Geothermal drilling – technologies and opportunities

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Outline

- Background
- Geothermal drilling challenges
- Drilling and rock breaking
- Paths to drilling improvements

About IRIS

- Client-oriented research institute – Energy, Environment and Social Science
- Clients from trade, industry and public sector – nationally and internationally
- Ca. 200 employees, from 23 different countries, 92 PhDs
- Main office in Stavanger, Norway

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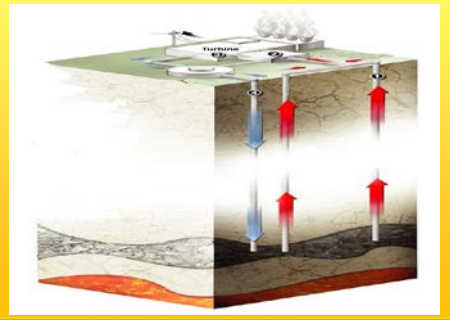
IRIS Energy – main areas

Drilling & well technology

Reservoir technology

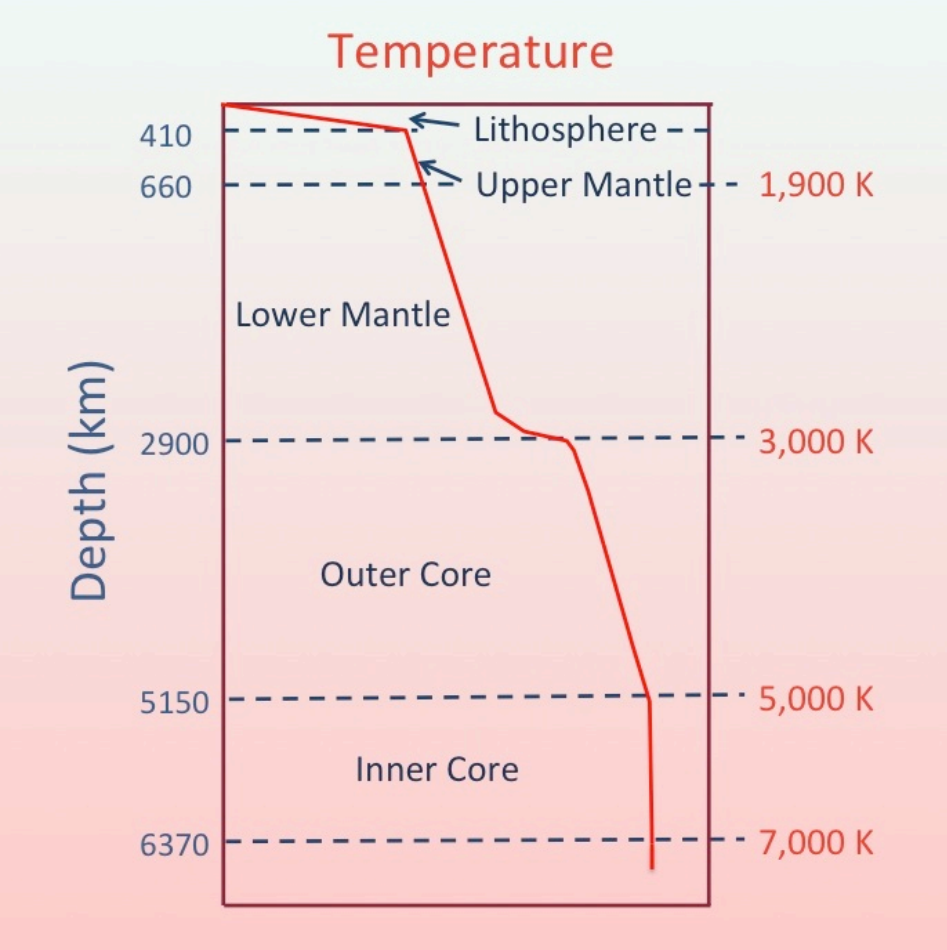
Research facilities

Green technologies



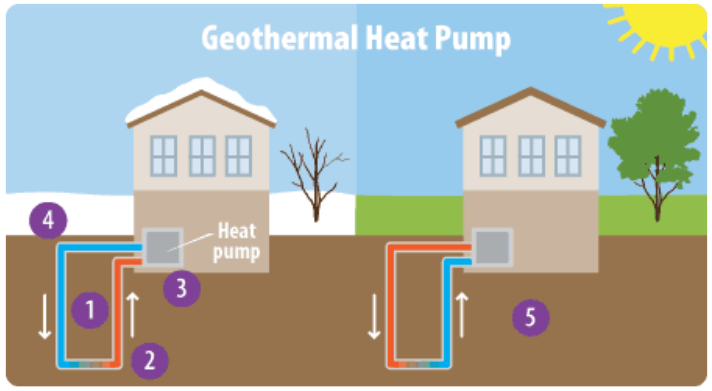
Geothermal energy resources

- Geothermal gradients
  - 5-70 °C/km in the earth's crust (typically ~30 °C/km)
  - Anomalies occur (volcanic regions)
- 'Unlimited' energy resource base
  - A matter of well depth
  - MIT report (2006): potential for 100 GW_e in the US
- **How to harvest the thermal energy resources?**

