Catalin Teodoriu | University of Oklahoma

A DRILLER'S VIEW OF THE GEOTHERMAL RESERVOIRS USES IN GERMANY: PAST, PRESENT AND FUTURE SOLUTIONS

Geothermal energy has recently evolved from an insignificant renewable solution to one of the most promising sources of heat and electricity.

However, the evolution of technology, especially in heat conversion and utilization, has further impacted the definitions of geothermal energy and implicitly the geothermal reservoir classification and definition. From a simple temperature ranking of geothermal reservoirs, we have a detailed classification with over six categories today. Furthermore, the reservoir types for geothermal were classified as hydrothermal versus petrothermal, but today these have been intensively changed. From Hot dry rock to Enhanced Geothermal Systems (EGS) and Advanced Geothermal Systems (AGS), the geothermal reservoir definition and applications have undergone updates.

This paper presents a drillers’ approach to geothermal reservoirs by documenting methods and solutions to tap a hot source (the reservoir) and how the evolution of drilling technology impacts this source. We will show the evolution of the well construction over time and its relation to reservoir type.

A Driller's View of the Geothermal Reservoirs Used in Germany: Past, Present and Future Solutions

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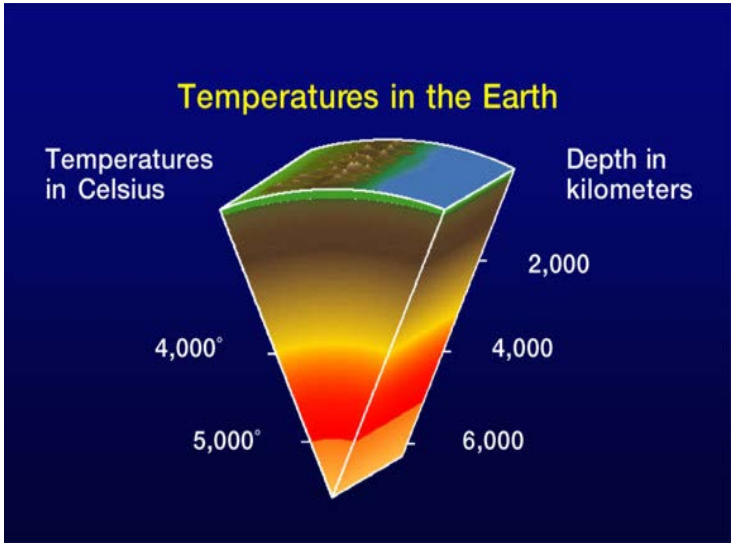
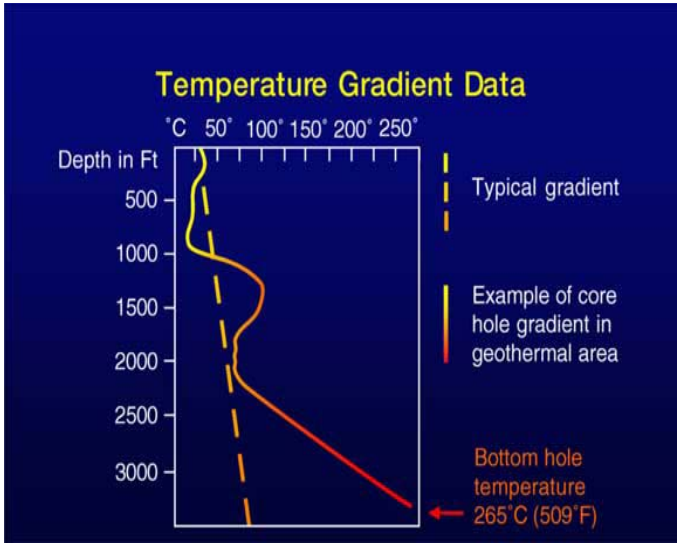
The Earth's Heat

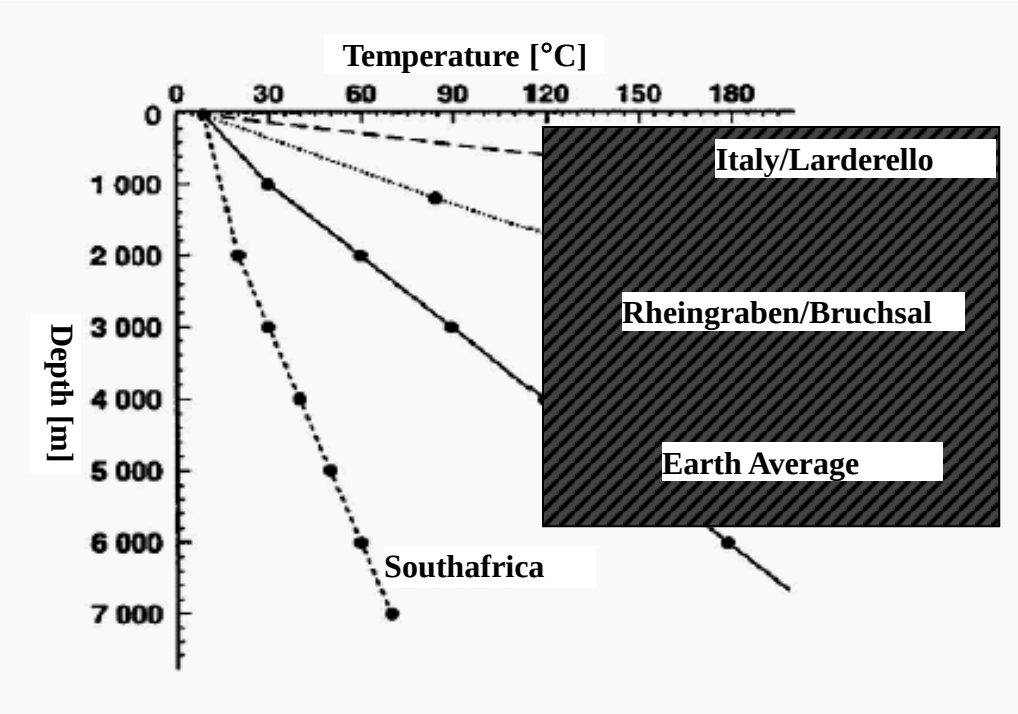
- Earth's cooling process is very slow
- Temperature of mantle has decreased by 300-350 °C in 3 billion years, remaining at ~4000 °C at its base
- 99% of Earth is hotter than 1000 ° C
- 99% of the 1% is hotter than 100 ° C





(Geothermal Education Office)

The Earth Temperature Gradient



(after Rogge)

