

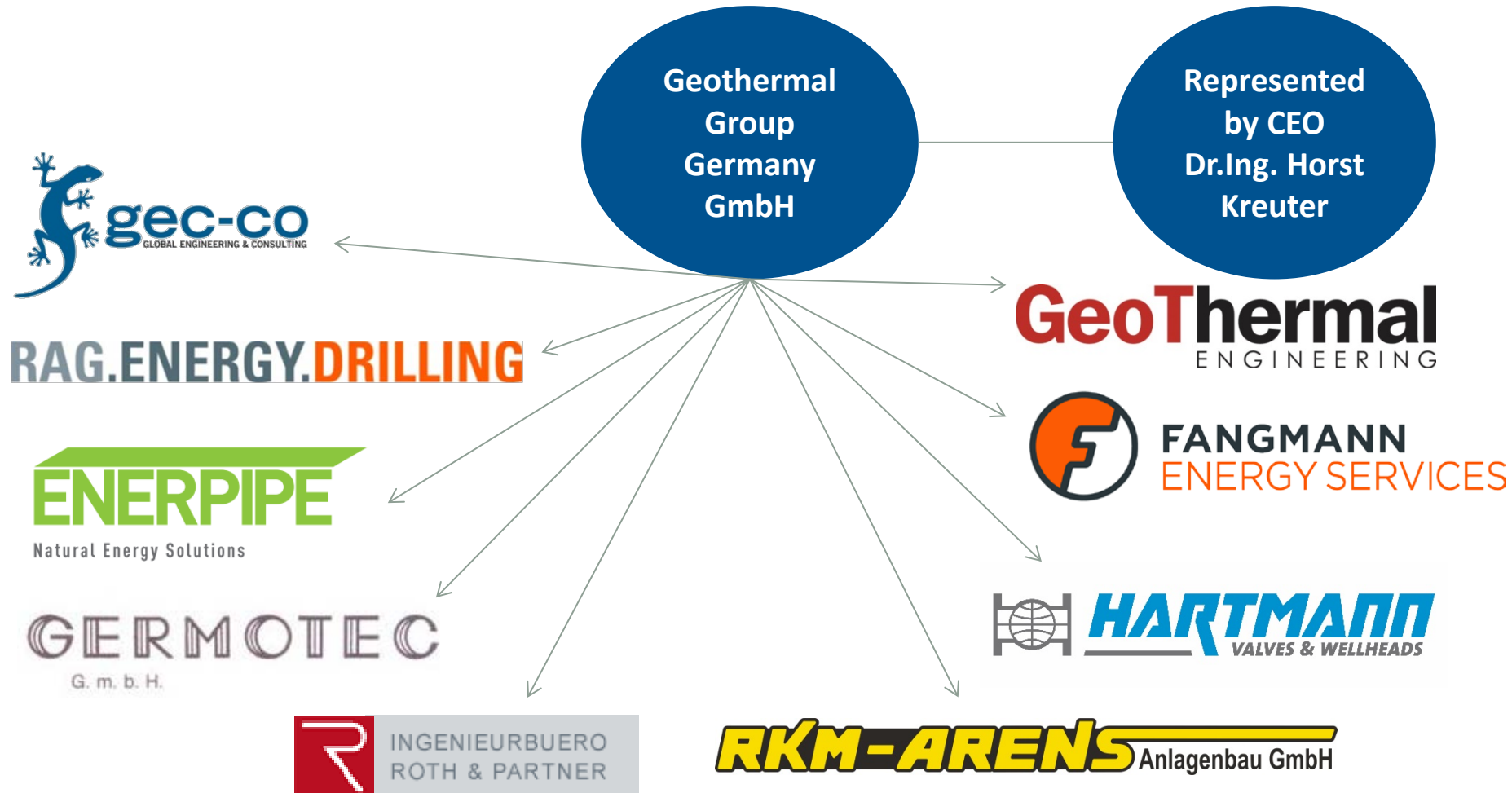


EGS Systems – Concepts and Project Examples

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1. Group of Companies



1. EGS- Definition

Enhanced Geothermal Systems / Engineered Geothermal Systems

- The use of any stimulation method which is used to enhance the productivity / injectivity of a well
- The stimulation methods are executed after initial drilling into the reservoir
- The stimulation methods used in an individual case depends on:
 - Geological setting (porous or fracture controlled reservoir, stressfield, ...)
 - Reservoir parameters (rock type, fluid composition, ...)
 - Initial permeability (low or medium)
 - Cost of stimulation (in budget?)
- Any use of a stimulation method defines a project as EGS?
- Only when a very low permeability is enhanced considerably?

