Geothermal TS

SPECIAL GEOTHERMAL TALKS

September 2026

SUPERCHARGING GEOTHERMAL POWER ECONOMICS BY APPLYING LESSONS LEARNED FROM THE UNCONVENTIONAL OIL & GAS REVOLUTION

SEPTEMBER 24TH | 10:00 AM – 11:00 AM | US CENTRAL TIME | ZOOM WEBINAR

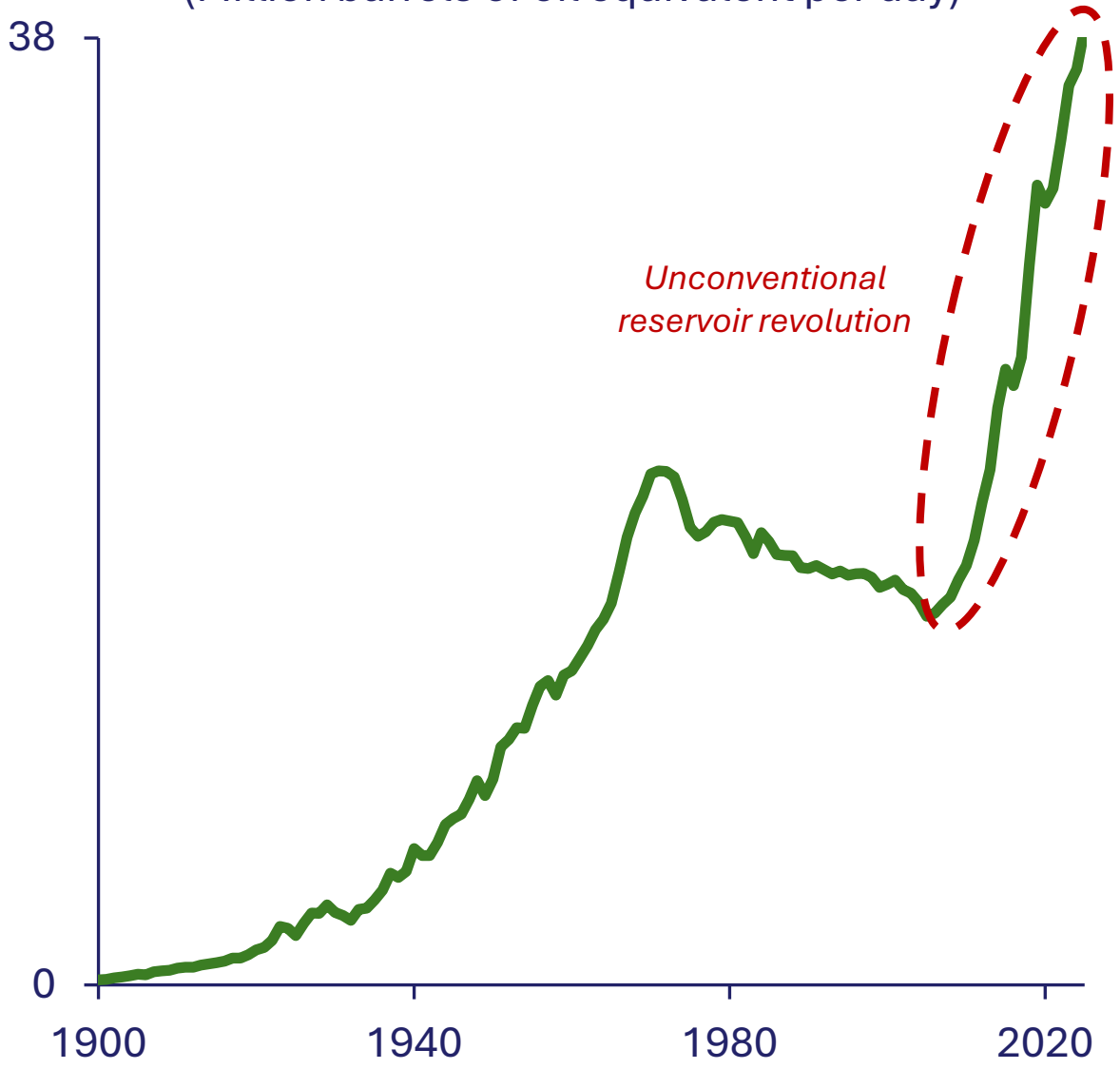
GREG LEVEILLE

CEO AT TIDAL WAVE TECHNOLOGIES LLC

The geothermal industry aspires to achieve unconventional O&G like growth

U.S. oil and natural gas production

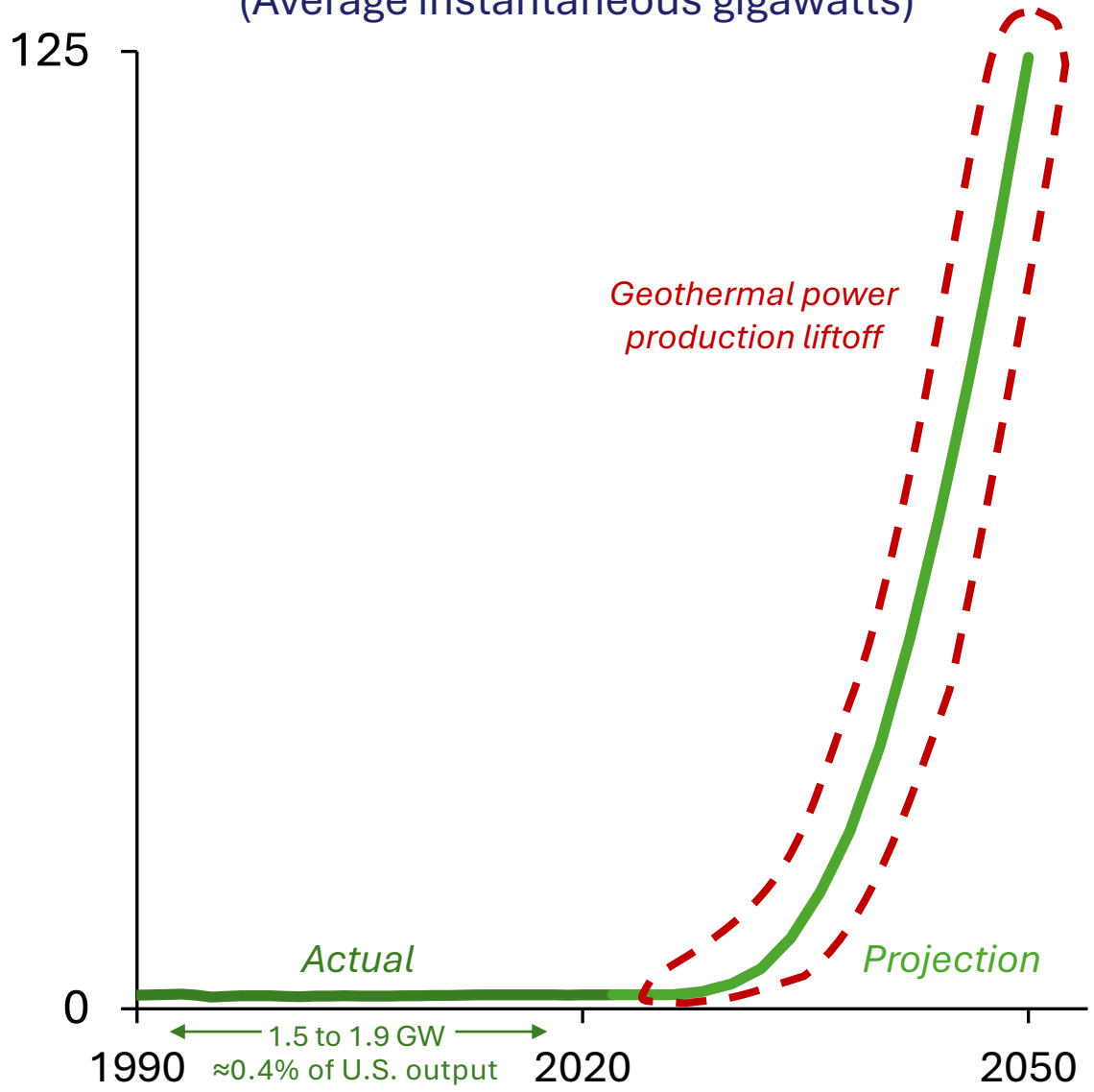
(Million barrels of oil equivalent per day)



Sources: U.S. EIA and Energy Institute websites

U.S. electricity output from geothermal

(Average instantaneous gigawatts)

