Geothermal Energy Solutions for Arid Environment:

Continous Hybrid Cooling

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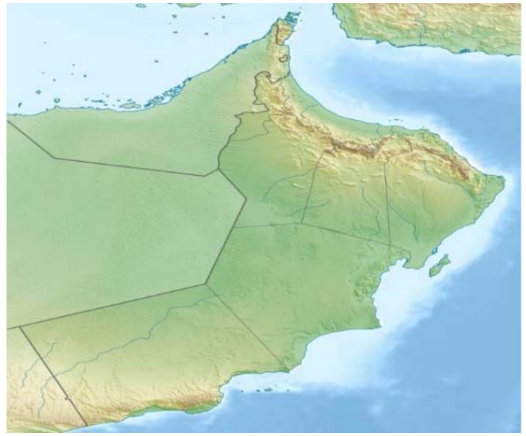
Energy Consumption in Oman

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])

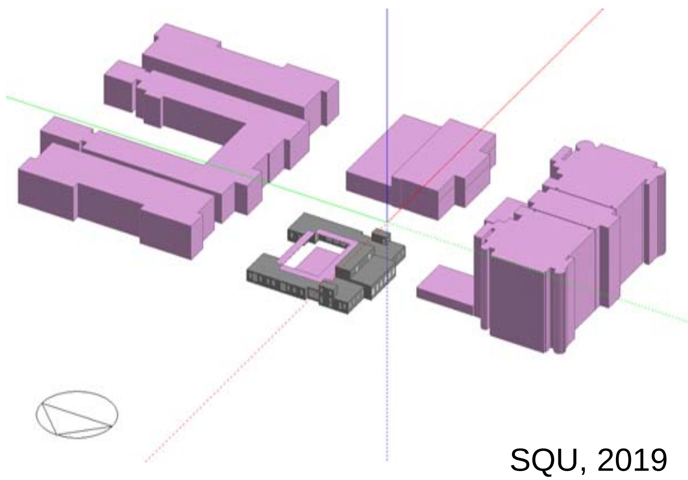
Residential annual power used for cooling in Muscat

~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].

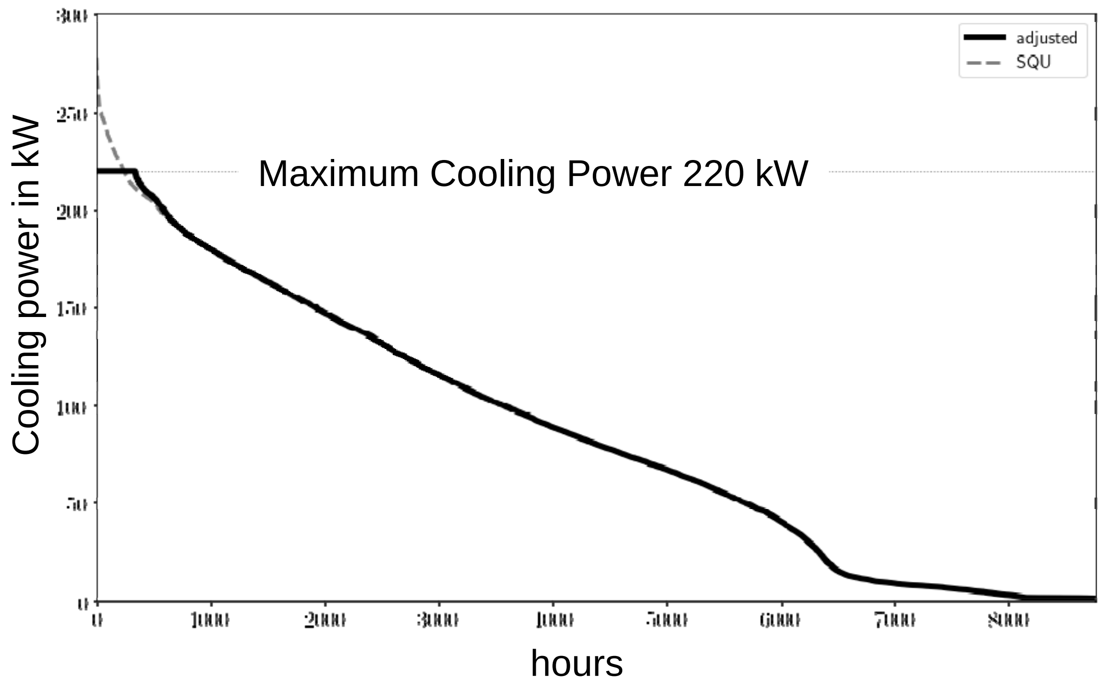
[a] Authority for Energy Regulation, Oman
[b] Residential Energy Use In Oman: A Scoping Study, Trevor Sweetnam
[e] DIW ECON
[c] Energy Information Agency, USA
[d] International Energy Agency

