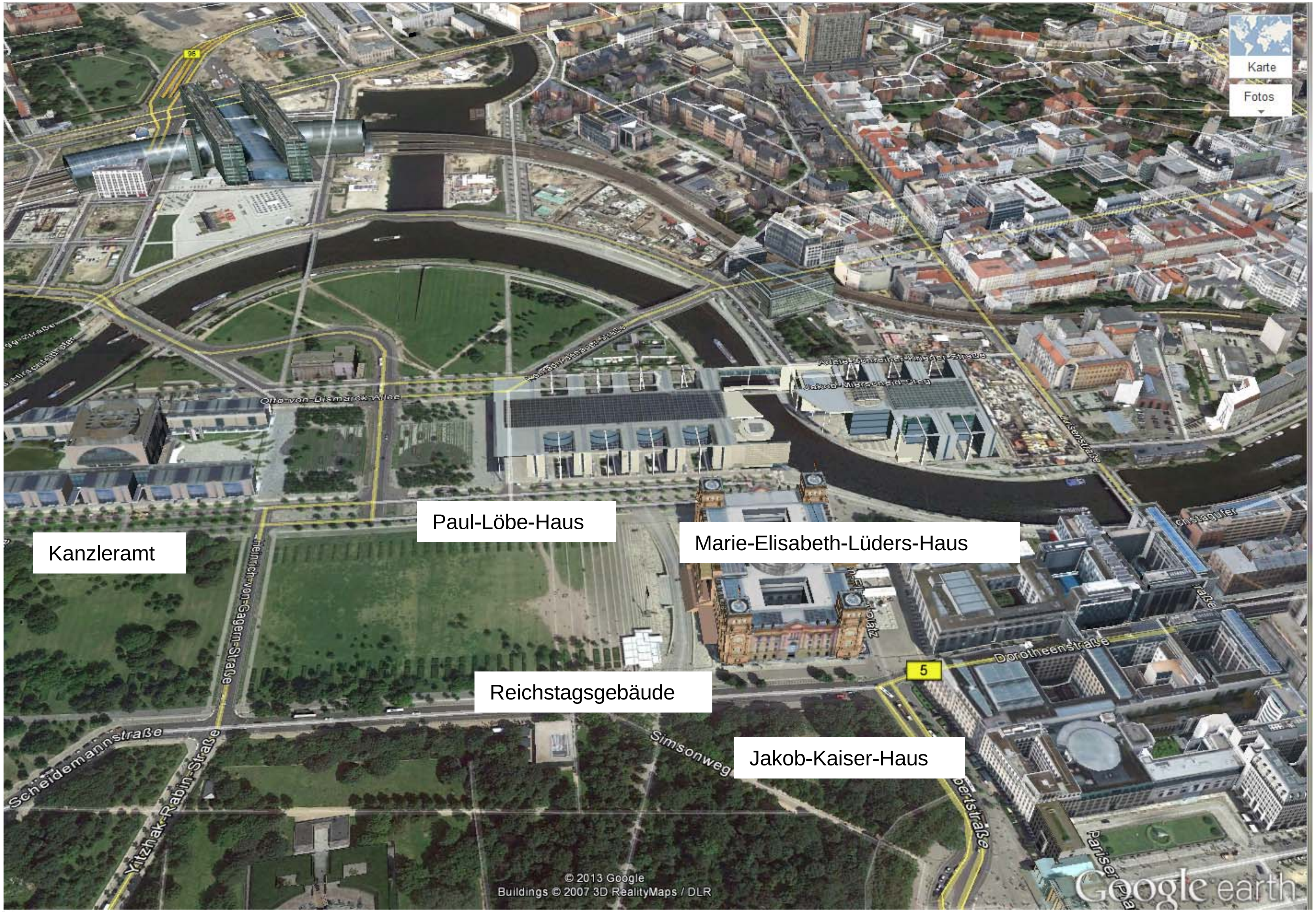
Convert geothermal heat to power

Challenge Indonesia – no binary plant so far (2017)

