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Welcome!

The program will begin soon.
You will not hear audio until we begin.

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The Technology to Drill High Temperature Geothermal Wells at Scale

John M Clegg
CTO, Hephae Energy Technology

HEPHAE ENERGY TECHNOLOGY

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Outline

- Geothermal energy and why we should be interested in it
- Key similarities with well construction for oil and gas
- Key differences to well construction for oil and gas
- Our opportunity

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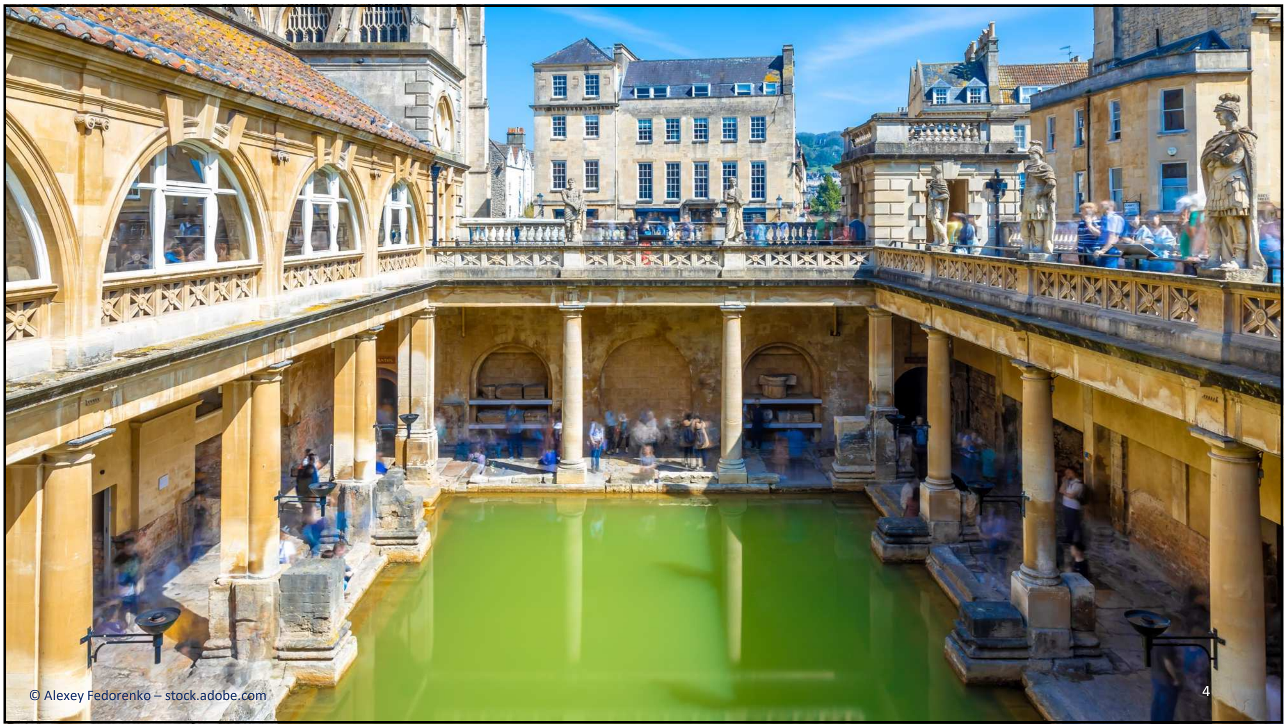
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A Broad Spread of Applications

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Direct-Use Geothermal

- Heat for residential and industrial applications
- 38°C is adequate

Hydrothermal

- Steam turbine to generate electricity
- Provided approx. 6% of California's electricity in 2020
- Demand is growing faster than hydrothermal capabilities

Enhanced Geothermal System (EGS)

- Steam turbine generates electricity
- Artificial hydrothermal systems
- Using rock as reservoir, 135 to 500°C

Advanced Geothermal System (AGS)

- Steam generates electricity
- Closed loop: relies on heat, 225 to 500°C (hotter is better)
- Independent of rock type or fractures