Case study for a Social Centre in Muscat



SQU, 2019

Cooling load per year: 761 MWh



Concept for a Continuously Operating Cooling System based on Renewables

Cooling driven by solar sources –
another option is using geothermal sources

Further potential underground use:

- **Rejection of waste heat** as an alternative to dry or wet cooling towers
- Storage Options: **aquifer thermal energy storage** (ATES) or borehole thermal energy storage (BTES)

Further partners:

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

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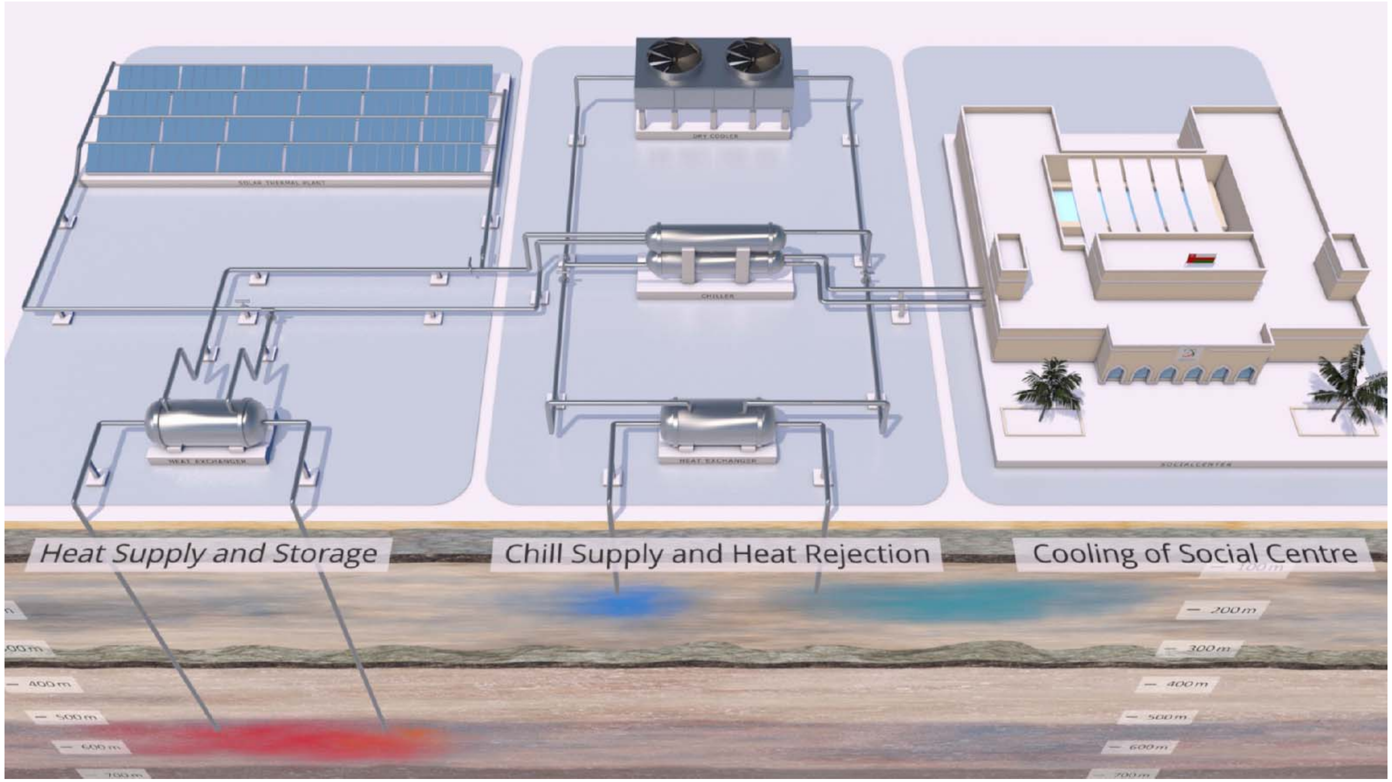
Towards an Effective National Innovation System