HP/HT and Geothermal

SPE · Stavanger — Society of Petroleum Engineers

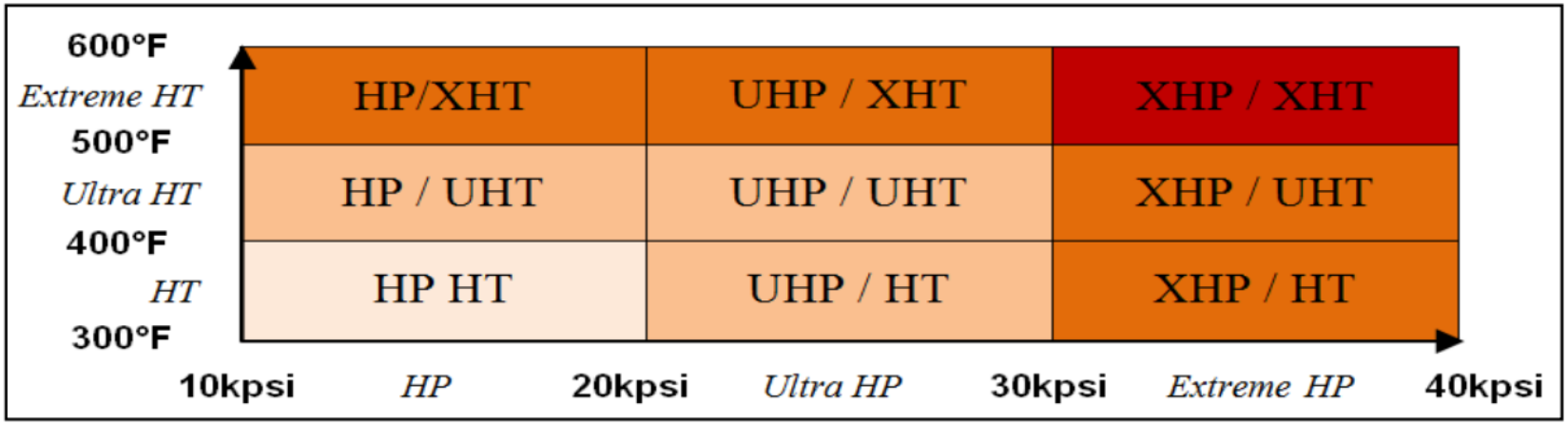
What is HP/HT?

Defined by NPD as
wells deeper than 4000mTVD and/or wells that have an expected wellhead shut-in pressure bigger than or equal to 690bar (10000psi), and/or wells with temperatures higher than 150degC.

Is this your definition too?

Peder Pedersen

Where is GEOTHERMAL?



Shadravan, 2012

HP/HT Classification

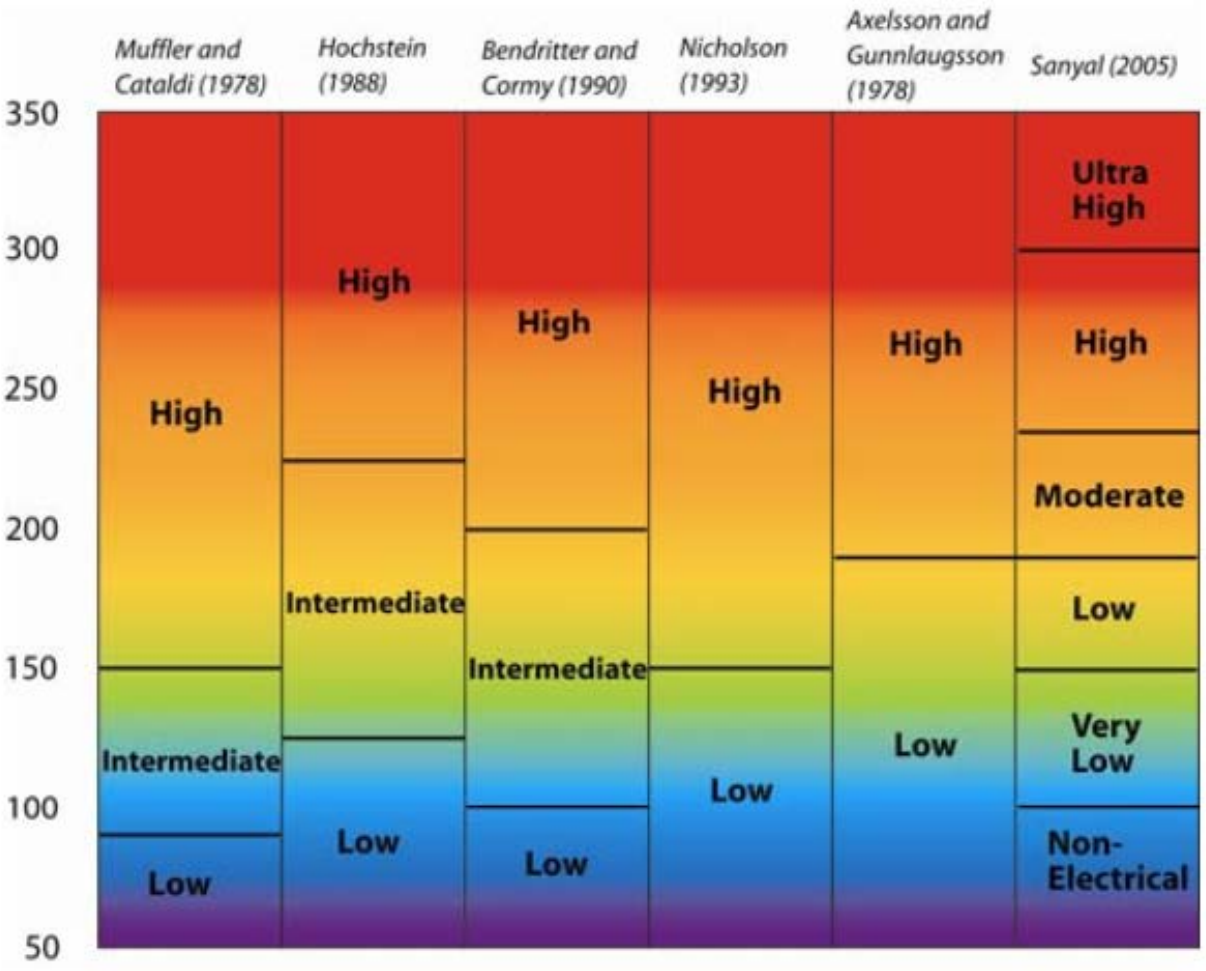
- HT Wells:
  - Steam Injection wells (200 -350°C)
  - Geothermal wells (80(!) – 200°C)
  - Wells in Underground combustion Fields (80-180°C)