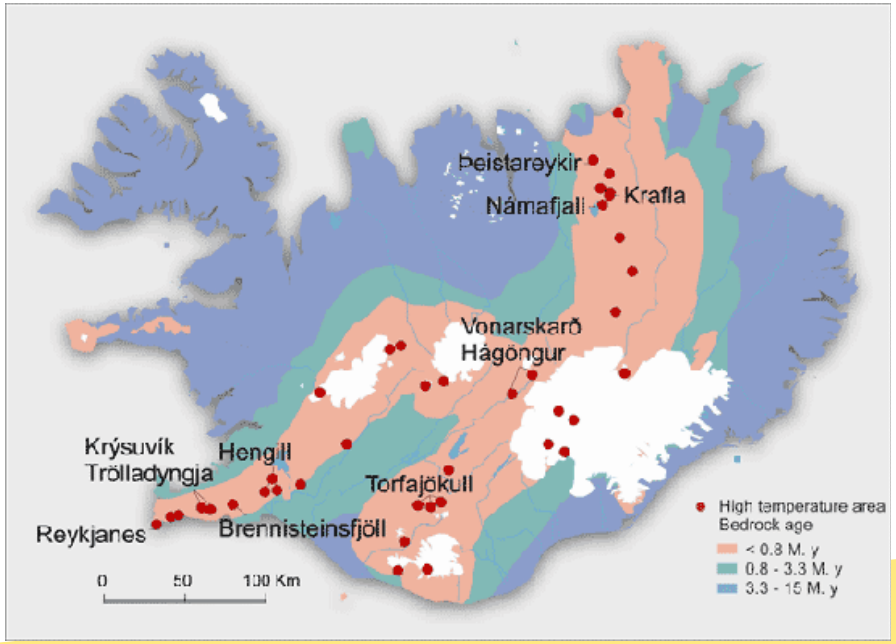


Geothermal energy today

1. Low temperature systems
   - With heat pump systems
   - Seasonal storage
   - Shallow wells (some 100 meters)
   - Relatively “easy” drilling (hammer/percussive)
   - Cost-effective heat and increasingly popular



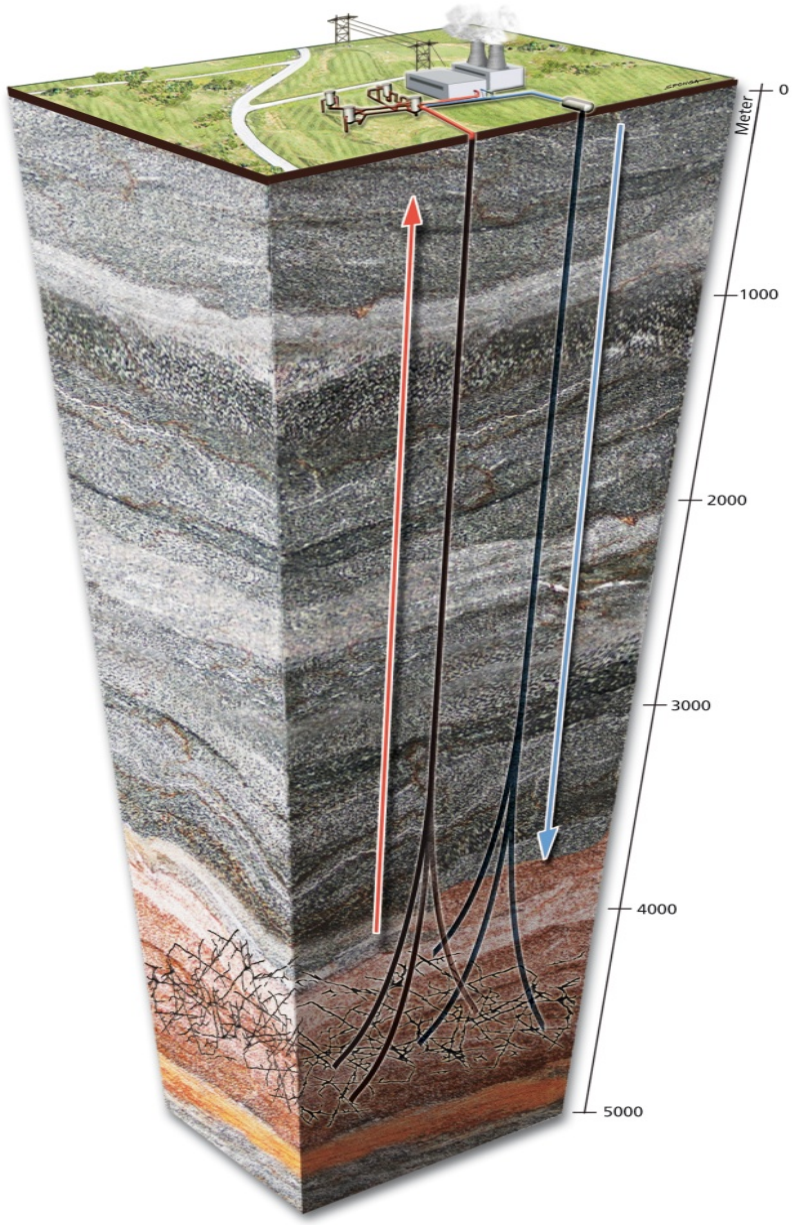
2. High temperature systems
   - Limited to “hydrothermal” sites – typically volcanic regions
   - Up to ~4 km depth
   - Sufficient water and high natural permeability
   - Suitable for power production – typically ~200 °C steam
   - Limited resource base (few regions in the world)