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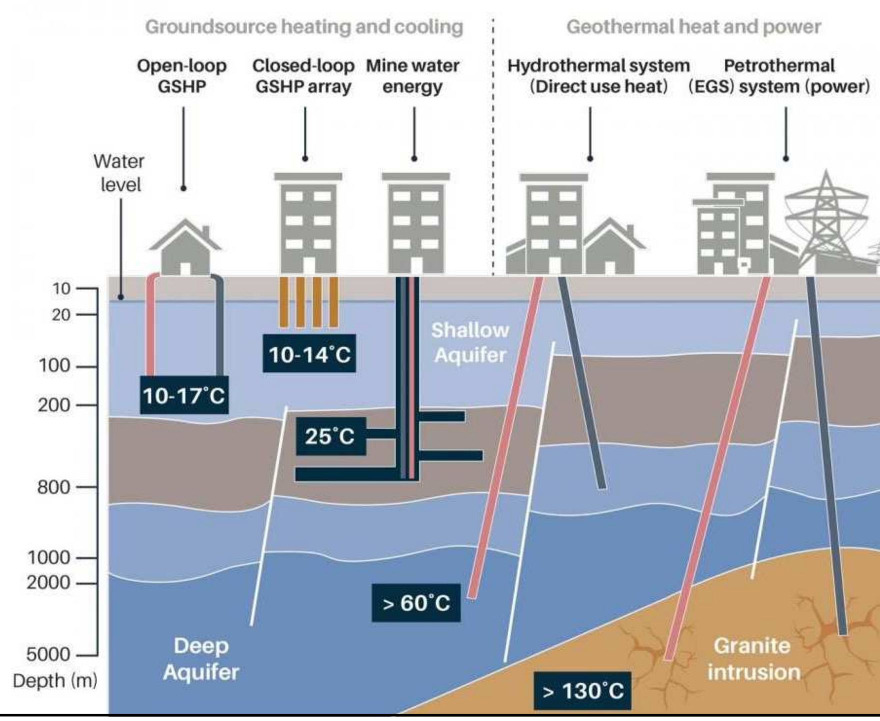

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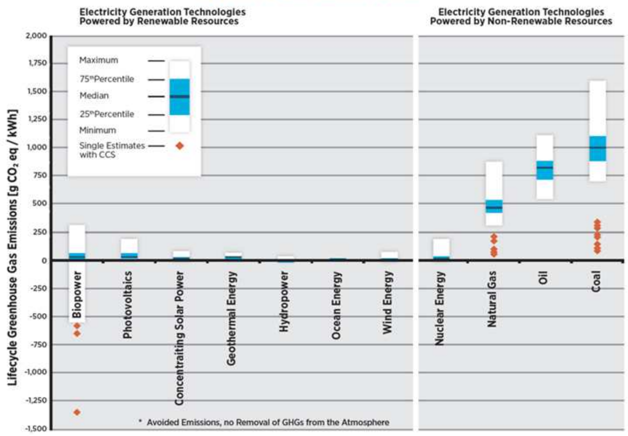
GHG Emissions

Figure 1: Estimates of lifecycle greenhouse gas emissions by power generation source



IRENA, 2017

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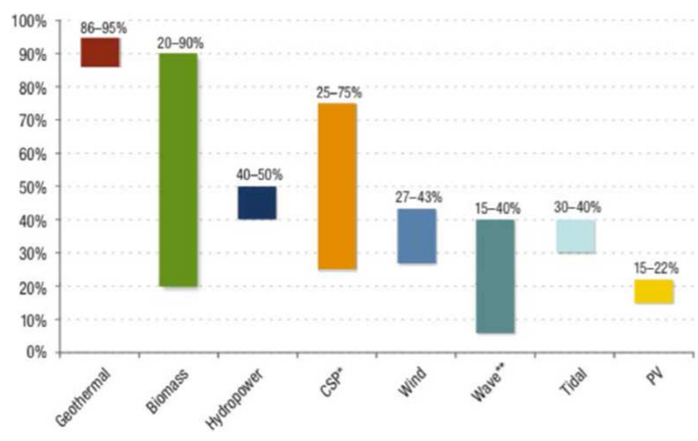
Capacity



Geothermal Canada, 2018

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LCOE Lower Than Coal or Nuclear