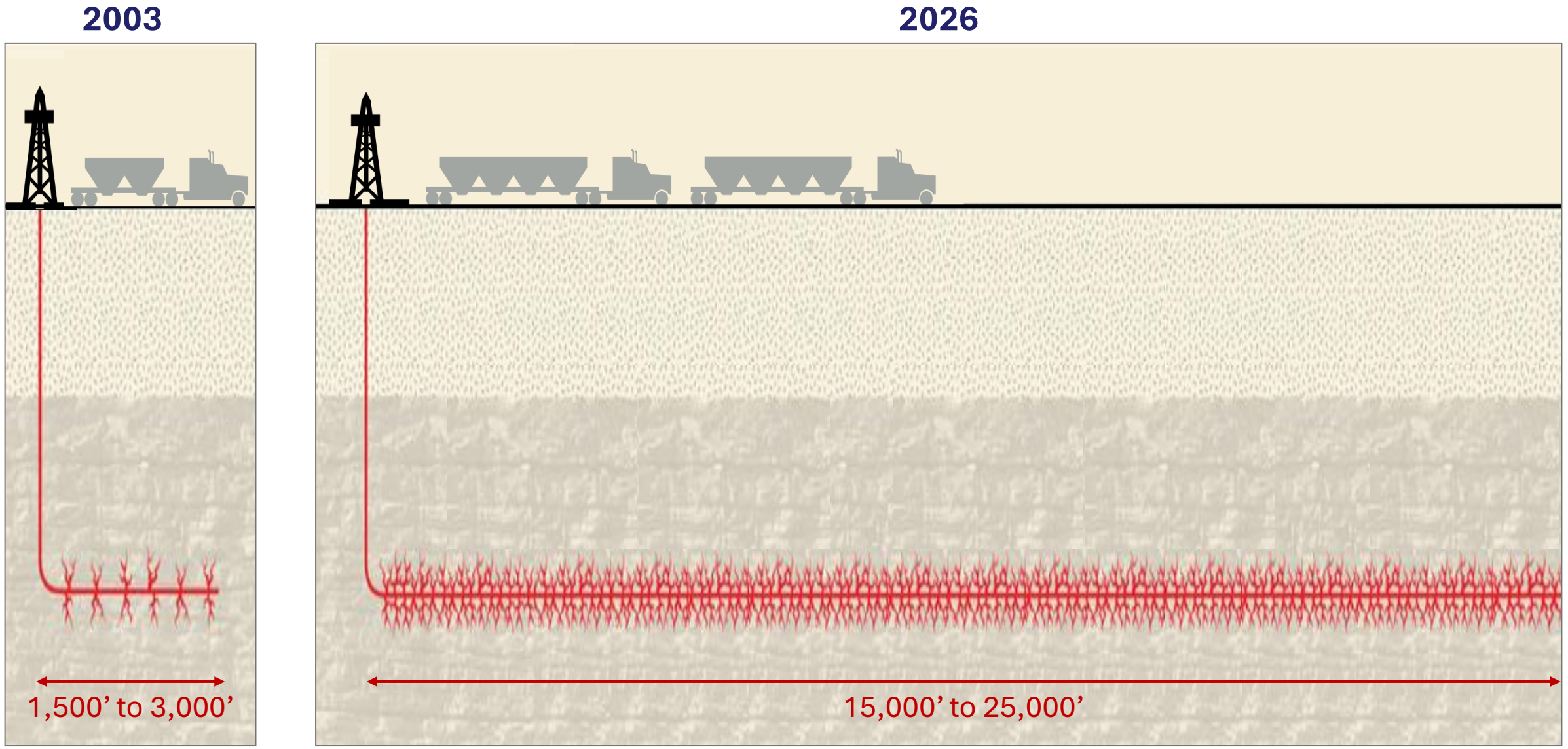


Sources: U.S. EIA for 1990 to 2022; 2022 average output = 1.8 GW (0.4% of U.S. total); Projection mimics U.S. DOE 2024 liftoff report.

Unconventional reservoir revolution lessons learned

- To achieve exceptional economics, **find a powerful lever**
- A technology revolution opens **multiple pathways to success**
- **Be bold** to avoid "good enough" becoming the enemy of "great"
- **There will be** under-appreciated and unexpected **challenges**
- **Build bridges, not moats** to maximize value creation
- **Land is the source of all wealth**

Find a powerful lever: For unconventionals, drill longer laterals



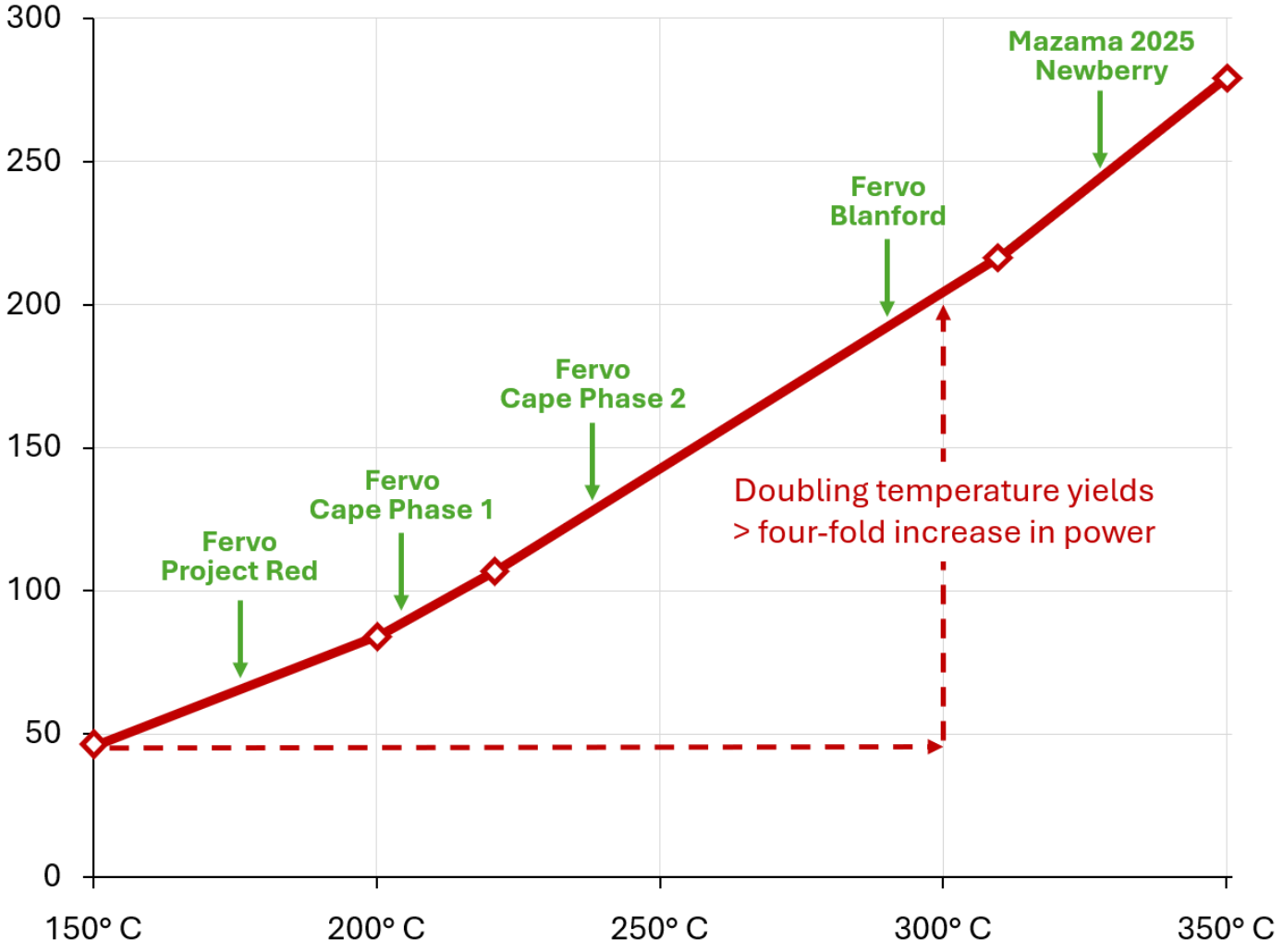
Cross section views; not to scale; See slides 19 – 21 for a listing of the many technological advancements in addition to longer laterals that helped the oil & gas industry dramatically lower costs and increase per well flow rates