Unconventional geothermal well types

- “Hot dry rock” or EGS (engineered/enhanced geothermal systems)
  - Possibility of “universal” geothermal solution
  - Need to drill sufficiently deep (hot enough)
  - Understanding the reservoir
  - Necessary to circulate through a large fracture network (subsurface heat exchanger)
- Future: Extreme temperatures (supercritical fluids)
  - 400-500 °C, high pressure
  - Hot research topic

- **A vast resource base is available**



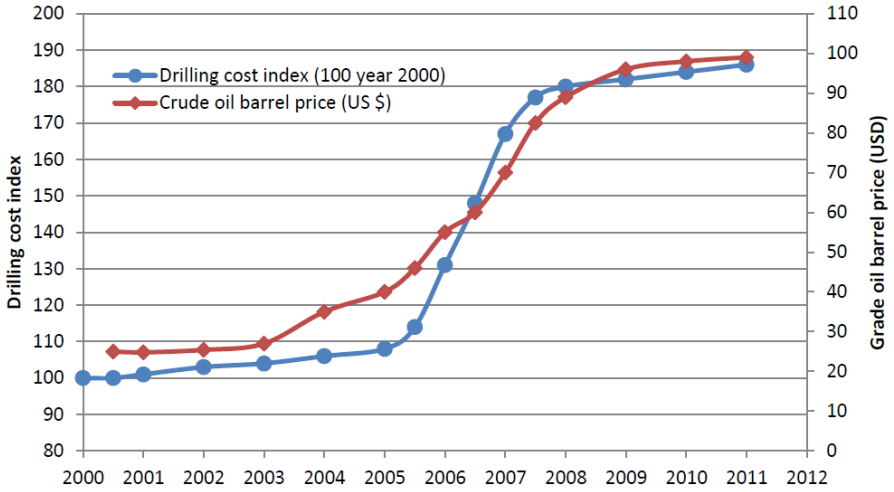
Deep geothermal vs. oil & gas

- Geothermal wells are similar to oil & gas:
  1. Drilling
  2. Completion
  3. Maintenance/ intervention (production)
  4. Plugging and abandonment

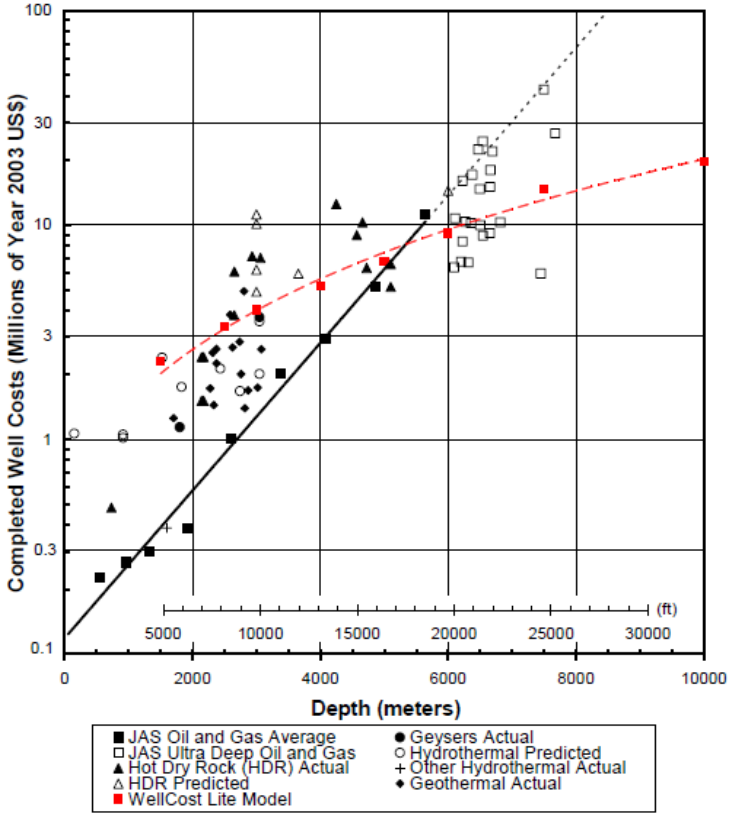
- Technology transfer (oil & gas vs. geothermal)?
  - Different incentives for cost reduction
  - Shared markets yield high costs (compete for rigs, crew etc.)
  - Geothermal as first mover?