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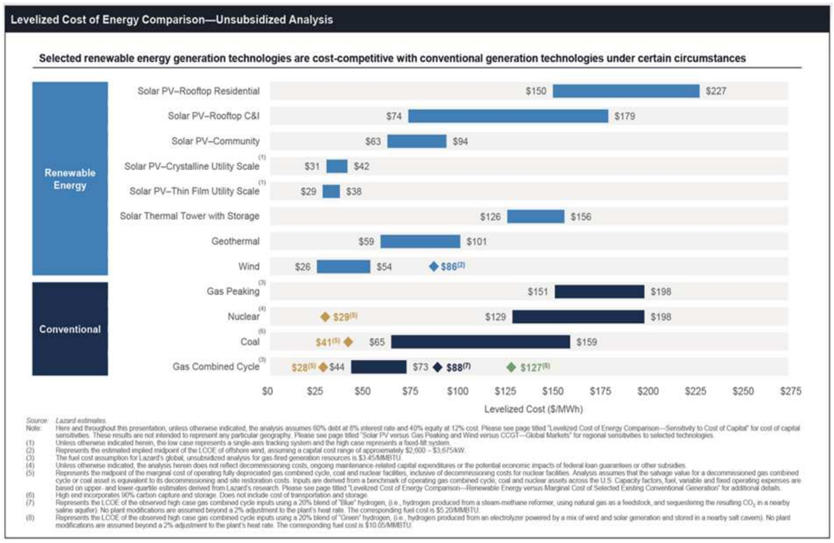

Lazard, 2020

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LCOE Potential

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- Tim Latimer, Fervo Energy
  - ✓ "The impact of drilling cost decline, PTC extension, and lower interest rates probably lead to a 20 to 30% decline in geothermal from the $65 to 75/MWh at the start of the year. We may see geothermal <$60 soon, and maybe even <$50."
- Michael Liebreich, founder of Bloomberg New Energy Finance
  - ✓ Eavor aiming for $50/MWh by 2030

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Rapid Growth, Modest Numbers

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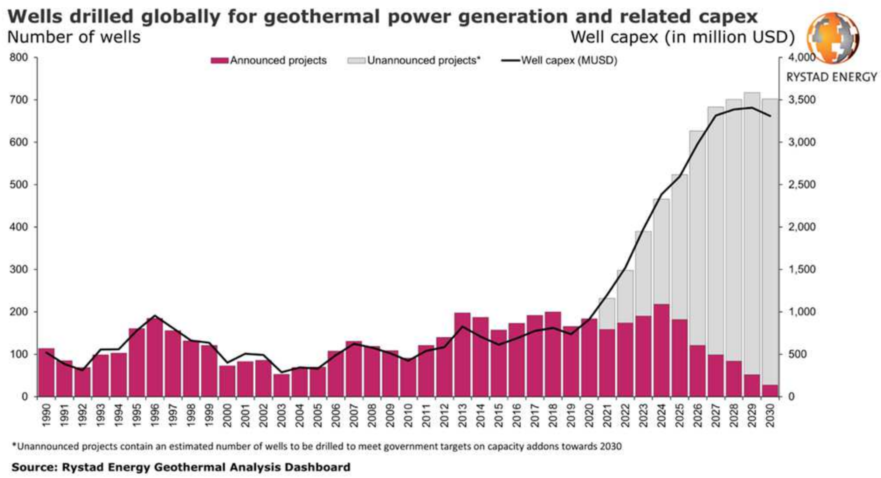

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…Or Not So Modest?

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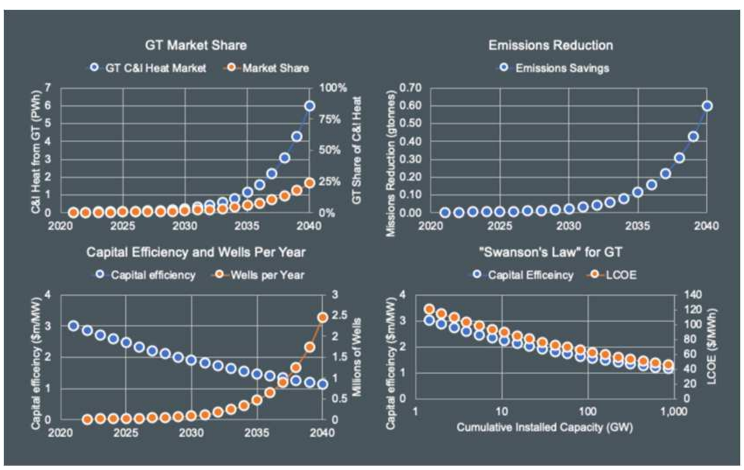