Organic Rankine Cycle power plant in Lahendong Indonesia (Stefan Kranz, GFZ)

Storage of heat and chill

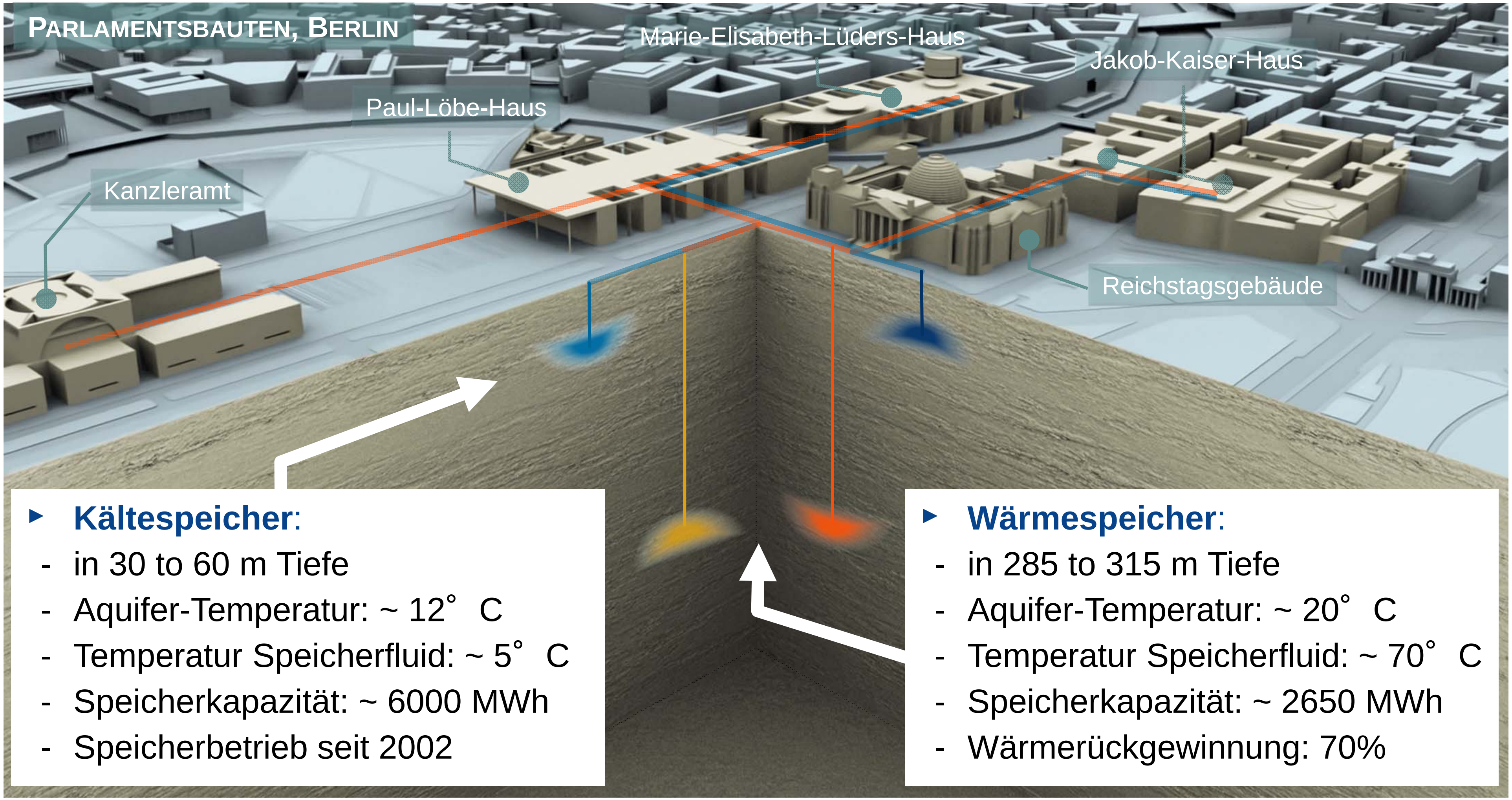




ATES Berliner Parlamentsbauten

Energiespeicherung in Aquiferen

Erdwärmespeicher Deutscher Bundestag



- **Kältespeicher**:
  - in 30 to 60 m Tiefe
  - Aquifer-Temperatur: ~ 12° C
  - Temperatur Speicherfluid: ~ 5° C
  - Speicherkapazität: ~ 6000 MWh
  - Speicherbetrieb seit 2002

- **Wärmespeicher**:
  - in 285 to 315 m Tiefe
  - Aquifer-Temperatur: ~ 20° C
  - Temperatur Speicherfluid: ~ 70° C
  - Speicherkapazität: ~ 2650 MWh
  - Wärmerückgewinnung: 70%