Benefits: Lower overall drilling, facilities, and operating costs & much higher per well production

Find a powerful lever: For geothermal, access higher temperatures

Power output vs. ORC plant inlet fluid temperature

(kW net power per kg/second of production versus degrees C)



Source for graph: Turboden, personal communication, 2026. Temperatures shown for projects are reservoir temperatures, not plant inlet temperatures

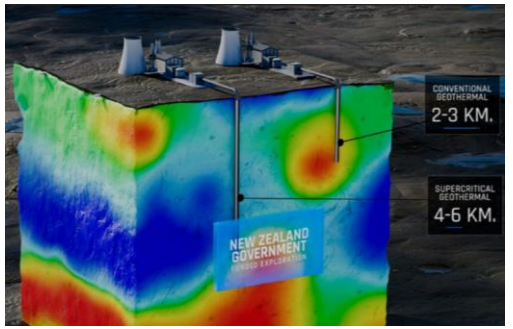
Super hot rock geothermal demonstration projects currently underway or planned in next 12 months

Mazama Newberry Volcano

Quaise Newberry Volcano

IDDP 3 Iceland

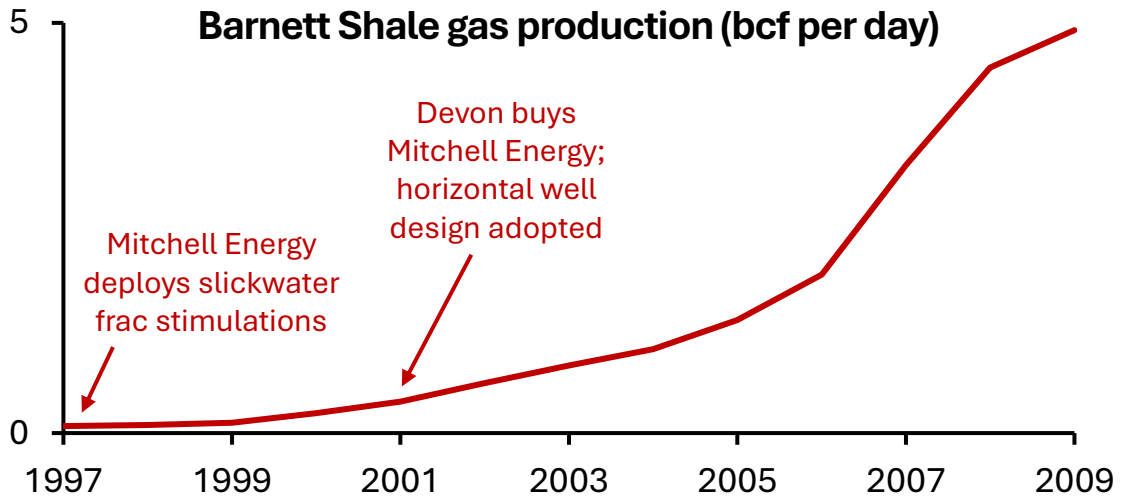
Geoshot New Zealand



"Super Hot" has generally been used to describe temperatures above 374° C. Some geothermal developers define it as > 300° C.

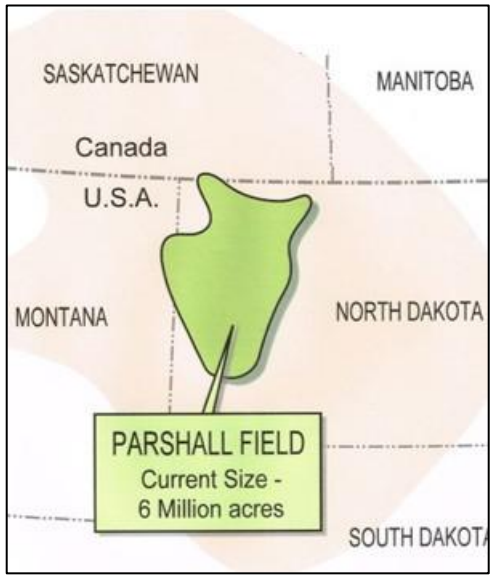
Multiple pathways to success: For unconventionals, first gas, then oil

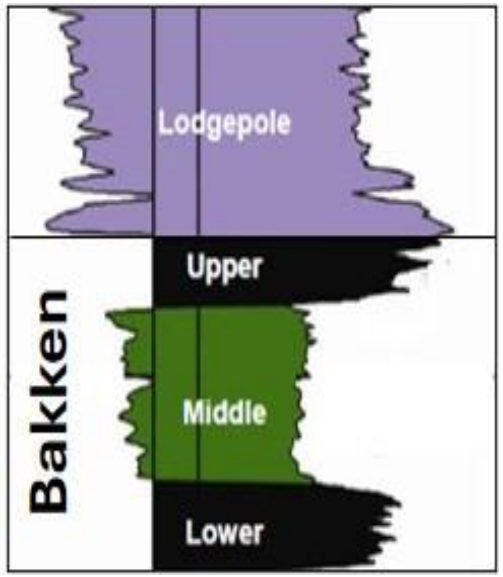
Shale gas liftoff circa 2000 in the Barnett Shale