Causeway GT, 2021

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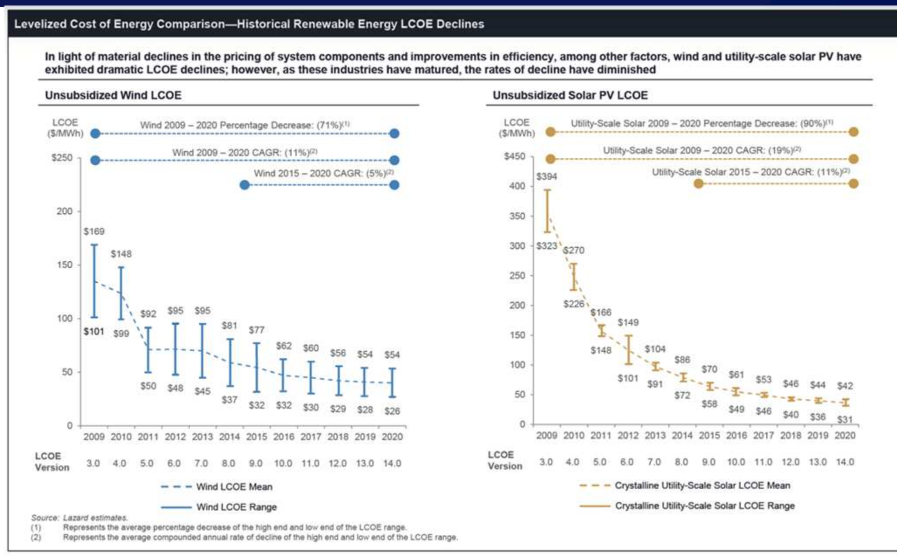
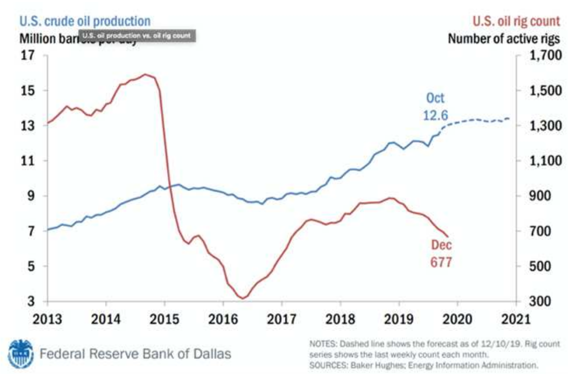
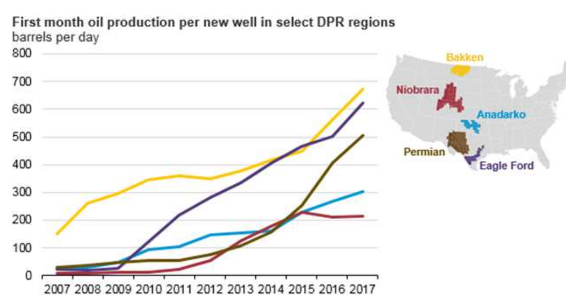
Geothermal Costs Will Decline With Scale



Lazard, 2020

…While Productivity Will Increase





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What do horizontal drilling and hydraulic fracturing have to do with geothermal?

Enhanced Geothermal System

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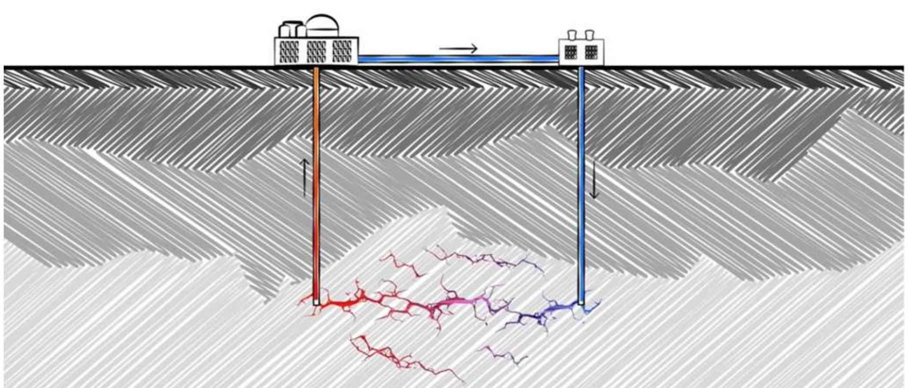