Concept of the GeoSolCool Project



Concept of the Absorption Chiller

Absorption chiller types:

A. **Single Stage Lithium-Bromide/Water Absorption Chiller**

B. Double Stage Lithium-Bromide/Water Absorption Chiller

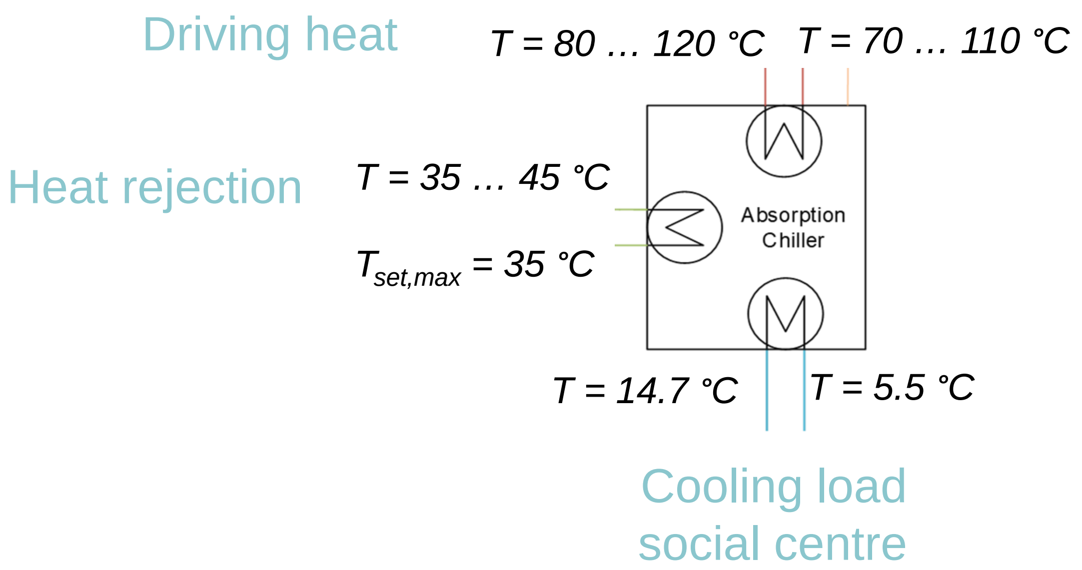
C. Water/Ammonia Absorption Chiller

Lithium-Bromide/Water Absorption Chiller

are the most efficient among absorption chiller types, but are limited through the maximum heat rejection temperature. To achieve the required chilled water temperature of 5.5 °C, the heat rejection temperature has to be below 40 °C.

Concept of the Absorption Chiller

Single Stage Li-Br Absorption Chiller:
with rated cooling power of 220 kW and maximum allowed heat rejection temperature below 40 °C for achieving 5.5 °C chilled water temperature