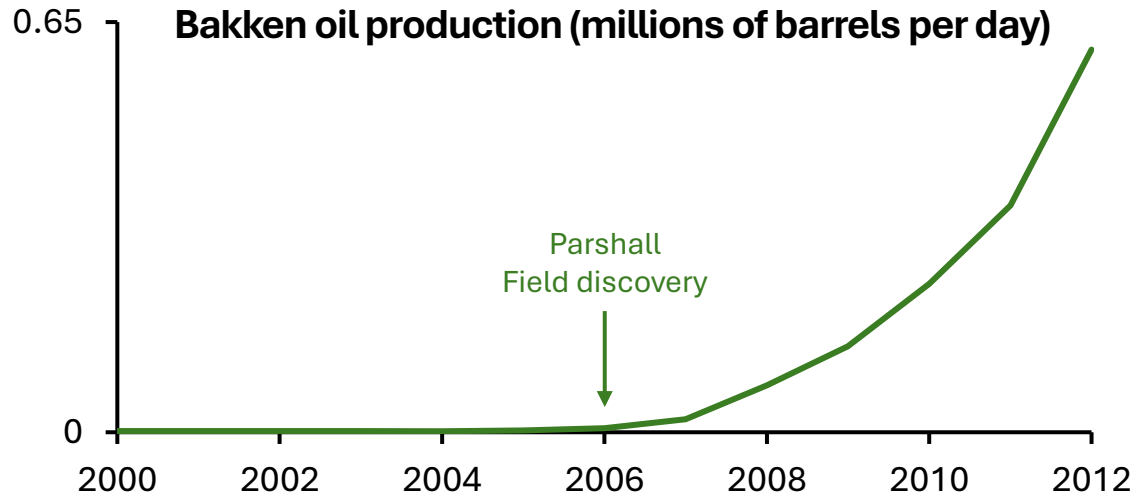


Source: Graph modified after JPT Oct. 31, 2013, article by Dan Steward

Unconventional oil liftoff circa 2006 in the Bakken



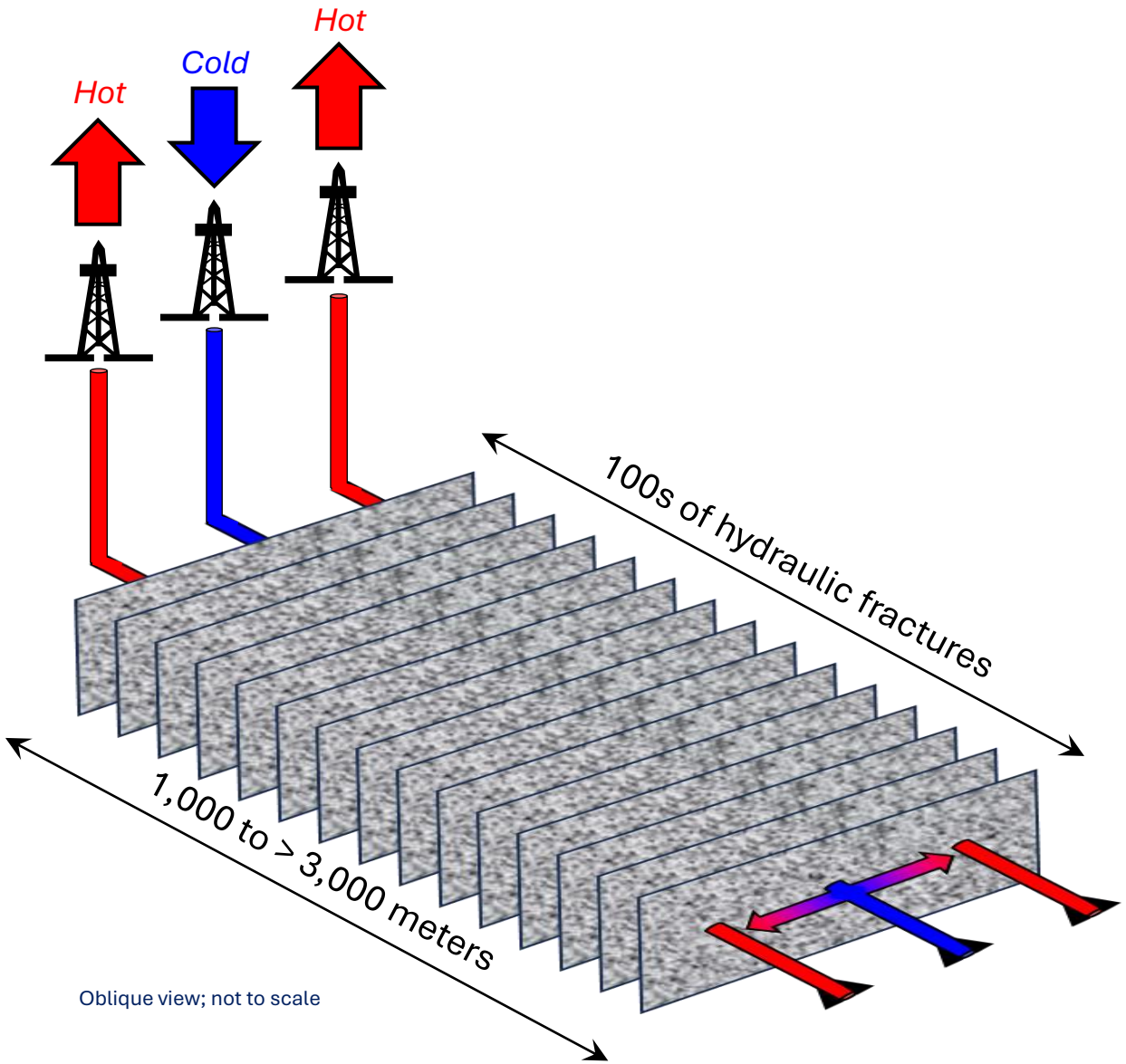