image courtesy J. Beard/Pivot2021: Geothermal Reimagined

Advanced Geothermal Systems

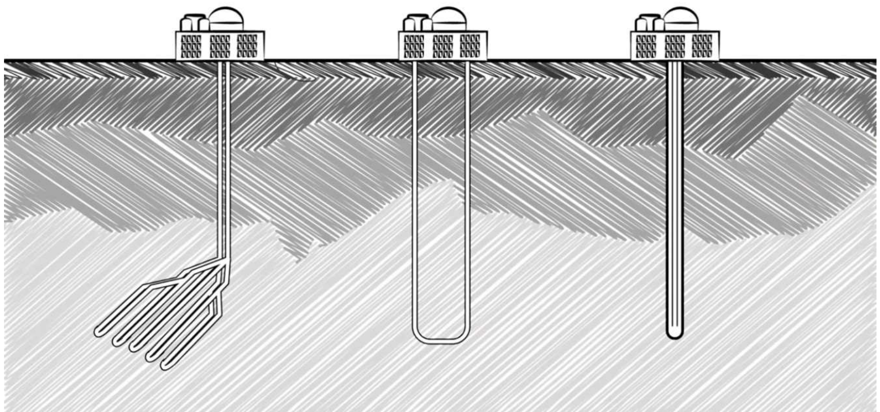

image courtesy J. Beard/Pivot2021: Geothermal Reimagined

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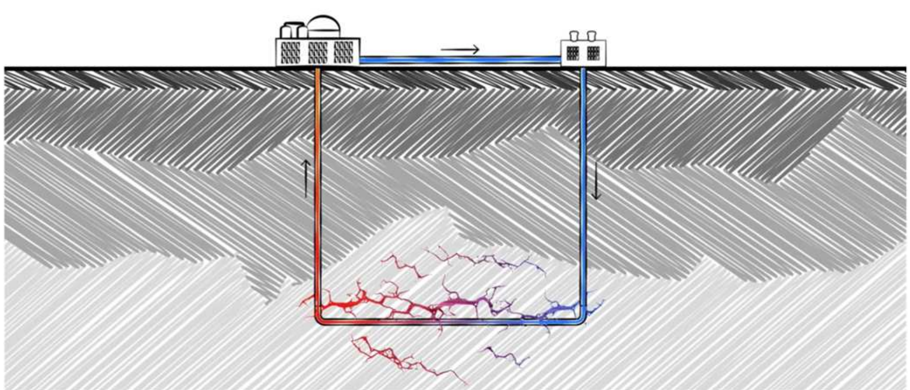
Hybrid Geothermal System



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Don’t these just look like oil and gas wells?

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“… oil and gas service companies who have positioned themselves as leaders in high-temperature and high-pressure drilling are going to own this future”

Vik Rao, Executive Director of the Research Triangle Energy Consortium, former CTO of Halliburton

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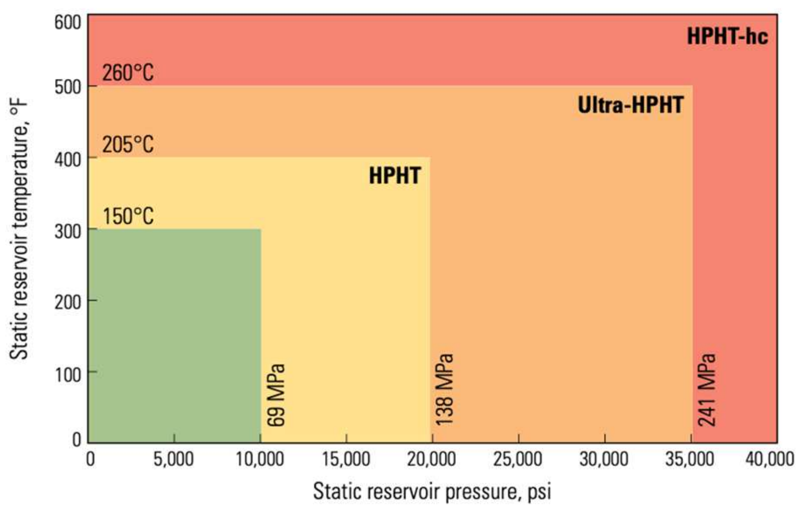
What are the key differences?