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Energy Consumption in Oman

Total power supplied in Oman

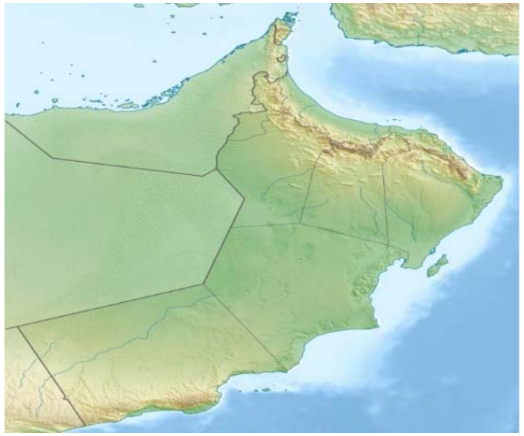
~25 TWh[a]   (Germany ~650 TWh[d])

Total residential cooling use 2014

~11.6 TWh[a]   (residential heating: Germany ~136 TWh[d])

Residential annual power used for cooling in Mus

~5.8 TWh[a]   (district heating Berlin ~8.5 TWh[e])



The electricity sector in Oman is primarily based on natural gas (97.5%) and diesel (2.5%) [a].

[a] *Authority for Energy Regulation, Oman*
[b] *Residential Energy Use In Oman: A Scoping Study, Trevor Sweetnam*
[e] *DIW ECON*
[c] *Energy Information Agency, USA*
[d] *International Energy Agency*