Source: Data from North Dakota Department of Mineral Resources; graph does not included production from the Bakken outside of North Dakota

For geothermal, first horizontal EGS, then horizontal hydrothermal

Horizontal EGS wells are a game changer



Numerous horizontal hydrothermal applications

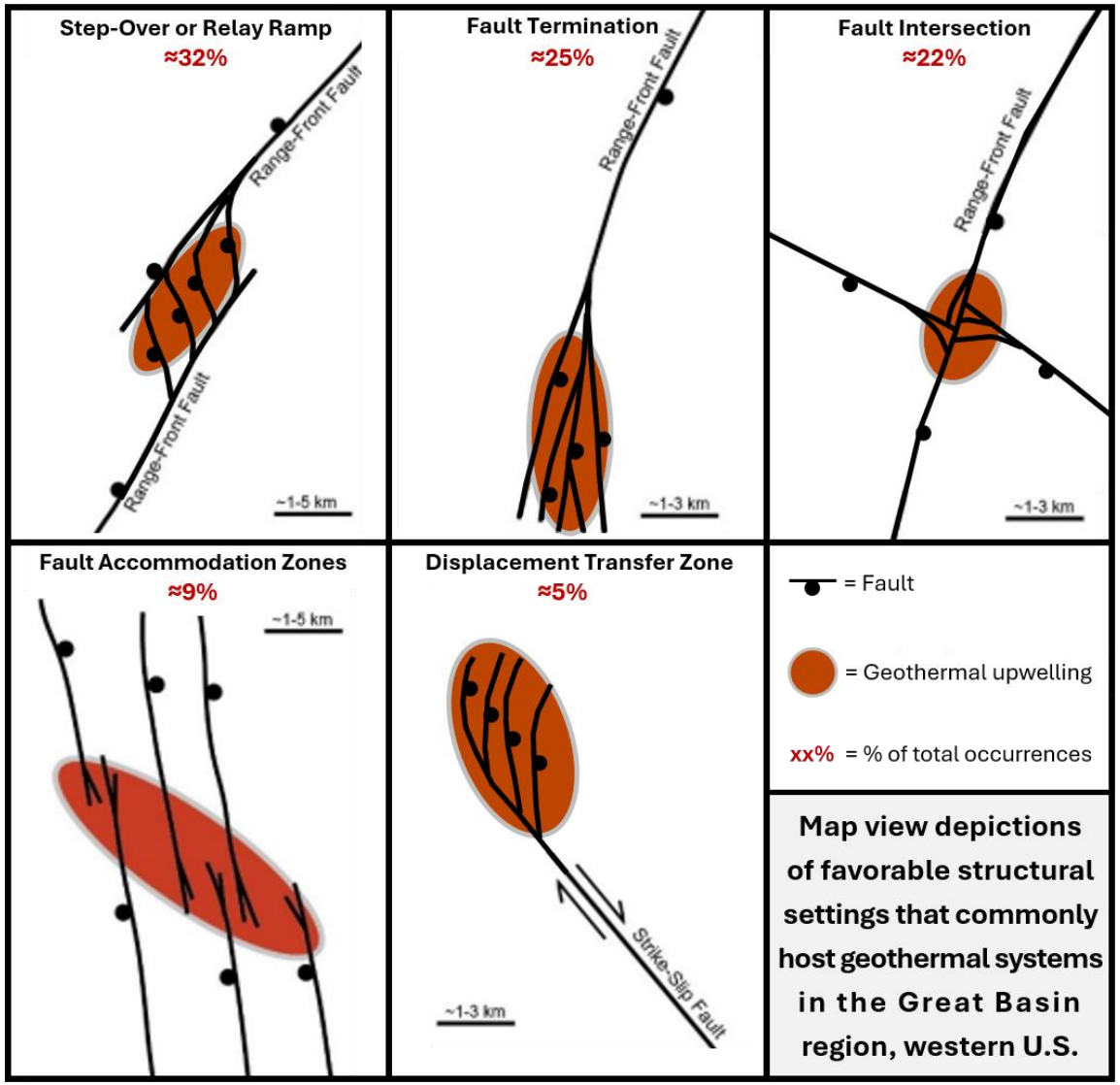
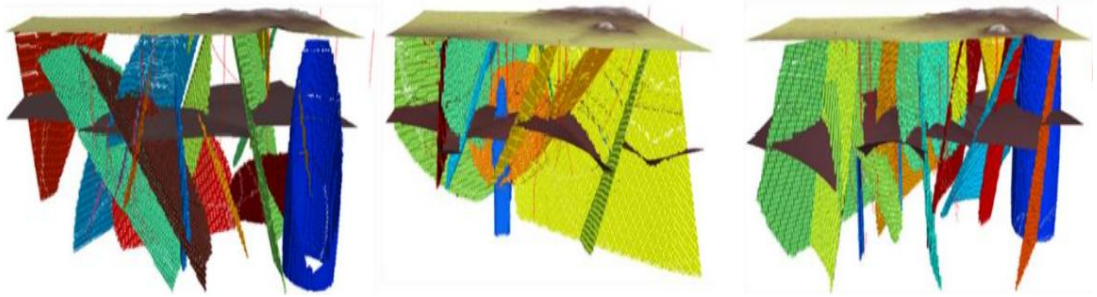
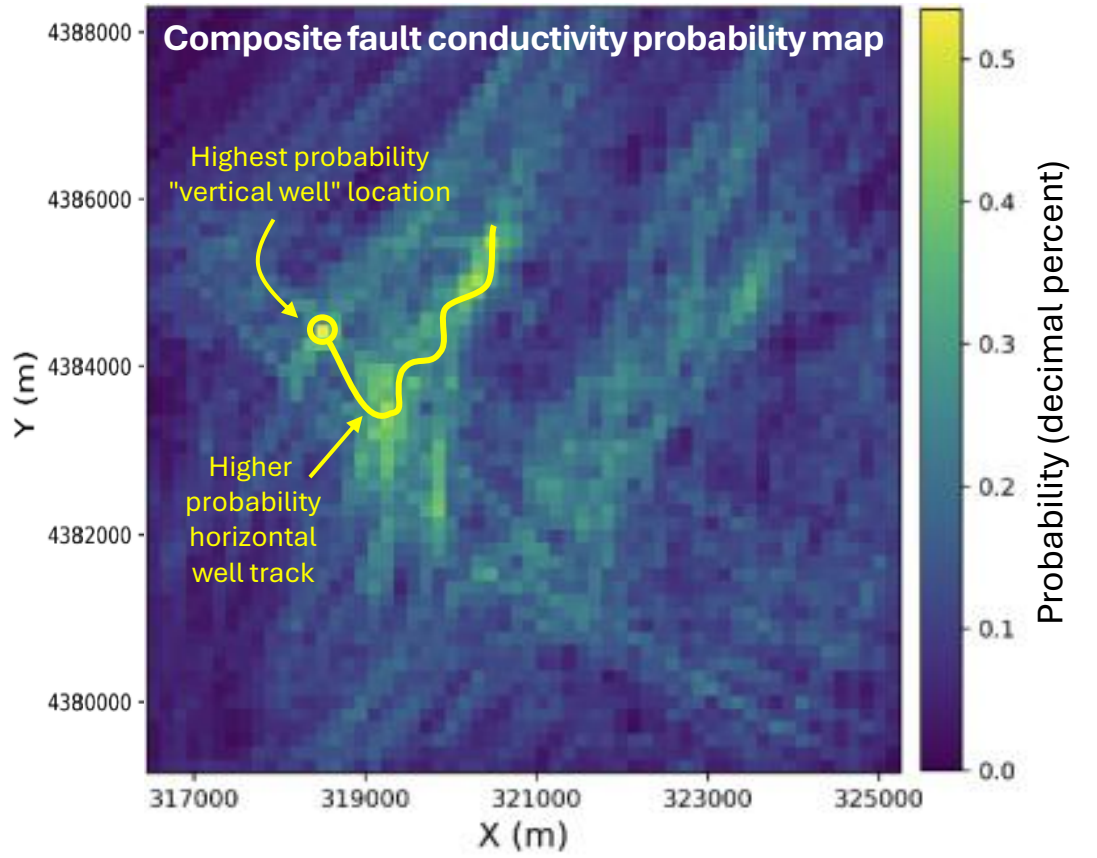