2. EGS Technologies

Stimulation Methods

- Chemical stimulation
 - Dissolvable rocks (carbonates, dolomites, ...)
 - Fracture fillings / cuttings
 - Acidizing
- Mechanical enhancement
 - Extended drilling (deeper or wider drilling)
 - Undercutting
 - Radial drilling
 - Multilateral drilling
- Hydraulic stimulation

3. EGS: Hydraulic Stimulation

- Initial Hot Dry Rock concept
 - Extend application of geothermal outside of existing reservoirs
 - Zero or very low initial permeability
 - Opening fractures in firm rock
 - Sufficient fracture permeability
 - Sufficient heat exchange surface
 - Injection and production well(s)
 - Fracture network interconnecting injection and production well(s)
 - Intended flow rate: > 50 l/s
 - Keep fractures permanently open
 - The fluid in the fractures should not be lost (closed reservoir)
 - Artificial subsurface heat exchanger

3. EGS: Hydraulic Stimulation

Challenges

- Size and shape of heat exchanger
- No 100% dry rock
- First fracture takes up all the fluid and stops new fractures to open
 - Temporarily chemical plugging of initial fracture
 - Stimulation of individual sections of the well
- Permeability < 50 l/s (example Soultz sous Forets)
- Loss of fluid
- Seismicity and public acceptance

4. EGS in the Geothermal Market

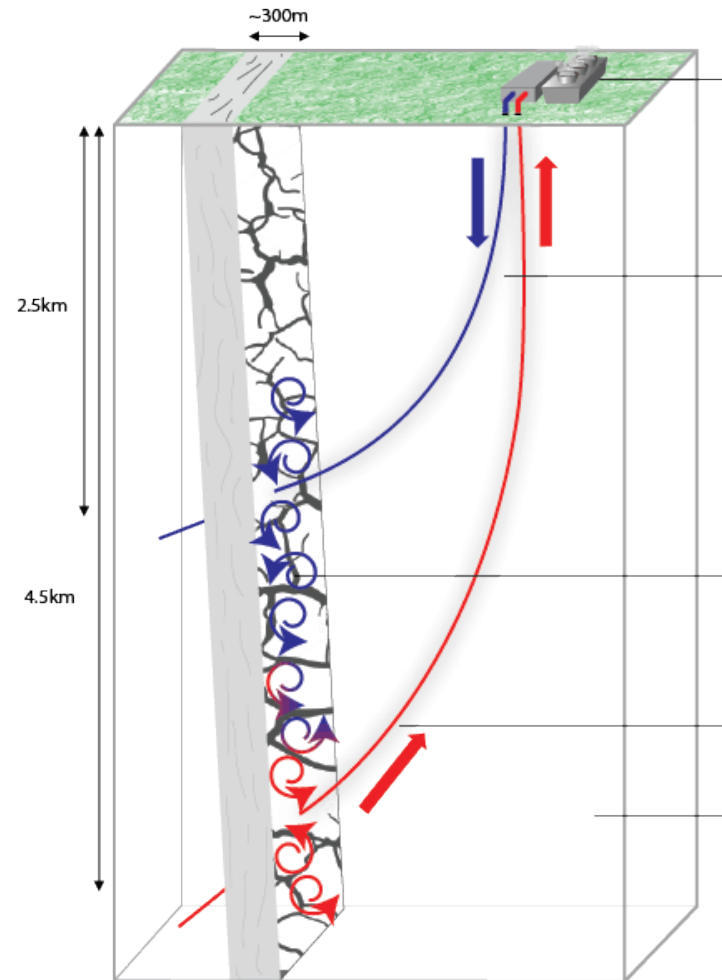
Research & Development

- Hot Dry Rock is not market ready
- Research projects
 - France (Soulz sous Forets, Alsace)
 - Britain (Rosemanoves project, Cornwall)
 - Australia (Cooper Basin, South Australia)
 - USA (Newberry Oregon)
 - South Korea (Pohang, seismicity)
 - Britain (United Downs)
 - Switzerland (Geo-Energie Suisse)