Concept for a Continuously Operating Cooling System based on Renewables

The absorption chiller requires water of 80–120°C to produce chill of 5.5°C

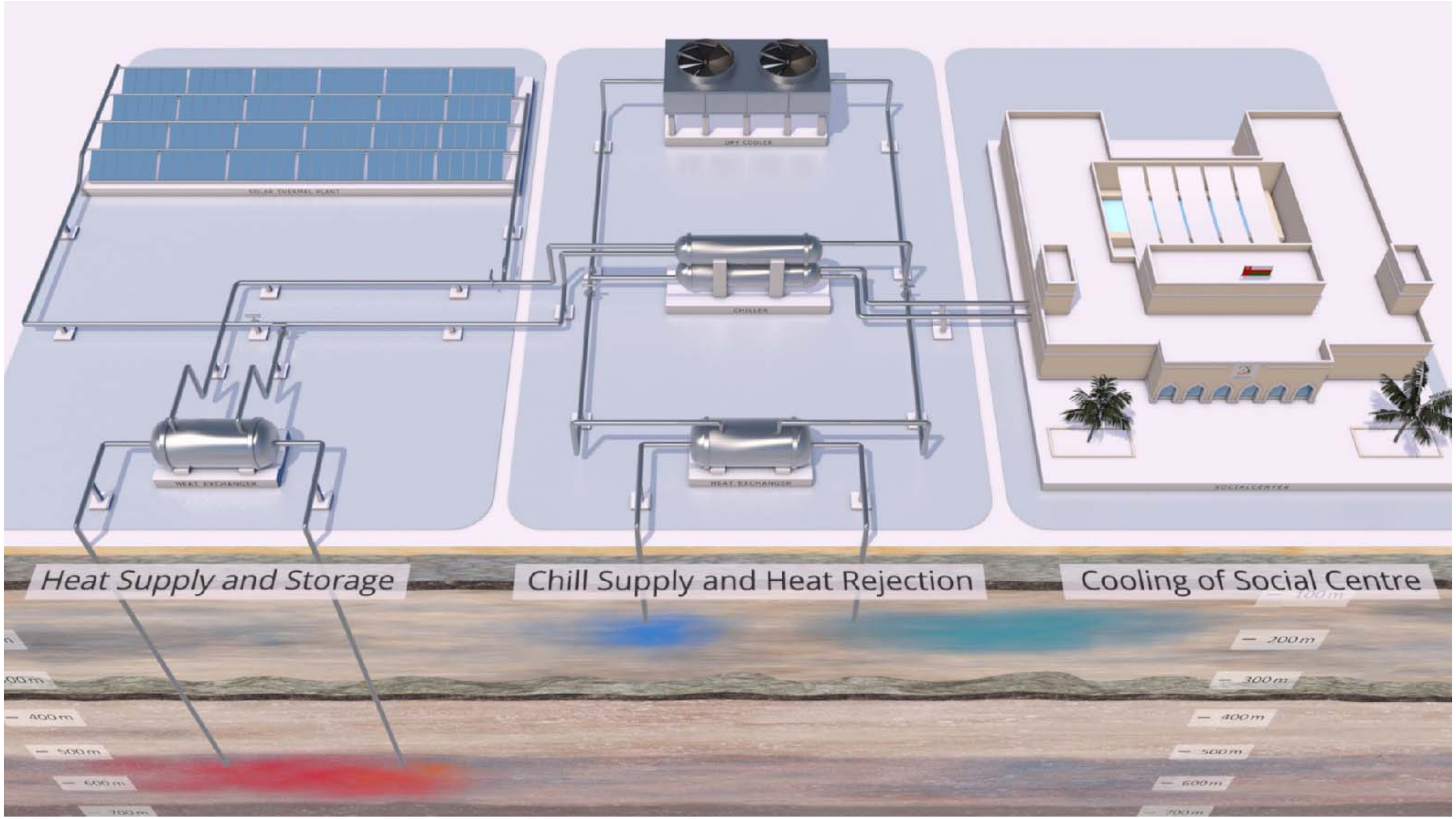
Shallow aquifers can be used to reject the waste heat of the system and to store excess energy.

Further partners:

- CAU-Christian Albrecht University zu Kiel
- Beuth University Berlin

Funded by: The Research Council — Towards an Effective National Innovation System