Cost of geothermal drilling

- Literature: 30-70 % of plant cost on well construction
- IEA (2011): Key R&D priority on cost-effective drilling technology
- EGEC (2016): Target of 25 % well construction cost reduction



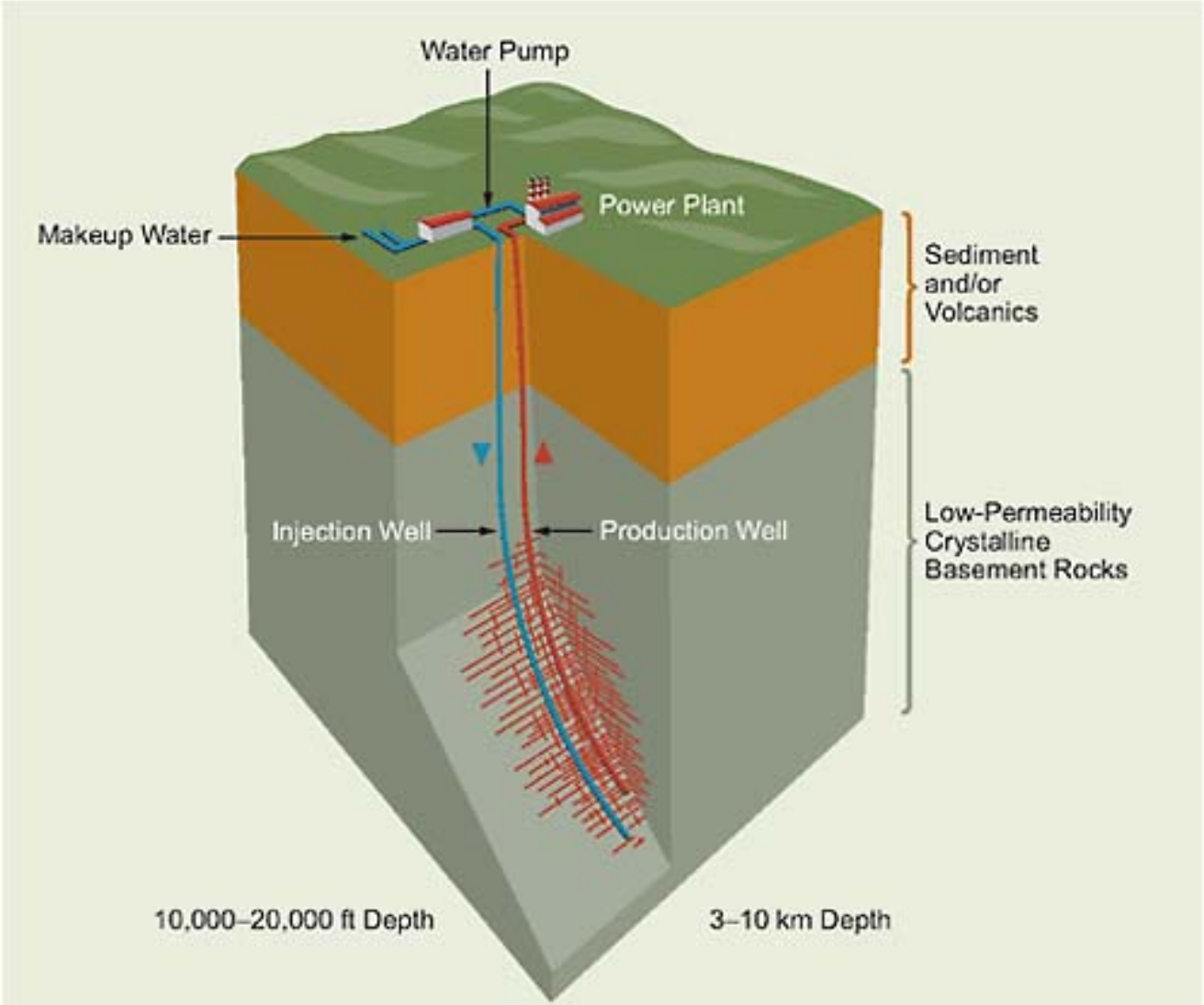
"Report on geothermal drilling", GEOELEC (2013)