- HP Wells:
  - Deep wells
  - Wells in low to moderate depth but under high pressure

Redefining Geothermal Wells

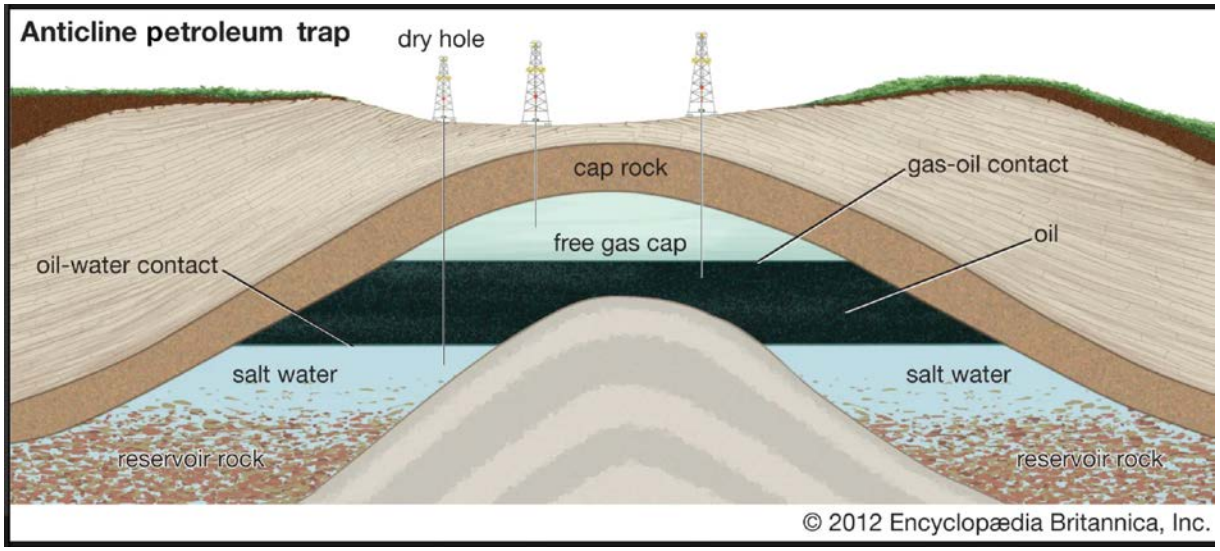
- High temperature only (T > 177°C), hence shut-in pressure is less than 103 MPa
- High temperature and high pressure, hence the shut-in pressure will exceed 103 MPa
- Moderate temperature wells (80°C < T < 177°C), pressure not expected to exceed 69 MPa
- Low temperature wells, temperature less than 80°C

Geothermal re-Classification

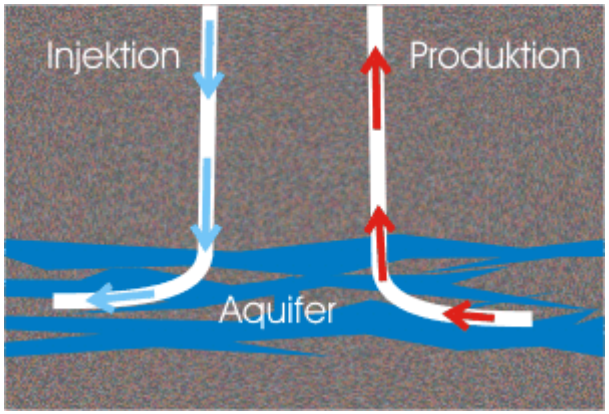


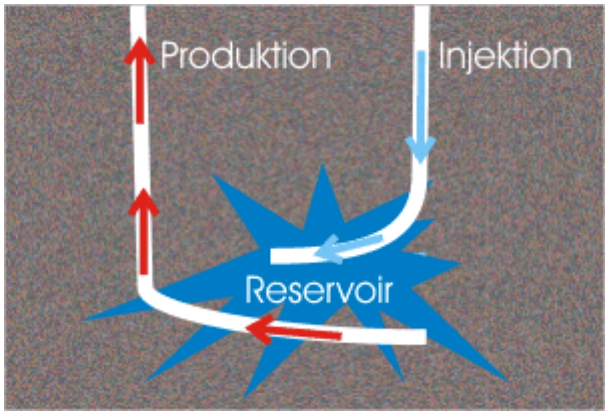
Williams et al. (2011)

What is a reservoir?



A subsurface accumulation of hydrocarbons (primarily oil and/or natural gas) within porous or fractured rock formations.