Temperature and Pressure



From www.slb.com

List of 200°C+ Commercial O&G MWD/DD Tools

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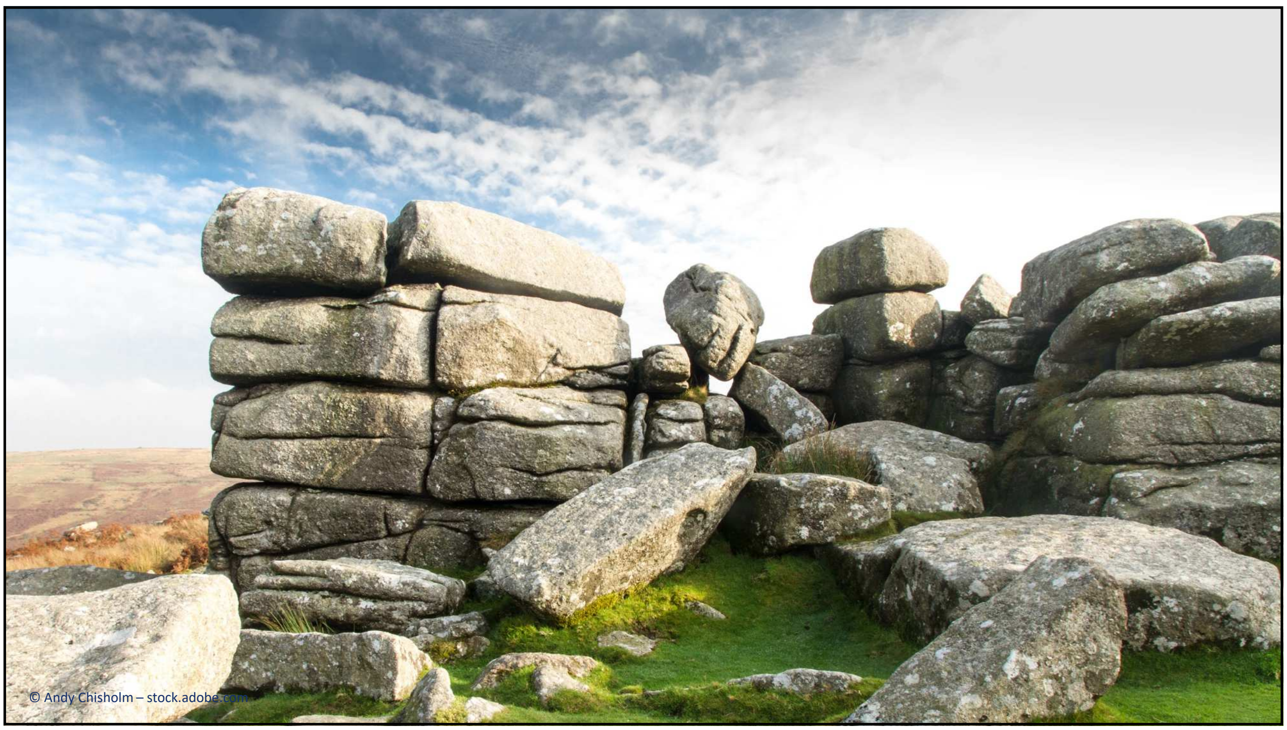
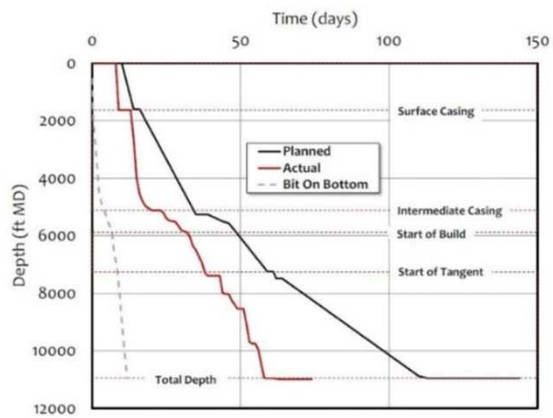