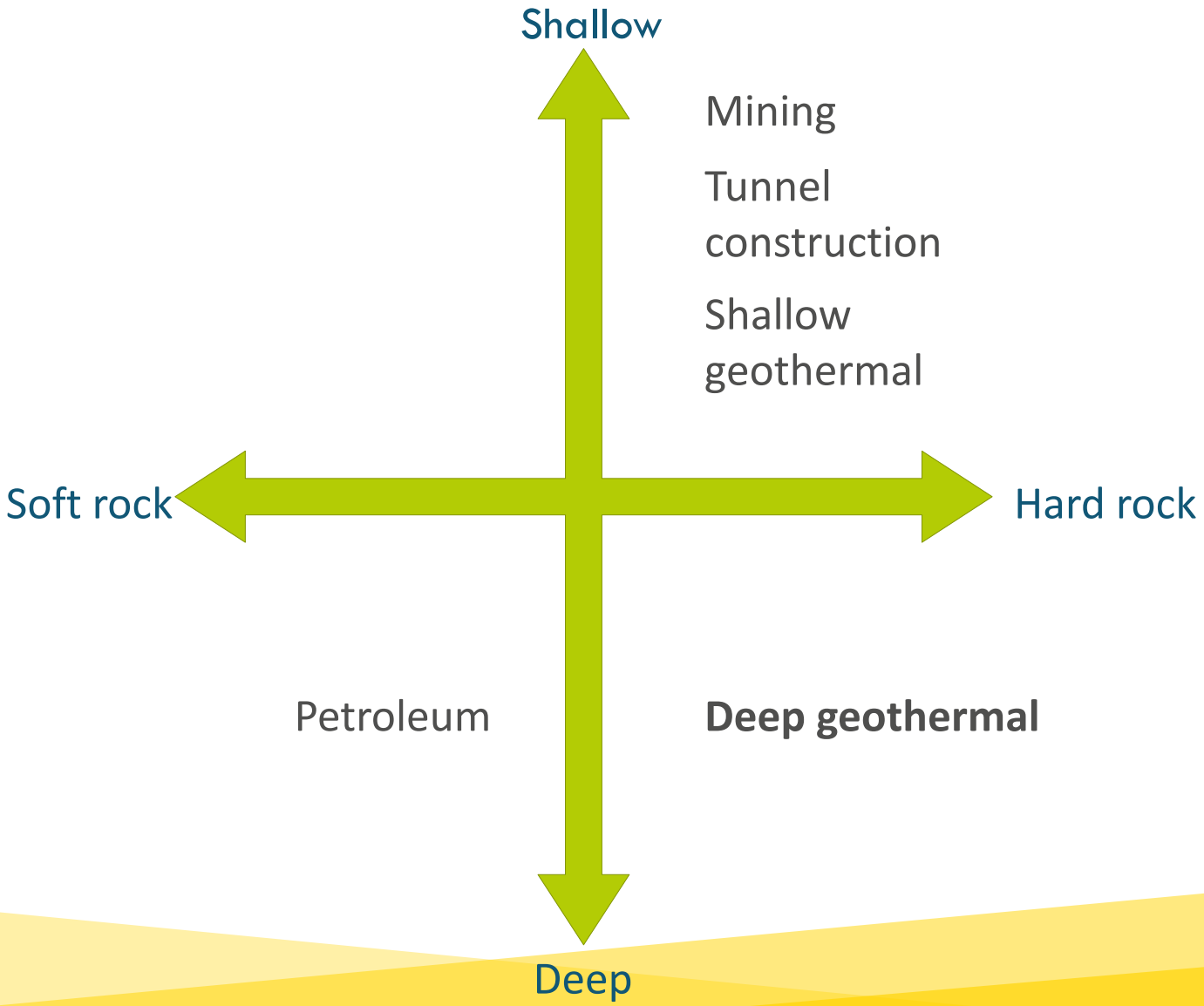
(Augustine *et al.*, 2006)

Some geothermal drilling cost drivers

- "Uniqueness"/learning curve effect
- Materials (casing/cement)
- Large hole diameters
- High temperatures
- Downhole environment
- Fractured rock
- **Hard rock**

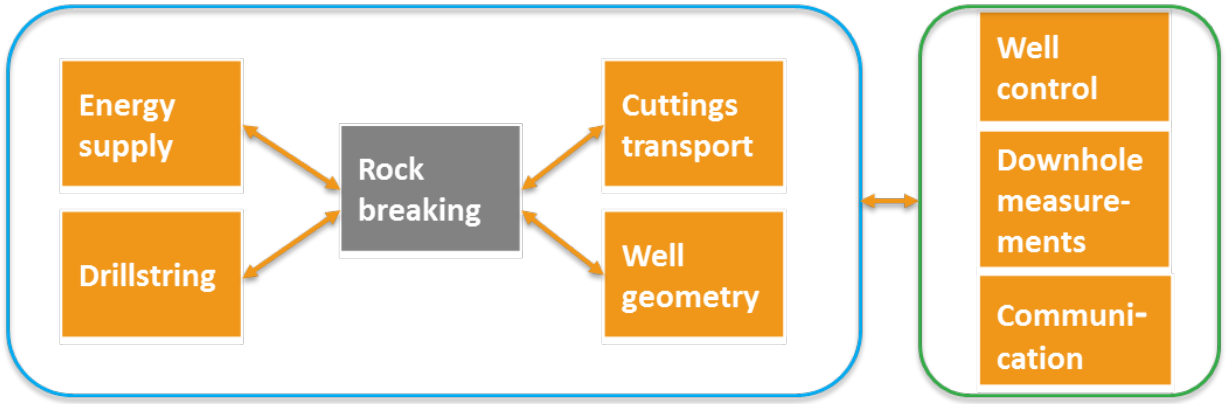


Drilling cases and applications



Technology development – deep hard rock (geothermal) drilling

- Rock breaking is the single most important factor
  - Low penetration rates
  - Equipment wear and failure
- Fundamental concerns of rock breaking process:
  - How energy is transferred to the rock (breaking the rock)
  - Controlling secondary effects (bit wear, drillstring dynamics)
  - Cuttings removal



Technologies for breaking rock

Thermal

- Flame
- Electric spark/arc
- Laser
- Electromagnetic
- …

Fluid-based

- Jetting
- Cavitation

Chemical

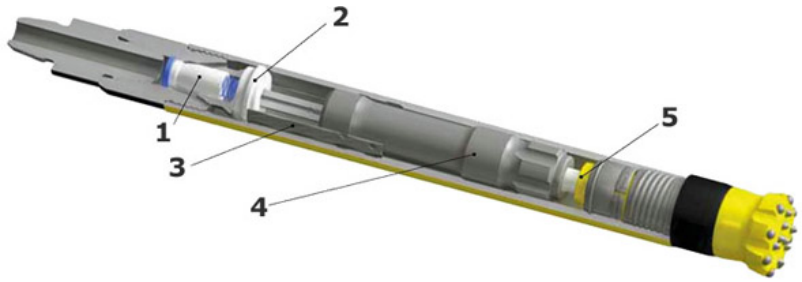
- Reactive acids, fluorine etc.
- Explosives
- …