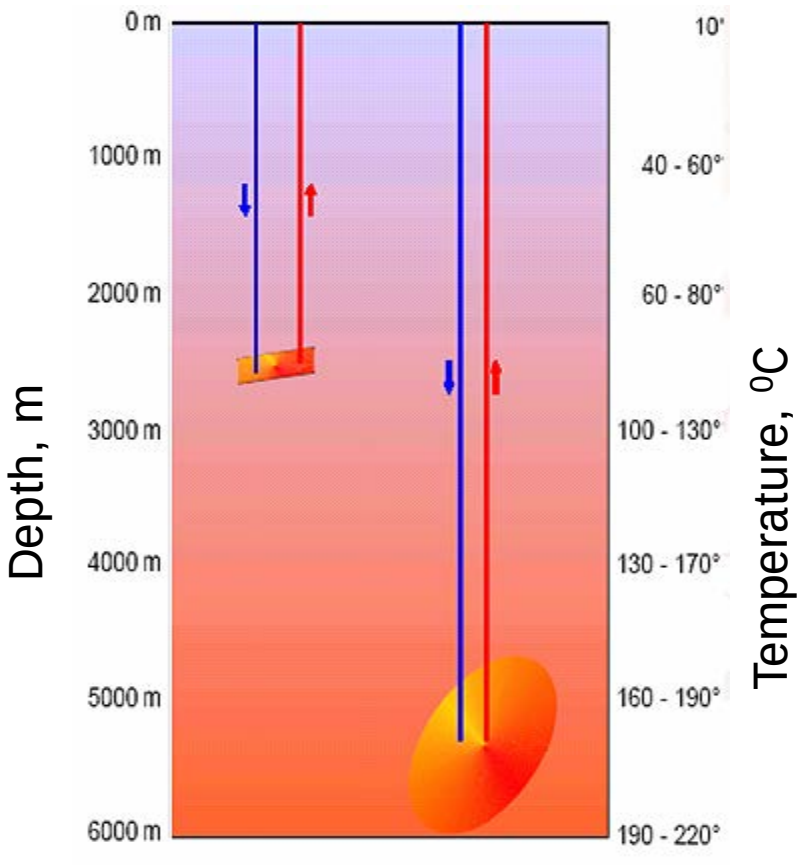


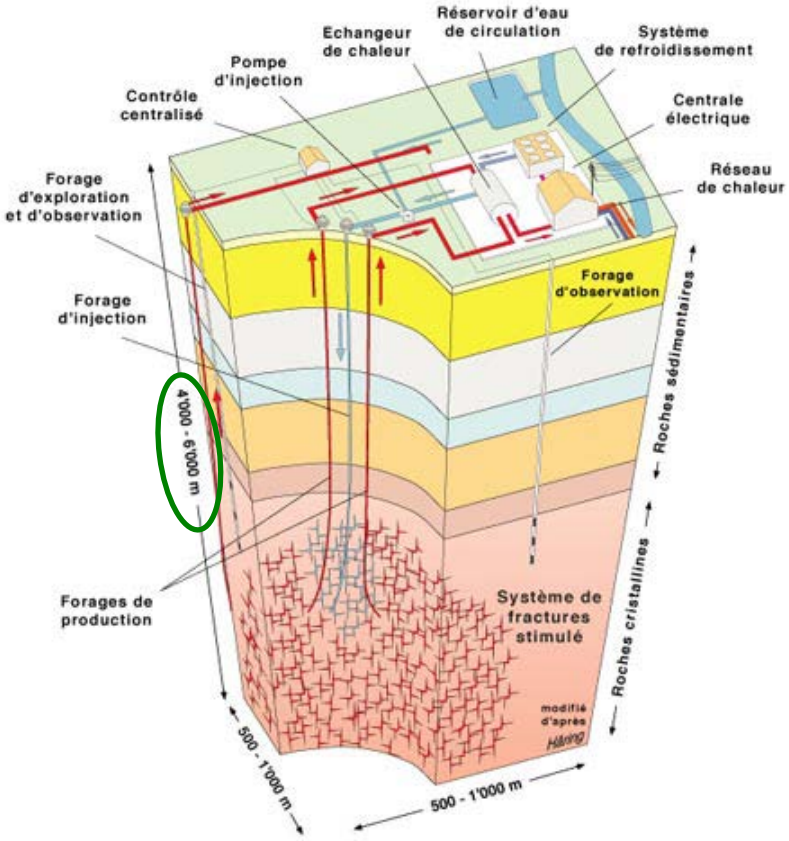


A subsurface accumulation of HEAT within pore space or directly in the rock formations.

Source: BGR

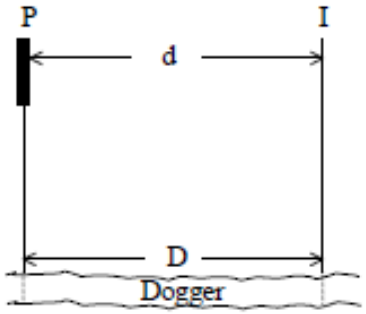
Complexity of Geothermal Projects - Depth





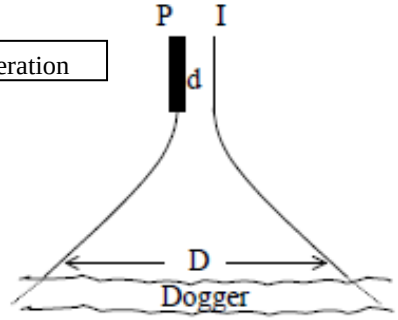
(Häring, M. & Hopkirk, R., 2002)

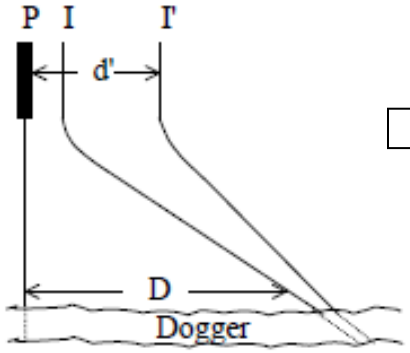
Geothermal Doublets Topology



first generation

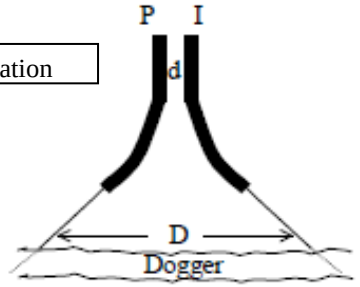
third generation





second generation

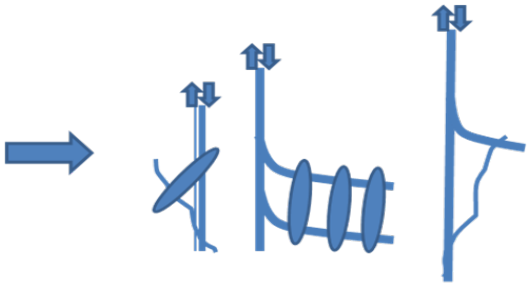
fourth generation



Geothermal Options

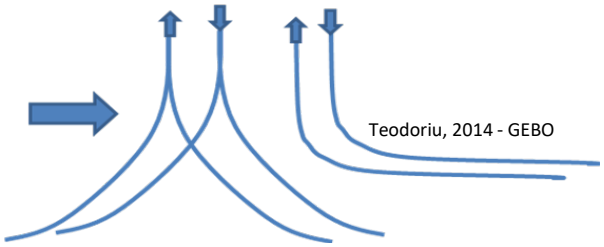
One Well Concepts

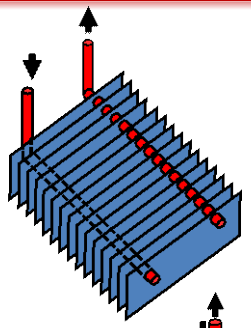
- Genesys-Typ
- gebo-multilateral with multifracs
- gebo-lateral through faults