Harsh weather conditions in Oman

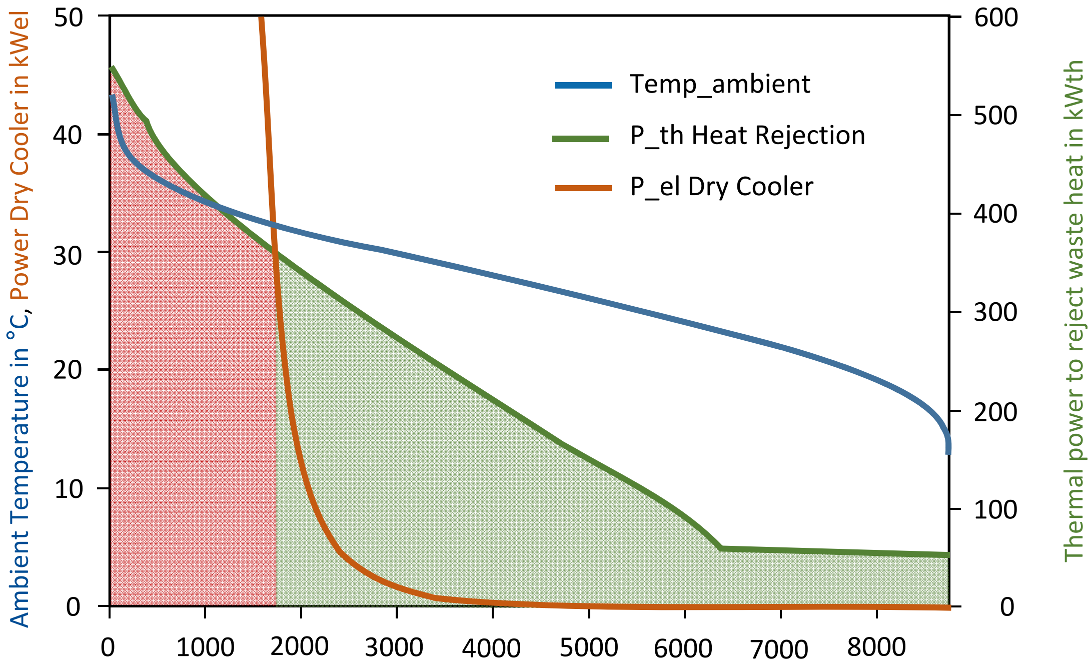
- Average annual temperature in Muscat: 29° C
  - May, June, July are the hottest months
  - temperature can rise to 50° C

➡

The ambient air temperature of Oman is too high to efficiently reject the waste heat of an absorption chiller to the surrounding environment

Concept of heat rejection – dry cooler/underground

- **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 33 °C
- **~1862 h/year with an amount of ~ 720 MWh cannot be rejected by the dry cooler**



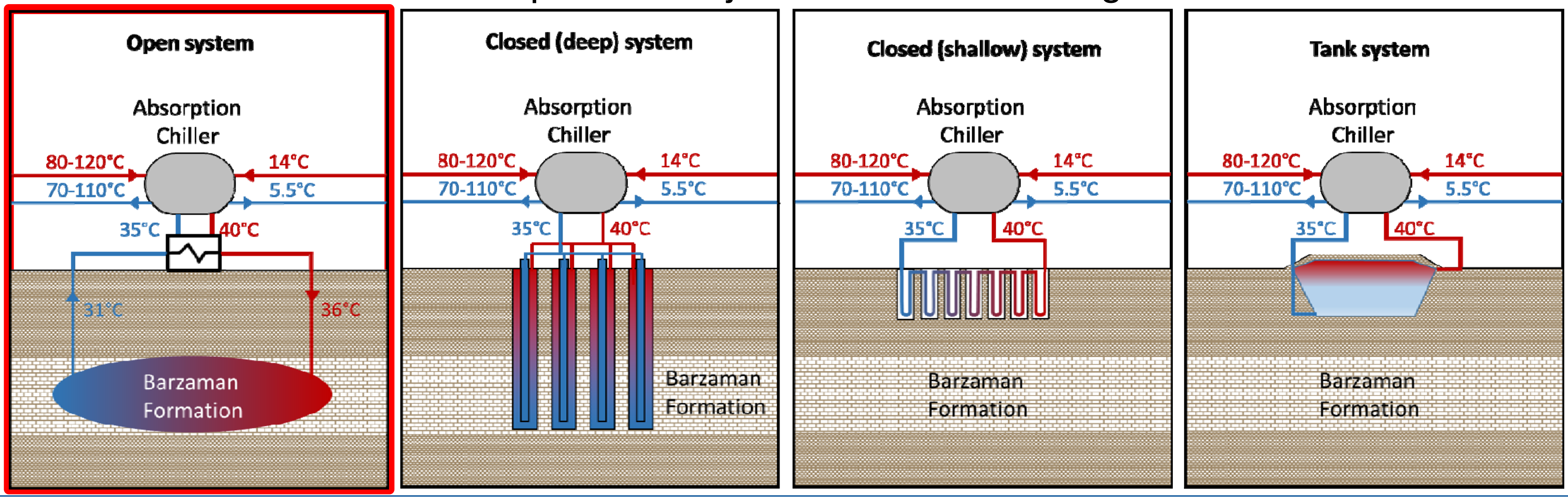
TU Berlin/GFZ

Solution for 33°C plus required!