Concept of the GeoSolCool Project

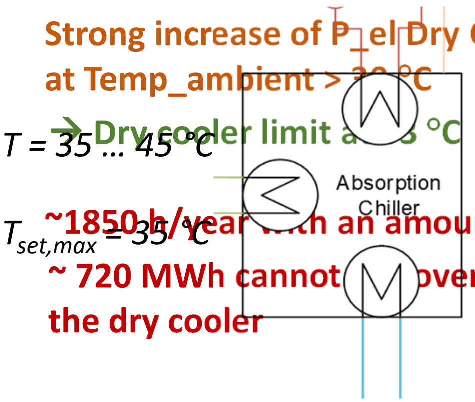


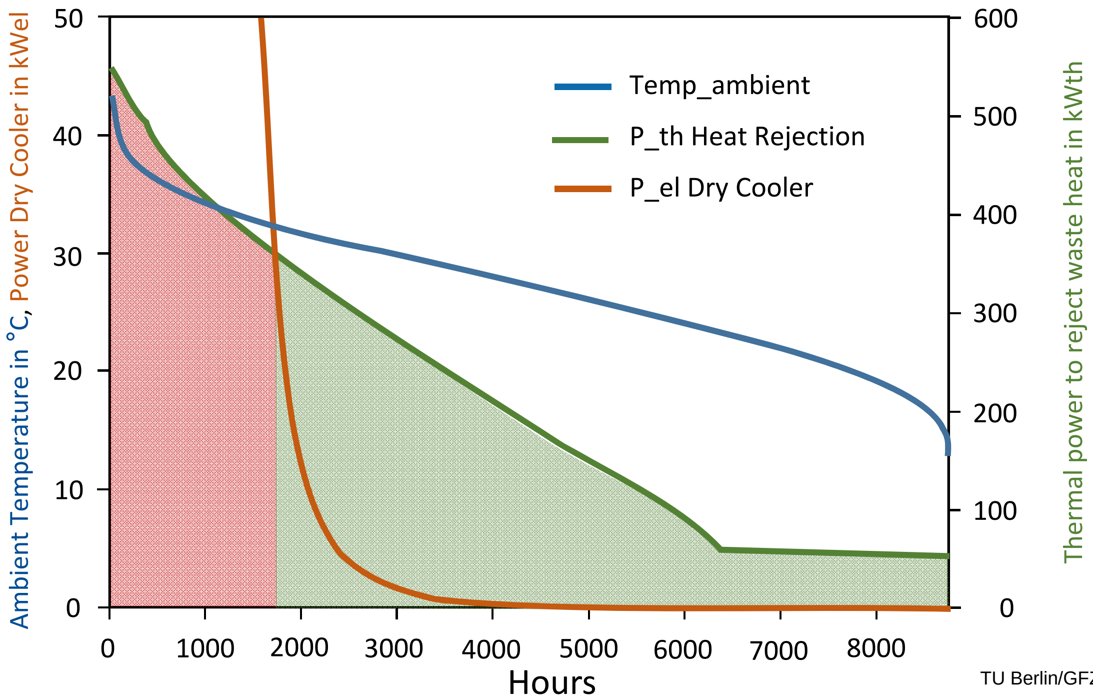
Concept of Heat Rejection – Dry Cooler

- **Total amount of waste heat: ~1850 MWh/year with $\dot{Q}_{max} \approx$ 550 kW , $\dot{Q}_{mean} \approx$ 210 kW**

- **Strong increase of P_el Dry Cooler at Temp_ambient > 30 °C**
  → Dry cooler limit at 35 °C