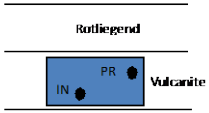


Two Well Concepts

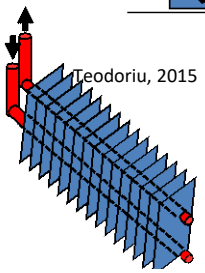
- Horizontal wells
- Fishtail

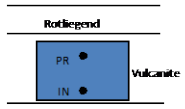


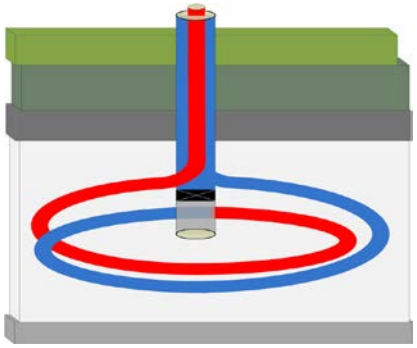




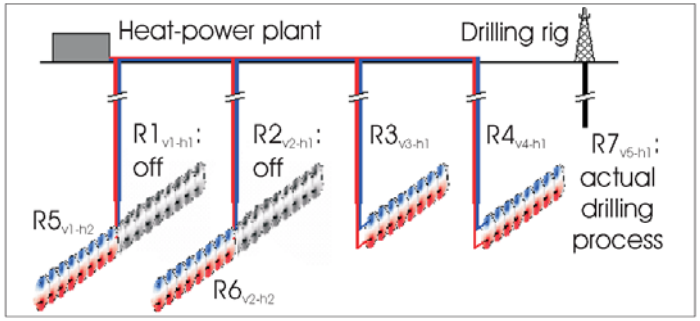
Teodoriu, 2015







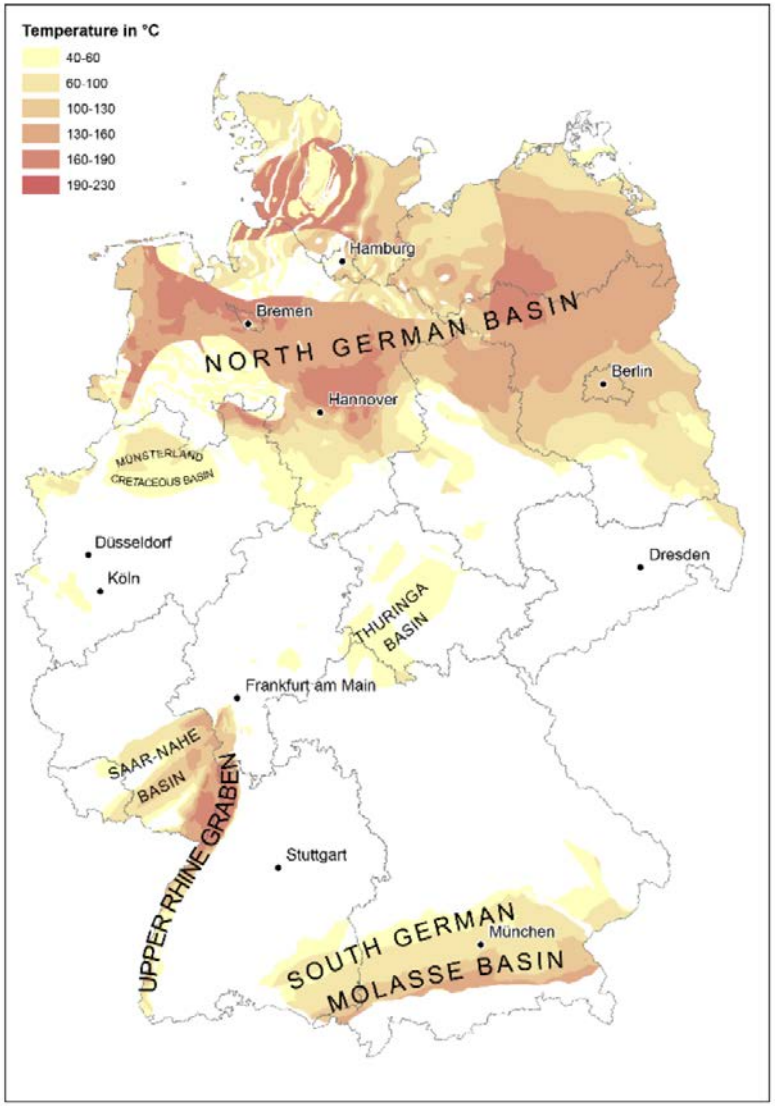
Innovative Closed System



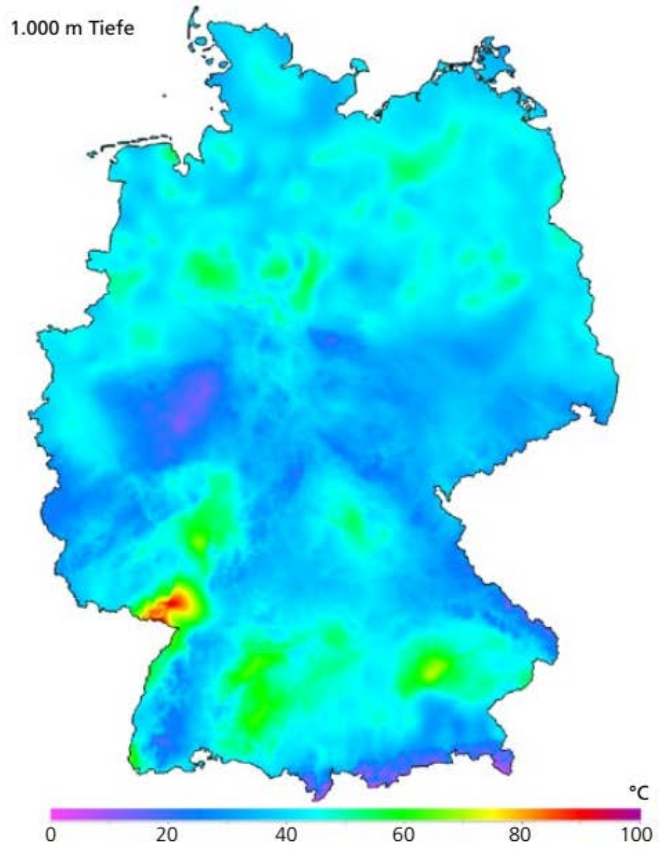
Heidinger, 2014

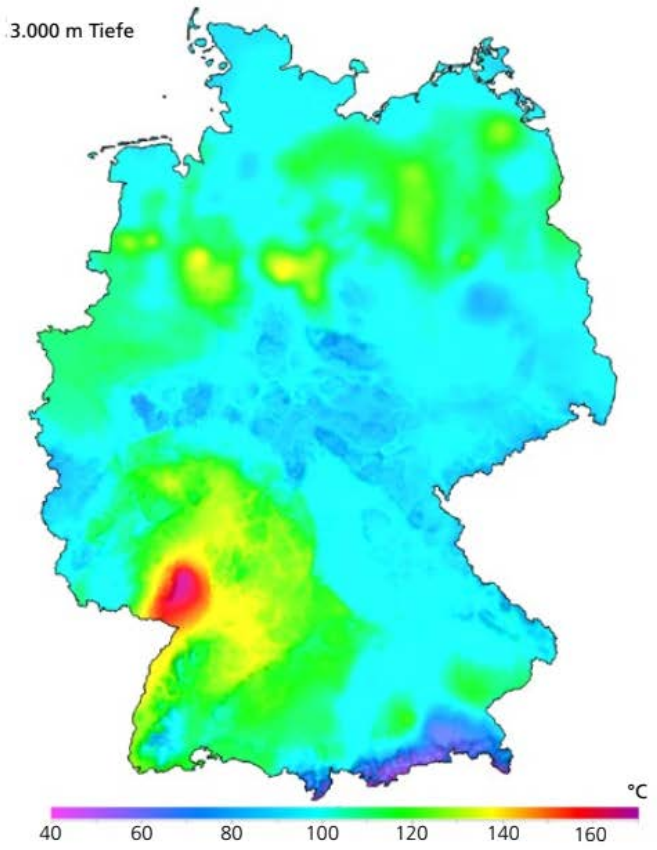
Geothermal Well Farms

Geothermal Reservoirs (hydrothermal) in Germany, after Webber et al. 2020



Geothermal temperature at different depths, Bracke et al.



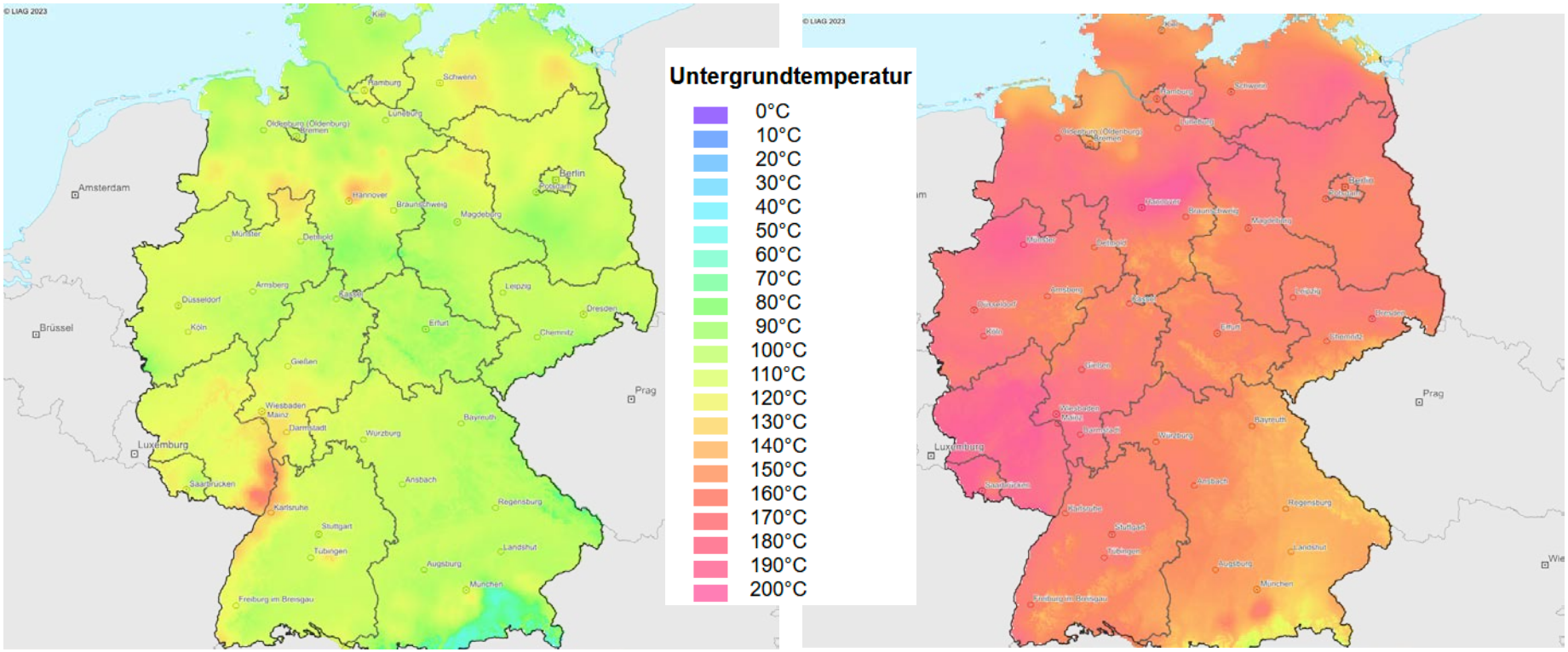


What is a Geothermal Reservoir for Germany?

- A formation that has a hot fluid to be extracted (hydrothermal) – moderate geosteering
- A formation that require artificial pathways to circulate a fluid (EGS) – intensive reservoir stimulation
- A formation with sufficient temperature and heat transfer potential (AGS) – intensive geosteering
- An existing oil and gas reservoir with mixed flow through porous media and fractures
- A formation that allows co-production of critical minerals

Geothermal Reservoir for Germany

- Deep drilling is the best solution for Germany Geothermal future.



3000 m

5000 m

Conclusions

- Geothermal needs
  - Drilling Faster
  - Drilling Deeper
  - Drilling Cheaper
  - Drilling Cleaner

However, in order to reduce total well costs by18% , drilling rig costs, drilling time and trip time must each be reduced by 50%.

Further cost reductions can only be achieved by reviewing current well construction strategies.

- Geothermal also means drilling a BIG BORE to depths beyond what conventionally done for oil & gas