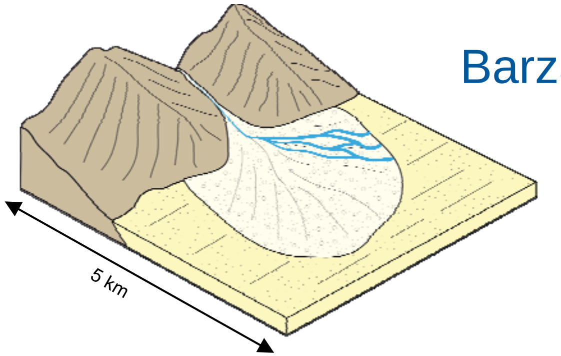
Innovative concept of heat rejection

Heat rejection: GeoSolCool Project - combination of dry cooler and underground cooling $\dot{Q}_{HR,max}$ = ~550 kW , $\dot{Q}_{HR,mean}$ = 400 kW

Different options to reject heat to the underground exist:

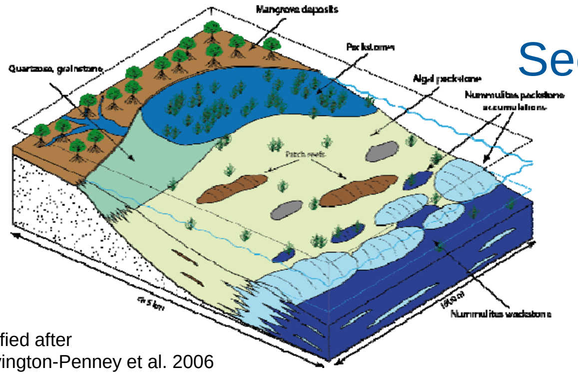


Potential storage systems



Barzaman Fm. - Alluvial fan system

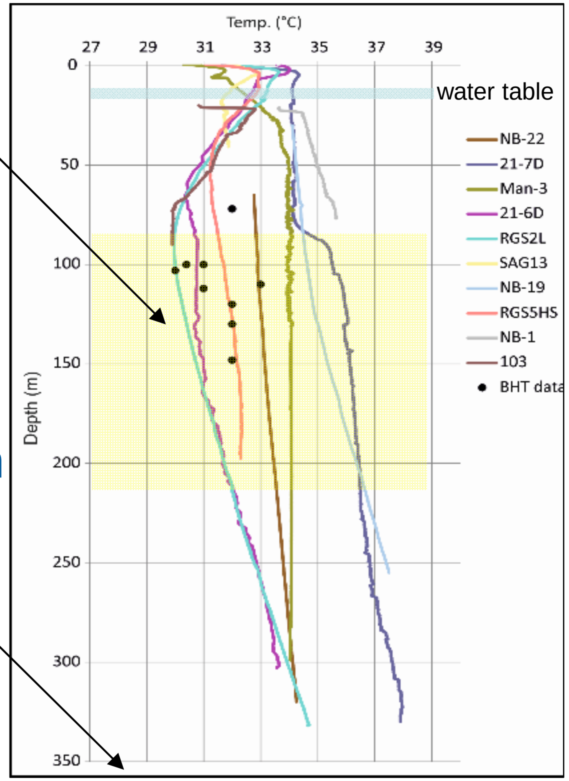
- High level of heterogeneity
- Complex facies patterns
- Coarse clastic sediments (sandstones & conglomerates)