5. New Concepts

United Downs, Cornwall

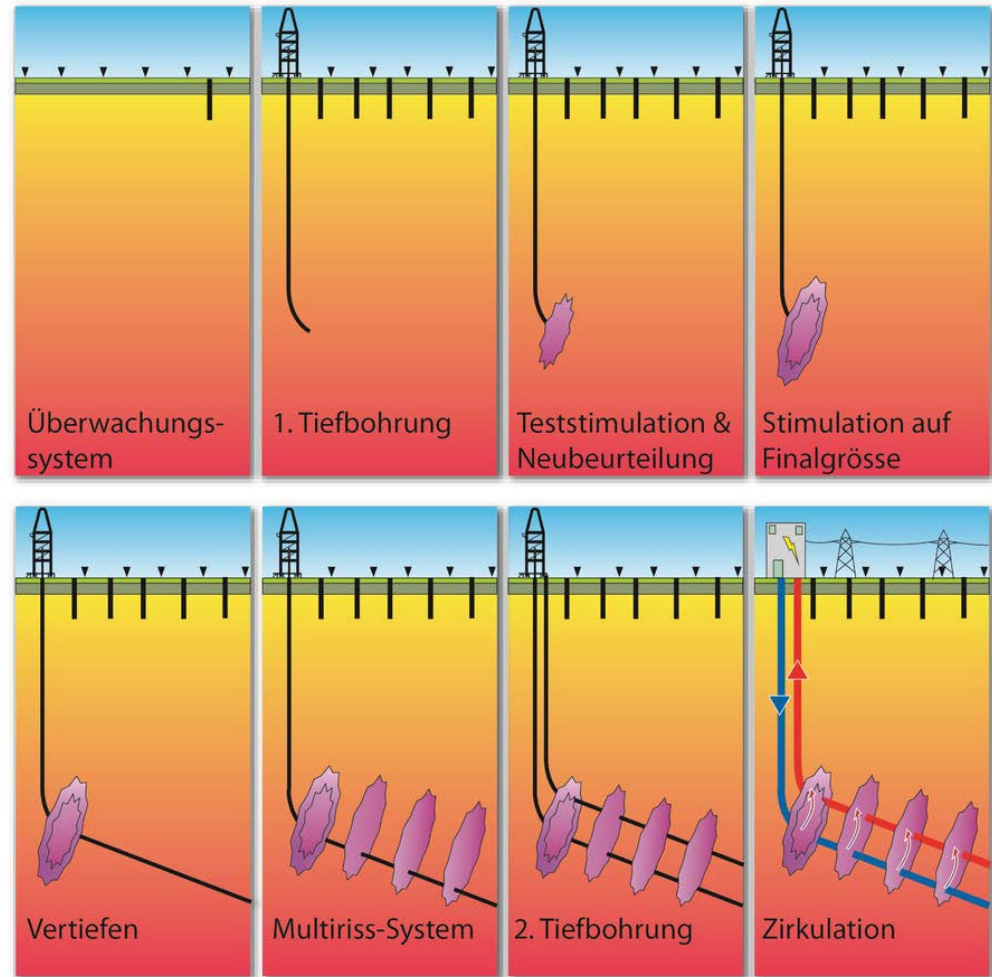
- Hot granite rock
- Large subvertical fault zone
- Circulation in fault zone
- EGS (if necessary)
 - Chemical stimulation
 - Side track
- Drilling of first well ongoing