Drill Bits

hypersciences.com



Well 16A(78)-32 Planned vs. Actual Depth vs. Days (source: NOV, ReedHycalog)

thinkgeoenergy.com

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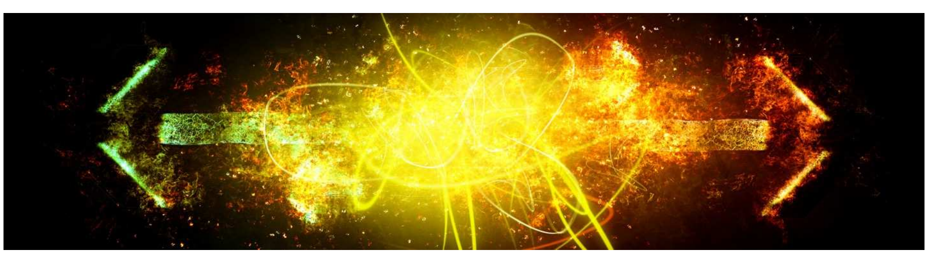
Friction

High coefficient of friction with igneous rocks

- Well bore quality is important
- Continuous rotation is important



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Losses

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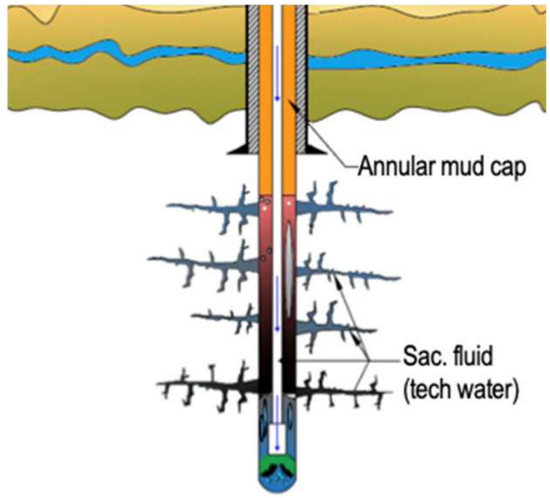
- Highly fractured formations
- Mud losses
- Air or foam drilling
- (Pressurized) mud cap drilling



Weatherford

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Sour Service

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- Ca_2+, Na+ CO_2, H_2S, HCl, NH_3 can all be present in hot geothermal fluids
- Combination with temperature = particular materials challenge

DNV

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Drilling Mud

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- Conventional WBM can lose viscosity at high temperatures
- OBM often preferred
  - Less environmentally friendly
  - Lower heat capacity
- Higher-temperature WBM required

PetGeo

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Mud Pumps and Chillers

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- Mud flow can be used to cool downhole tools
- High flow rates = large pumps, big rigs
- Mud chillers can also help

NOV

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Continuous Flow

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- Continuous circulation systems can prevent rapid temperature increase of downhole tools during connections
- Implications for rig design

Halliburton

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Deeper and Hotter

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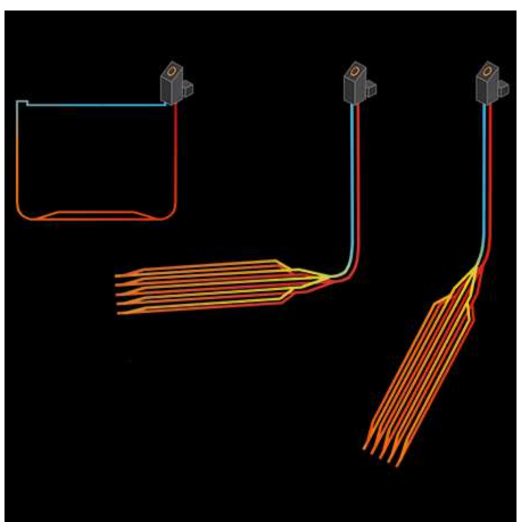

Eavor

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There is One 200°C LWD Tool

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- Required “ground-up redesign”

Kleawyothatis el at, SPE-191054-MS 2018

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~~Plastic Packaged Electronics at 200°C~~

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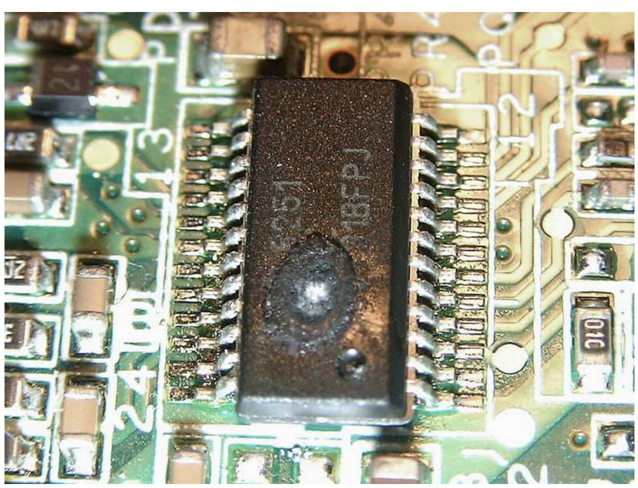