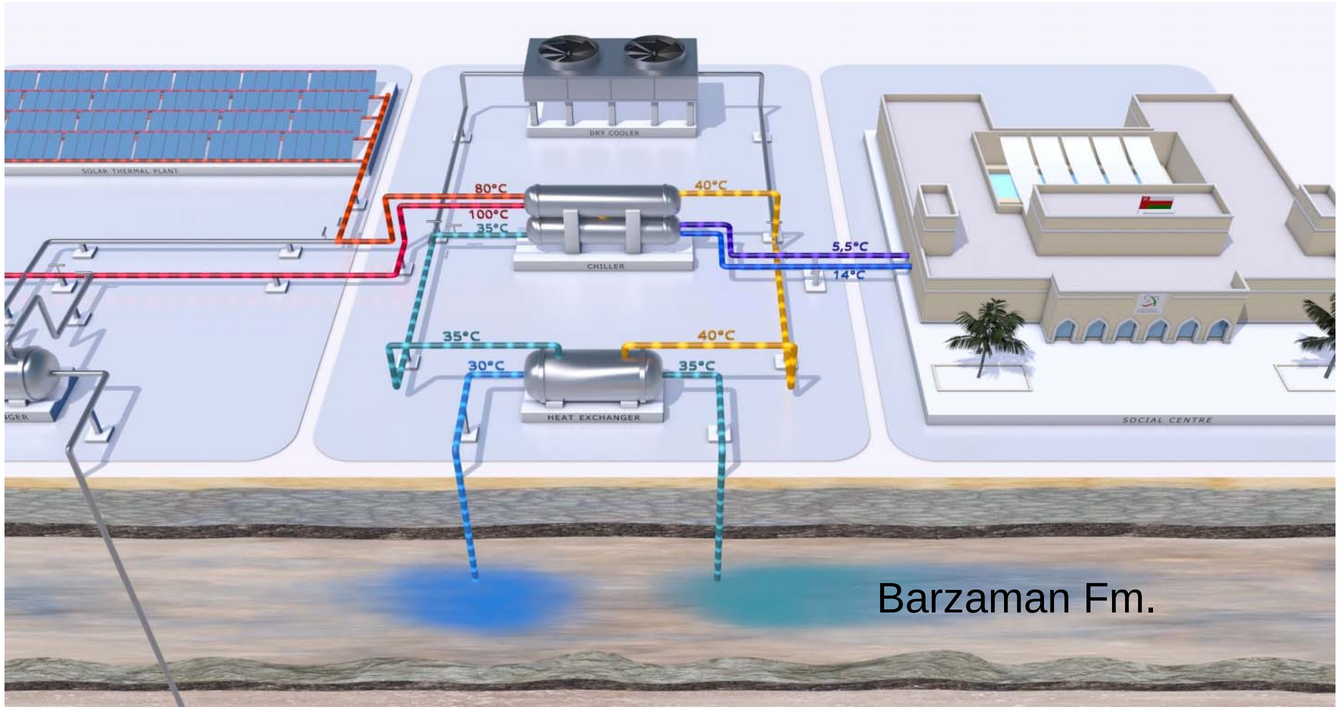
Modified after
Beavington-Penney et al. 2006

Seeb Fm. - Carbonate ramp system

- Wide facies belts
- Layer cake architecture
- Carbonate sediments (fossil-rich packstones)