Diagram modified after Faulds and Hinz (2015) and Faulds et al. (2026)

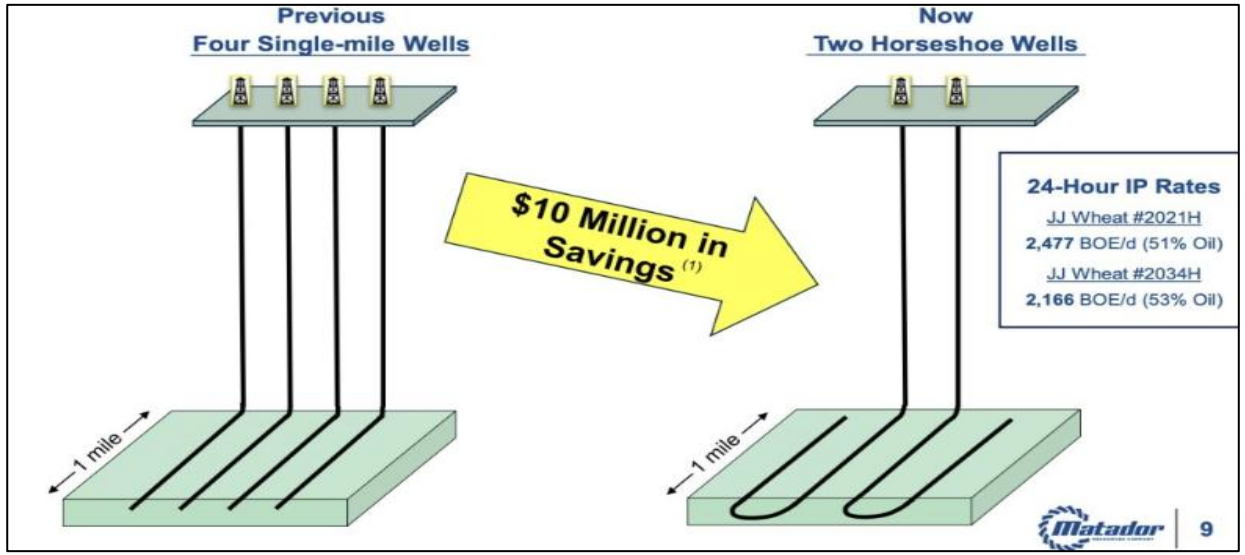
Horizontal wells – a solution to the multiple possible upflow pathways problem