5. New Concepts

Geo-Energie Suisse

- Hard rock
- Hydraulic stimulation
- Sequential stimulation
- Horizontal wells
- First project in preparation



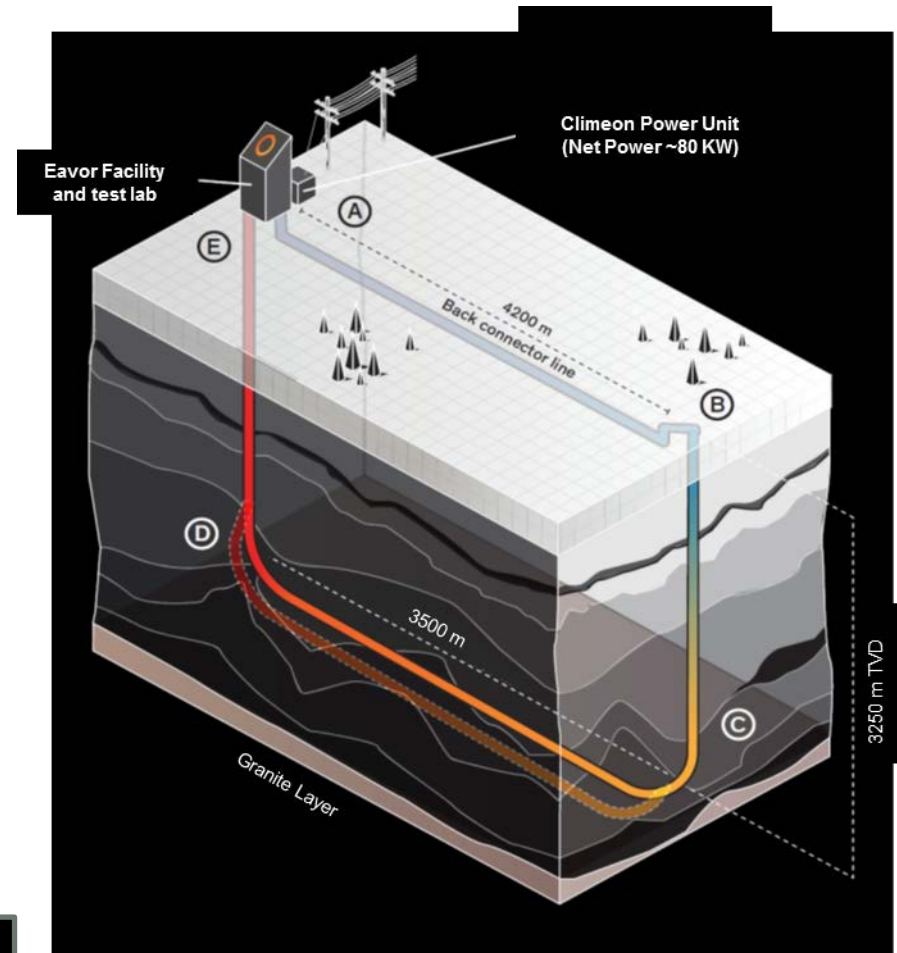
6. Old Concept – New Ideas

Closed Loop System

Advantages

- Initially sedimentary rocks
- Drilling one closed loop
- Drilling multiple loops
- Closed system
- No permeability required
- No seismicity
- Public acceptance