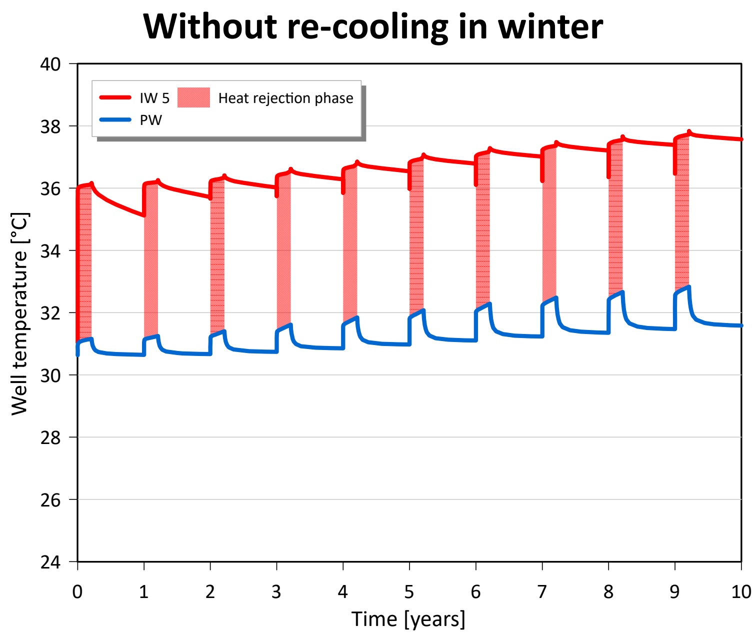


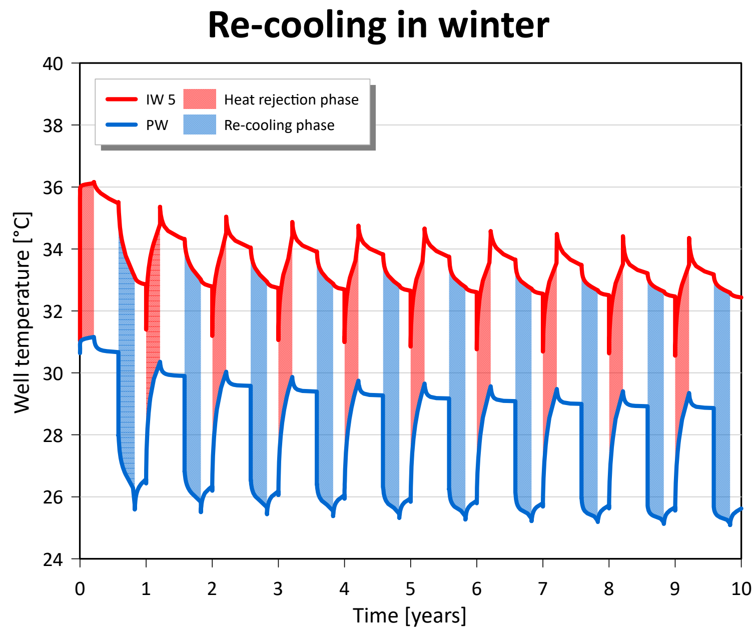
Heat rejection to the underground through a doublet



- operation per year:
  ca. 1850 h
- rejected heat 718 MWh,
  mean heat flux 392 kW,
  max. heat flux 550 kW
  temperature 40°C
  to be cooled to < 35°C
- temperature in the target
  horizon: 31°C

Comparison re-cooling vs no re-cooling in winter





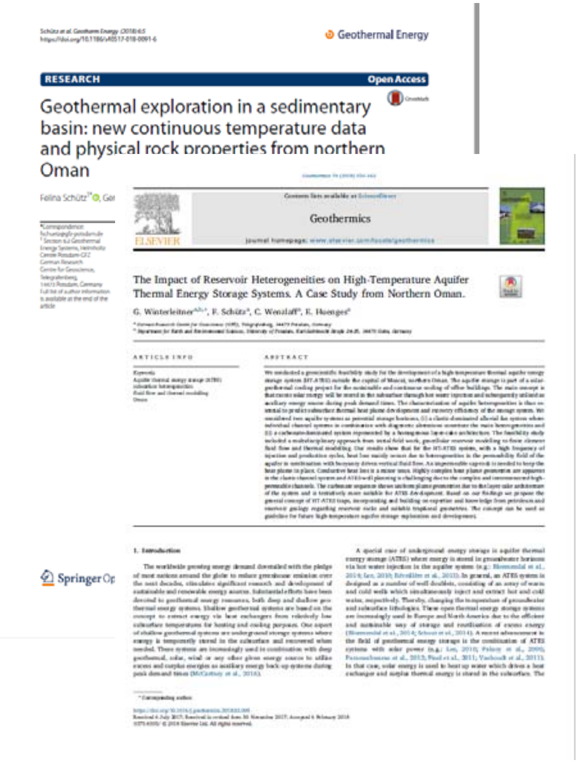
- Production temperature is increasing over time
- No sustainable process possible

- Sustainable process possible
- Amount of re-cooling could be decreased with increasing natural groundwater flow

Lessons learned

- Geothermal options in arid climates:
  - Heat recovery from deep sources to operate absorption chillers
  - ATES for continuous chill supply (either hot or cold side)
  - Underground heat rejection because dry coolers consume a lot of energy
- The underground provides stable temperature conditions throughout the year
- a doublet can be used to reject the heat of a thermally driven cooling system during the hottest summer month (T > 33° C)
- A sustainable process can be reached when the aquifer is re-cooled during the colder winter month
- Deep borehole heat exchanger are also an option; disadvantage - higher costs; advantage - less interaction with the environment

Publications/Conferences


Geothermal Energy
RESEARCH
Open Access
Geothermal exploration in a sedimentary basin: new continuous temperature data and physical rock properties from northern Oman

Geothermics
ELSEVIER
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