Mechanical

- Impact (axial)
- Shearing (torsional)

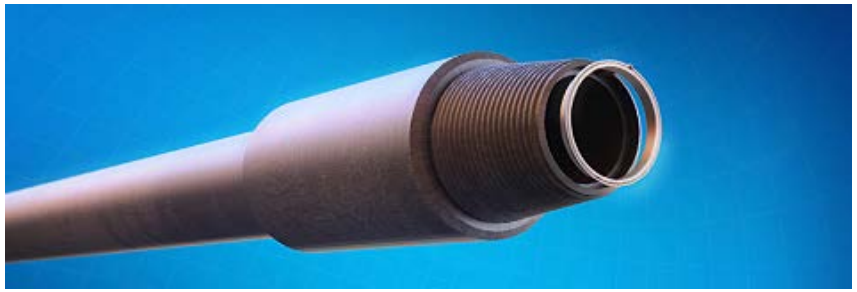
Mechanical drilling improvements

Percussive drilling



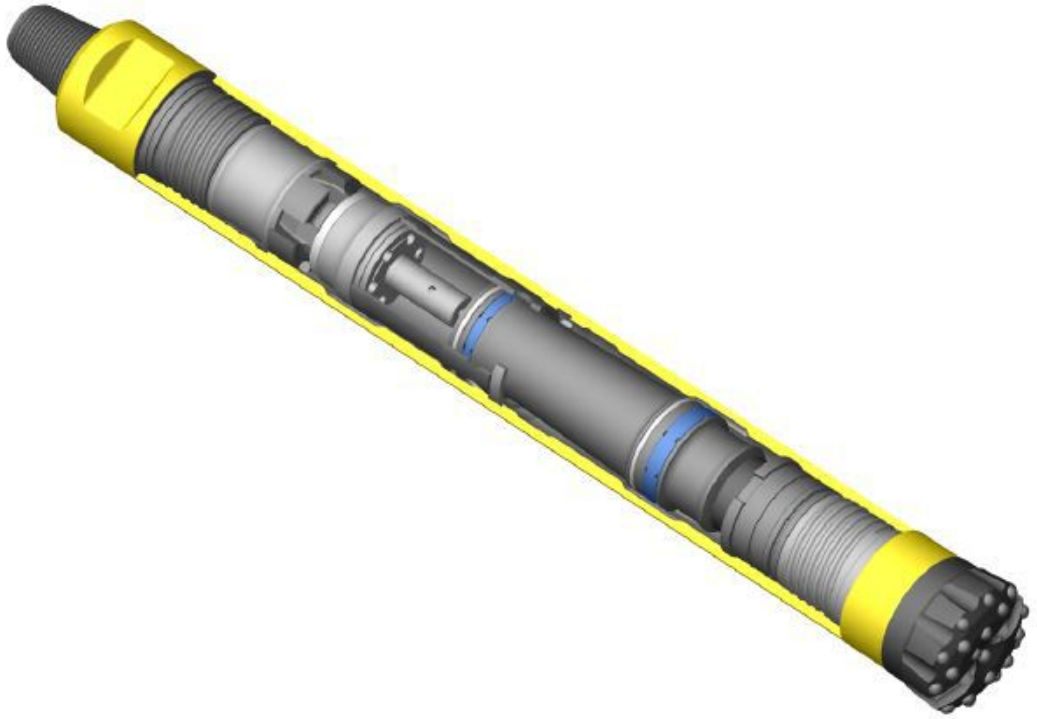
Rotary drilling

Drilling process control



Percussive drilling

- Effective for hard rock
  - High rock breaking efficiency
- Limited depth
  - Air drilling for shallow wells
  - Unconventional for deep wells
- Development for deep drilling
  - Operation
  - Hammer
  - Drillbit
  - Drilling fluids
  - Rotary/percussive action