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6. Old Concept – New Ideas

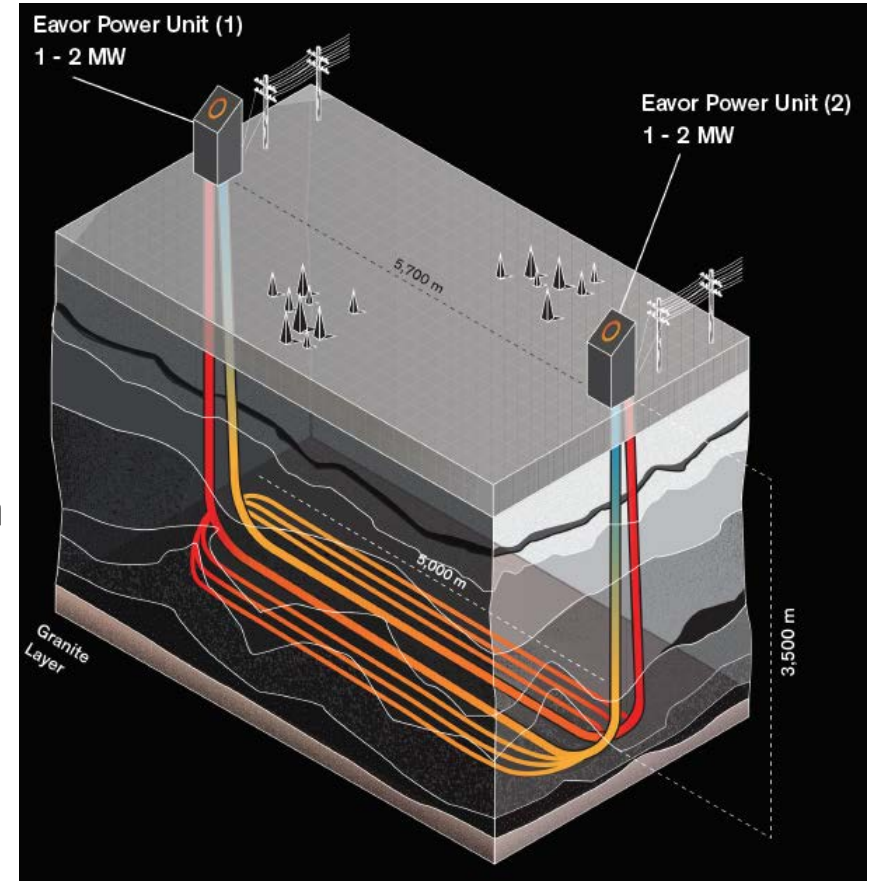
Closed Loop System

Challenges

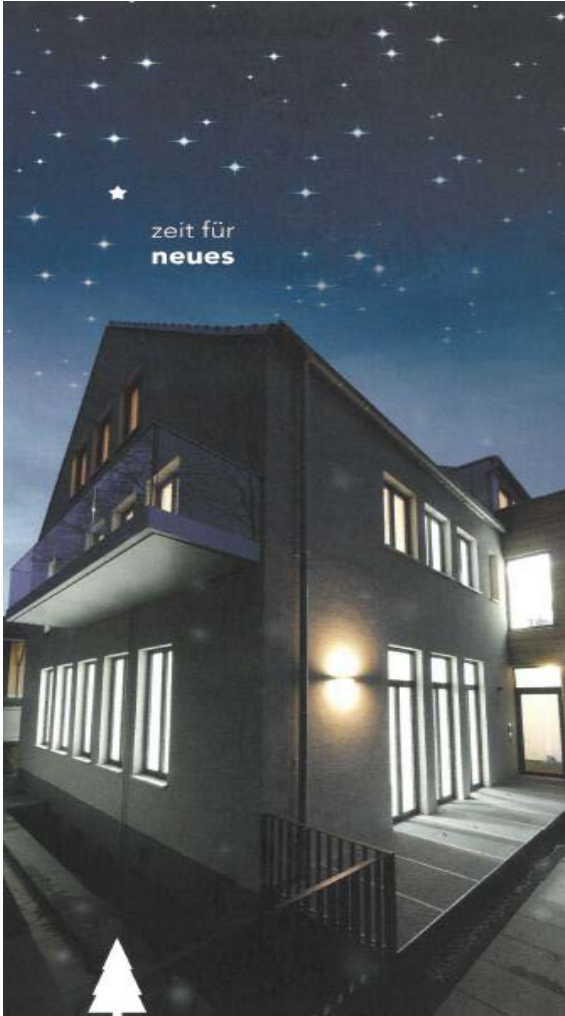
- Drilling technology
- Drilling cost
- Heat in place
- Sustainable heat source extraction

Future

- Optimizing system and drilling
- Hard rock (granite)
- Temperatures $> 150^{\circ}\text{C}$



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Çok Teşekkürler!