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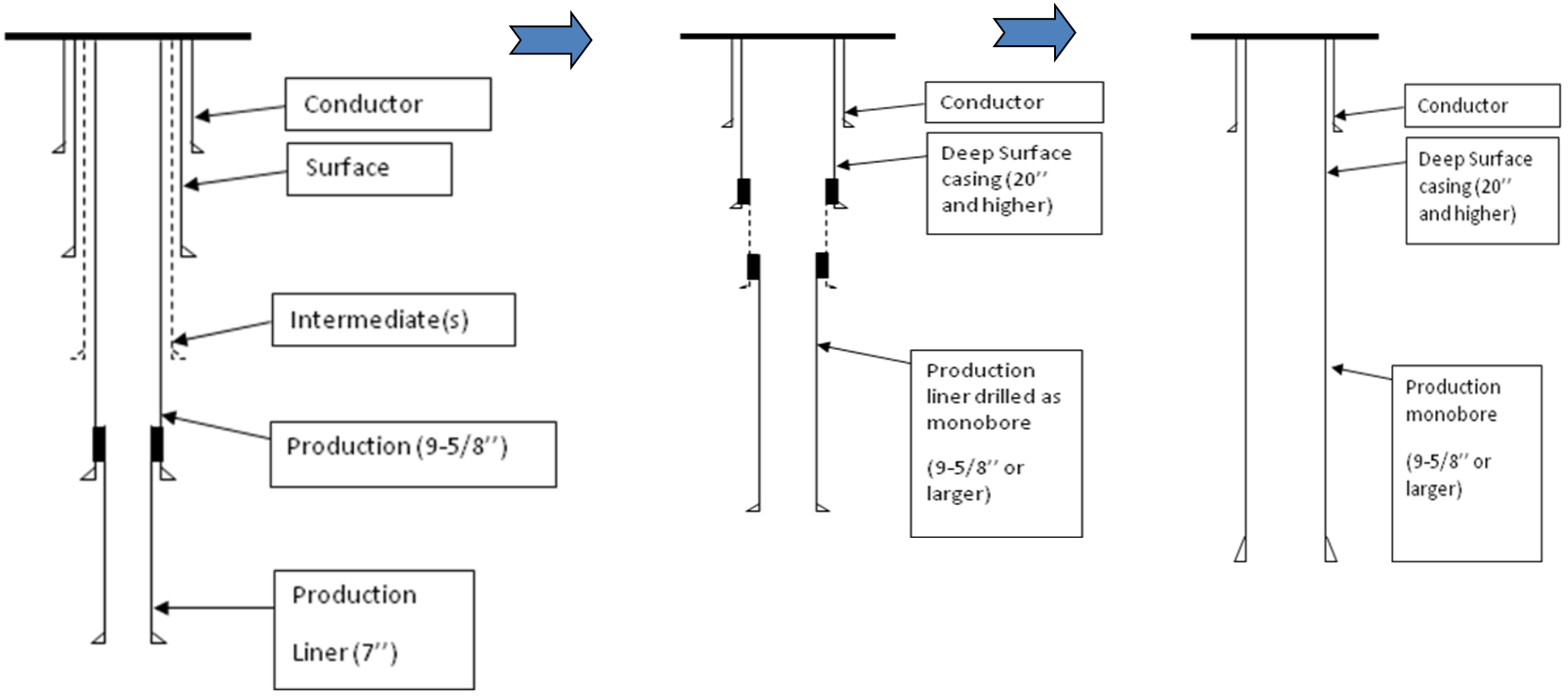
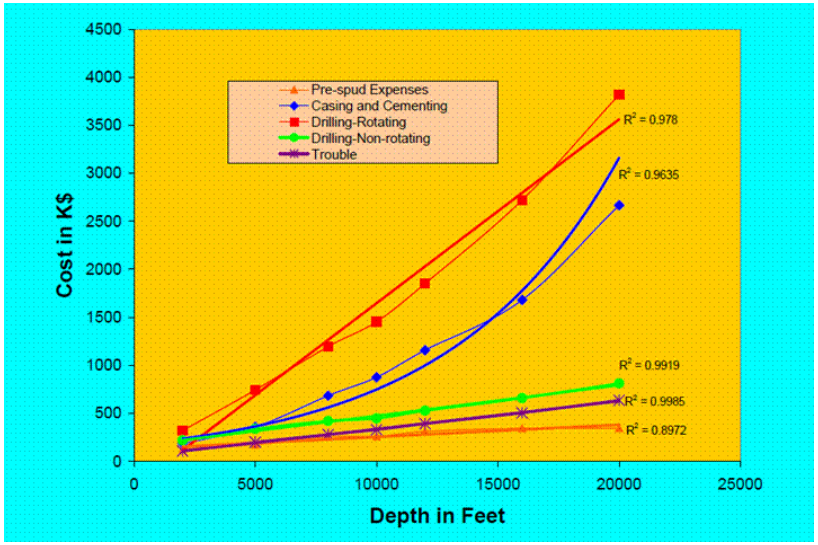
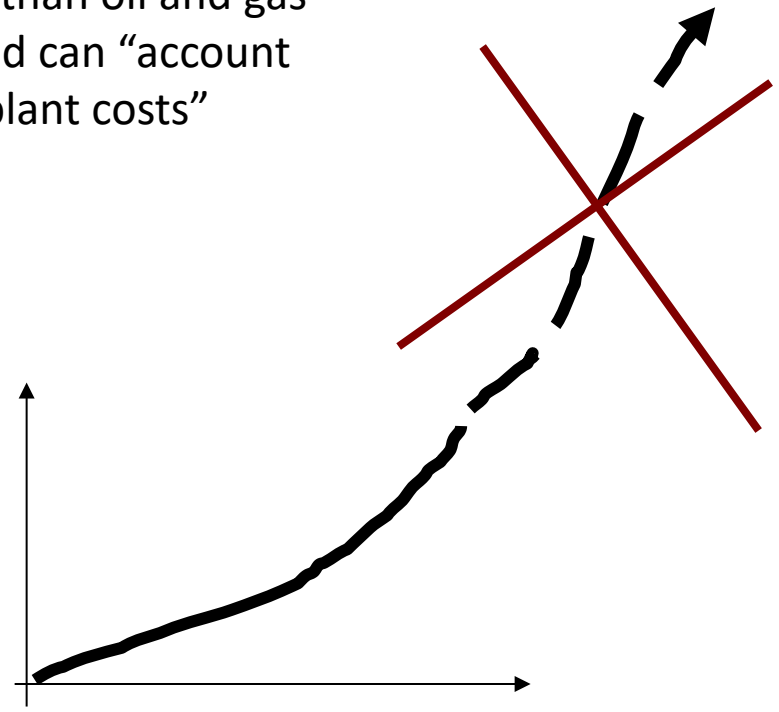
A possible Evolution of Geothermal Well Construction