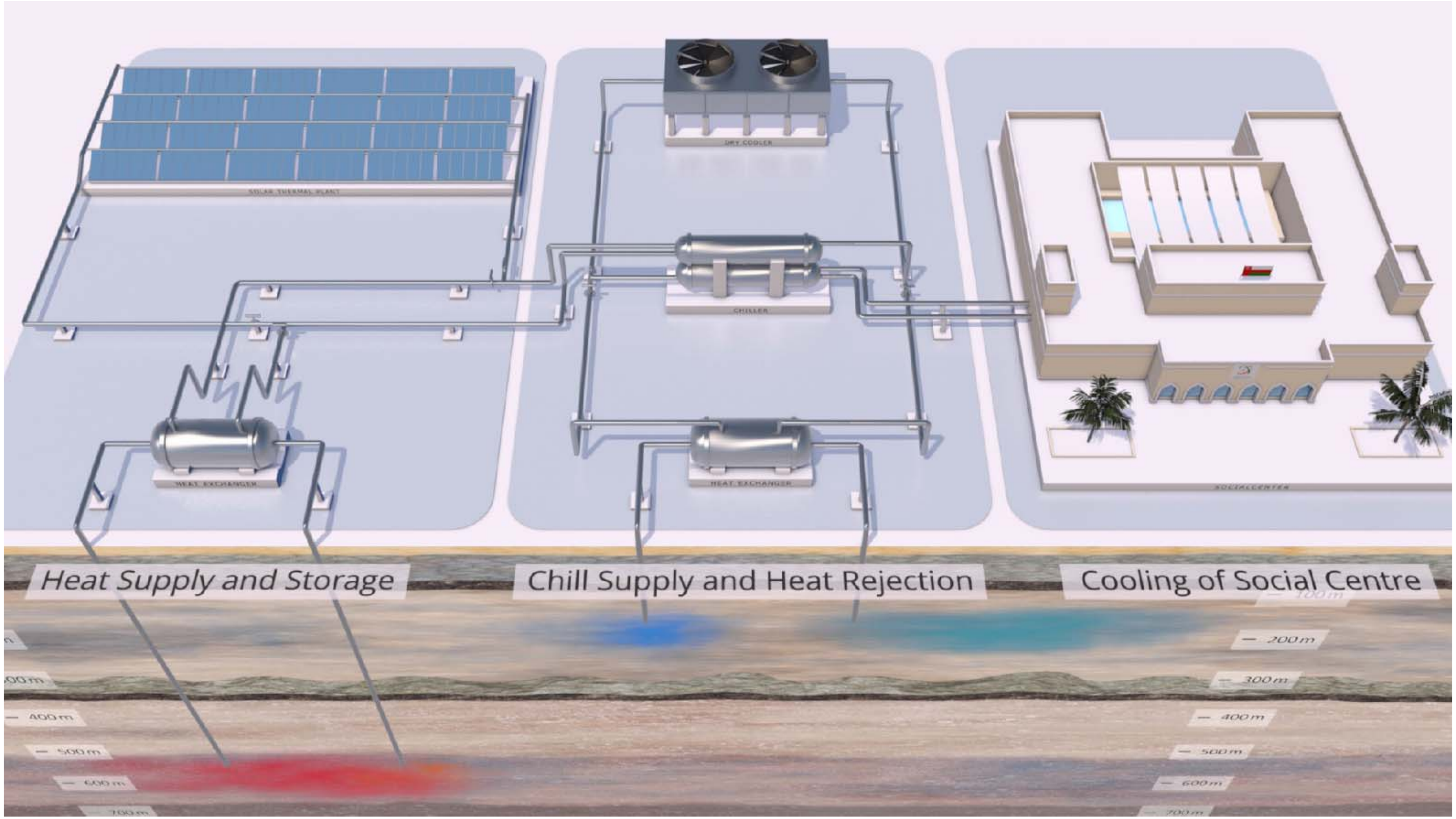
- **~1850 h/year with an amount of ~ 720 MWh cannot be covered by the dry cooler**





TU Berlin/GFZ

Concept of the GeoSolCool Project



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Beiträge Geothermie zur klimaneutralen Deckung des Energiebedarfs

- Mittlere Breiten ohne vulkanische Systeme (e.g. Deutschland):
  - Hydrothermale Systeme: ggfs. mit chemischer Stimulation
  - Petrothermale Systeme: „sanfte“ Stimulation (kontrollierte seismische Aktivität)
  - Neue Explorationsmethoden mit Hilfe Faseroptik
- Hochenthalpielagerstätten (Hot Geothermal Systems) (e.g. Indonesien):
  - Direkte Dampfnutzung (flash) (nicht gezeigt)
  - Nutzung der Hitze des abgetrennten heißen Wassers (ORC)
- Quartierslösungen hiesiger urbaner Räume:
  - Heimische geothermische Quellen nutzen (nicht gezeigt)
  - Thermische Energiespeicherung in Aquifere (ATES)
- Lösungen für aride Gebiete
  - Solare oder geothermische Kühlung mit Absorptionskältemaschinen
  - „Heat rejection“ bei Außentemperaturen größer 30 °C