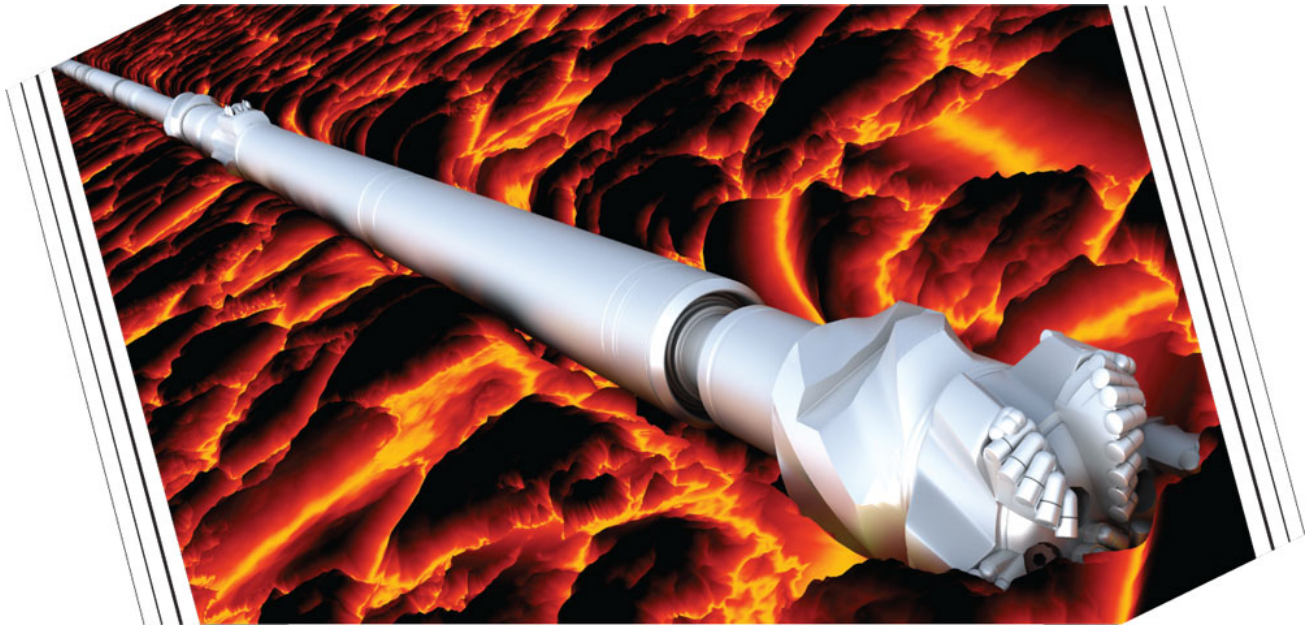
(Atlas Copco hammer/drillbit)

Rotary drilling

- Today’s method for deep wells
  - Efficient shearing mechanism
- Hard rock challenges
  - Drillbit wear
  - Dysfunctional vibrations
- Development areas
  - Drillbits
  - Other tools in the string
  - Control/operation

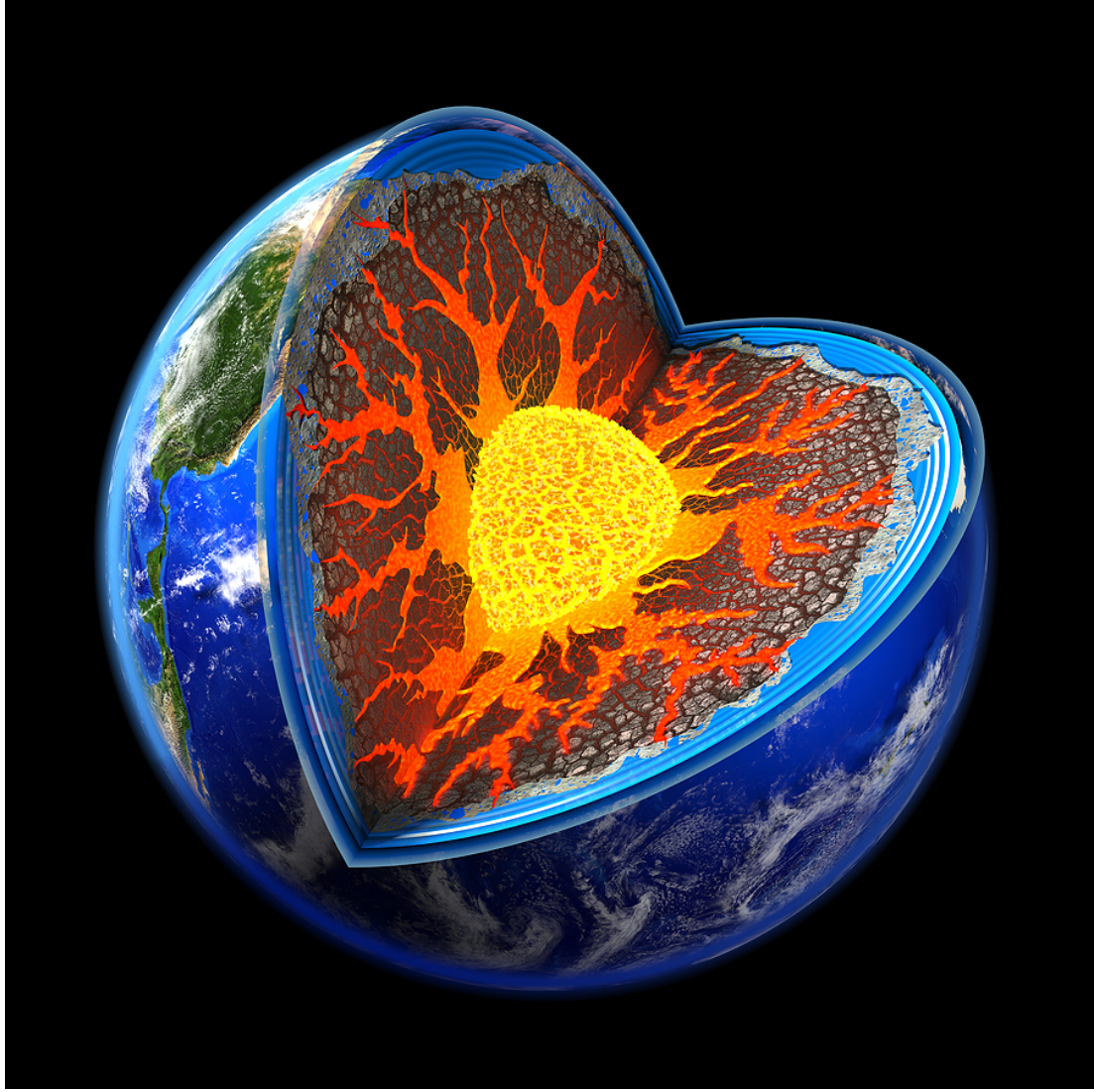
Geothermal drilling: Short term improvements