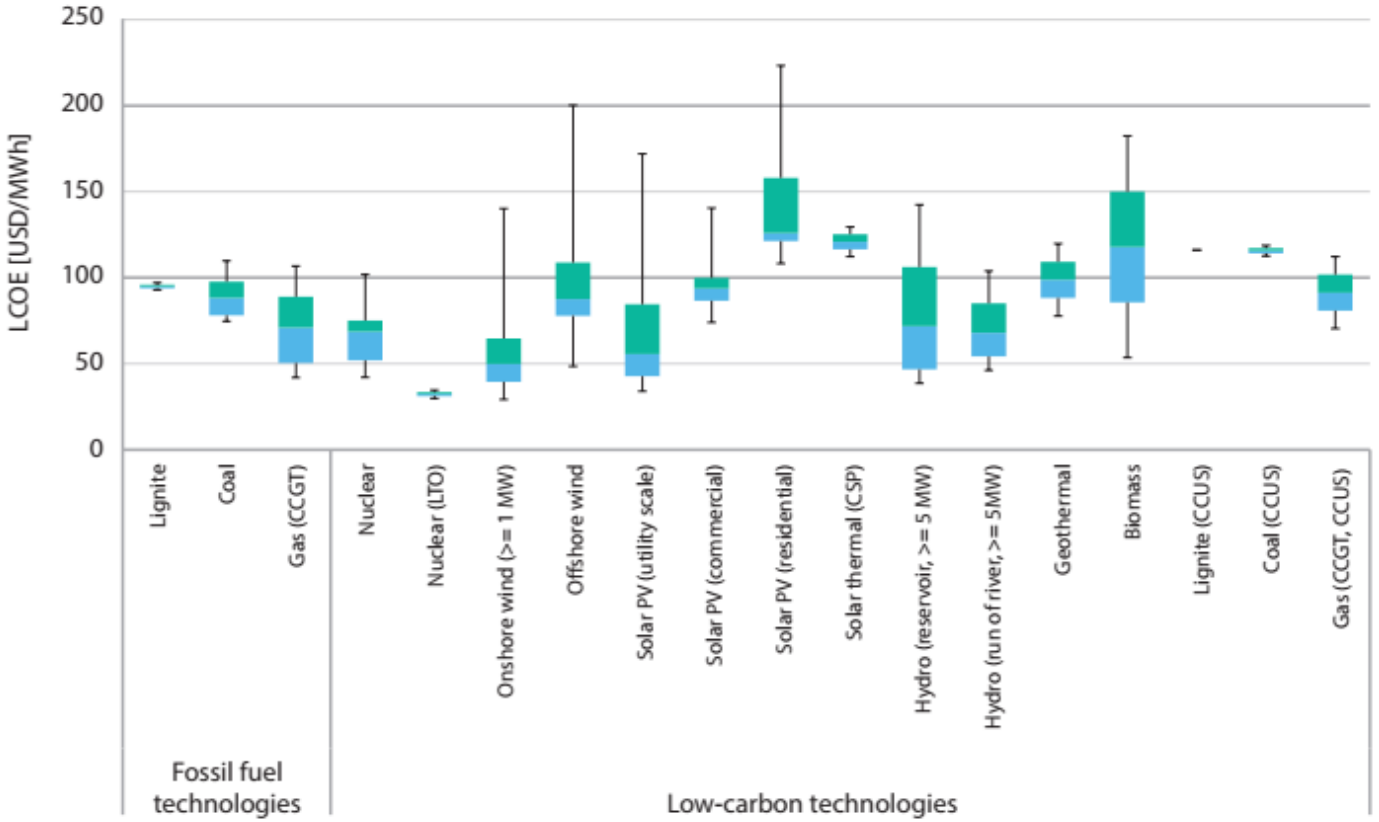
The Challenges of Deep Heat Mining

For deep heat mining, drilling & completions costs can be “2-5 times greater than oil and gas wells of comparable depths” and can “account for 42% to 95% of total power plant costs”





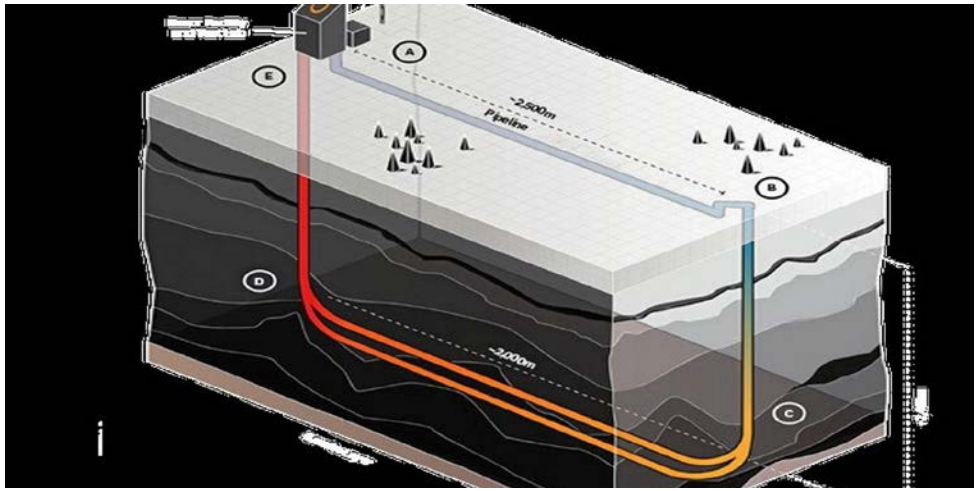
Cost-Competitiveness of Renewable Technologies

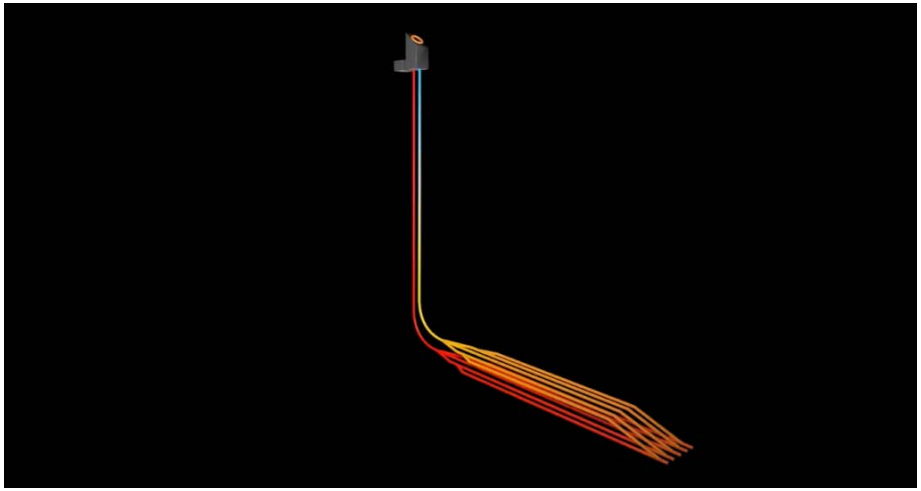


Note: Values at 7% discount rate. Box plots indicate maximum, median and minimum values. The boxes indicate the central 50% of values, i.e. the second and the third quartile.

IEA, 2022

Geothermal Extreme





Source: BP and Chevron become part-owners of deep-geothermal innovator Eavor | Upstream Online

Eavor and Deep Capital to build five geothermal projects (thinkgeoenergy.com)