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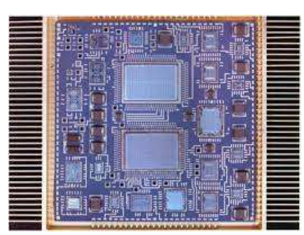
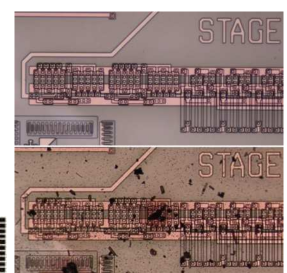
Hotter is Better

- Novel packaging
- Novel joining

Quartzdyne



Smithsonian



NASA

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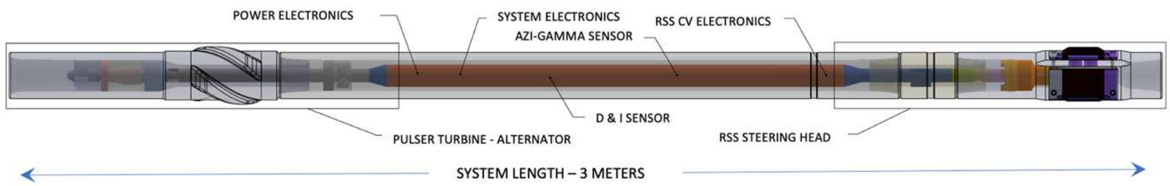
HT Integrated Directional Drilling Tool



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Hybrid Geothermal System

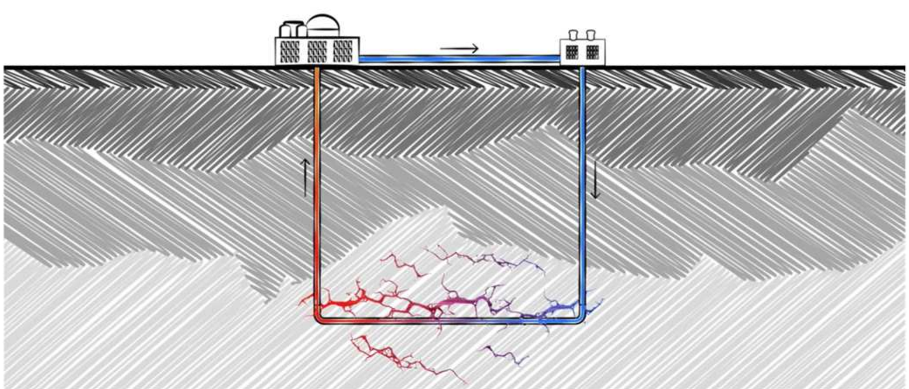

image courtesy J. Beard/Pivot2021: Geothermal Reimagined

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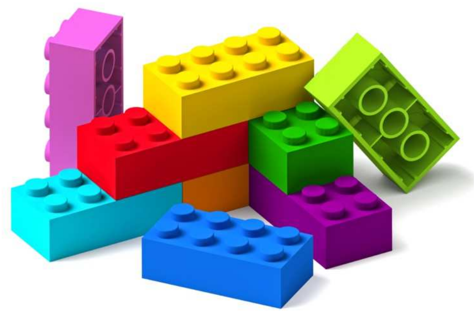
LEGO

- HT building blocks allow:
  - Drilling and measurements
  - Logging
  - Intelligent completions
  - Production monitoring
  - Production optimization



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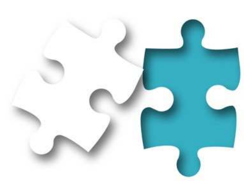
The Opportunity is There

New technology transformed and scaled unconventional O/G

Combine new technology + O/G expertise + decades of Geothermal experience…

…and scale Geothermal to previously unimagined heights



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The Technology to Drill High Temperature Geothermal Wells at Scale

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