- Percussive drilling for deeper wells
  - Increased applicability (depth)
  - Potential for step changes
- Rotary drilling for increasingly harder rocks
  - Shearing (PDC) bits for geothermal
  - Increased applicability (control, materials…)
  - Gradual improvements



Geothermal drilling: Longer term improvements

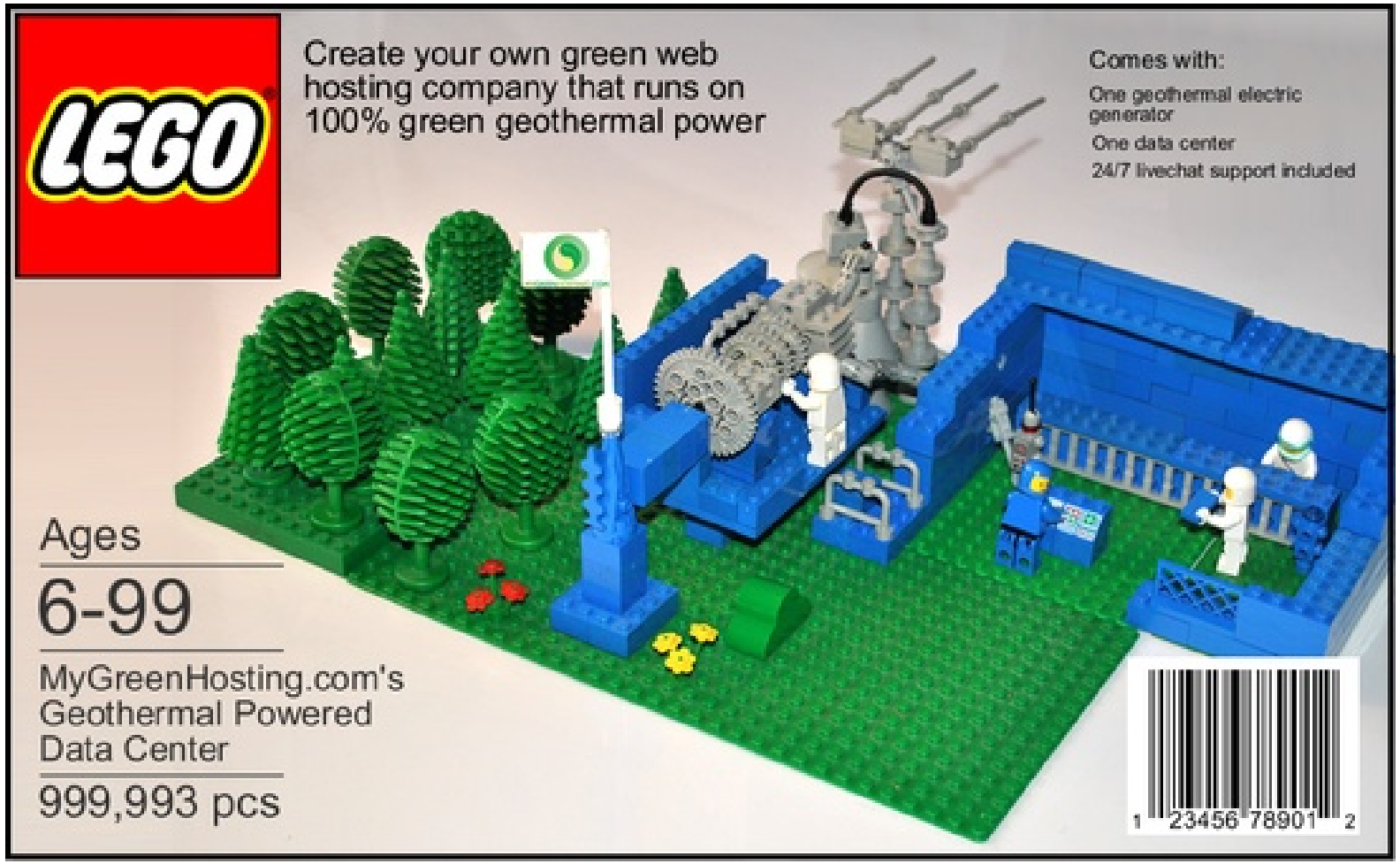
- Electrical power from surface to downhole
  - Efficiency and robustness
  - Powering and direct control of drilling tool
  - Traction
  - High bandwidth communication (wired pipe)
- Development of “unproven” methods
  - High rock breaking potential: Laser, microwaves, plasma, electric sparks etc.
  - Performance at depth, e.g. power supply, high pressure



Summary and conclusions

- Accessing the geothermal energy is a major challenge (cost issue)
- The Norwegian oil & gas drilling expertise gives us a benefit
  - Close collaboration with drilling industry
  - From petroleum to geothermal well construction – similarities and differences
- IRIS wants to contribute to the geothermal community

Thank you for your attention!



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