Three of many possible fault geometries (oblique views)





Nearly any "horizontal" well design one can imagine can be executed



Fervo has shown that long horizontal wells can be drilled in hard rocks

Project	Measured depth	Lateral length	Casing at TD	Temperature	Days
Red	11,220’	3,250’	5”	350° F	70
Cape Phase 1	14,483’	5,000’	7”	400° F	21
Cape Phase 2	19,448’	7,500’	8 5/8”	460° F	21

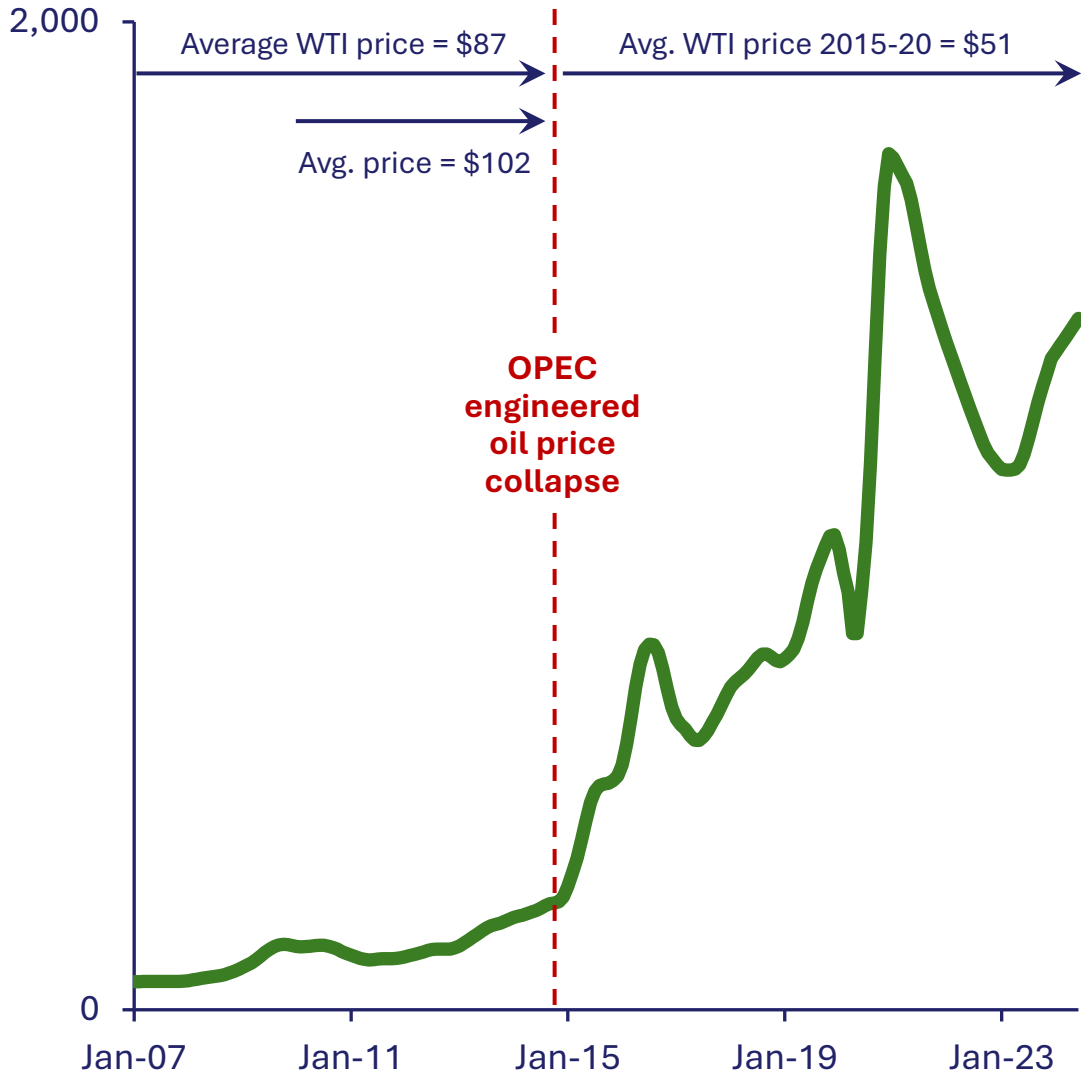
Sources: Fault geometry diagrams and fault conductivity map from Pollack 2020 Stanford PhD dissertation; well locations added

Source: Fervo July 8, 2026, post. Measured depth = average for Cape Phase 1; Sawtooth 7 MD for Phase 2. Days = spud to total depth (TD)

Be bold! Don't wait for "necessity to be the mother of invention"

Permian Basin new oil production

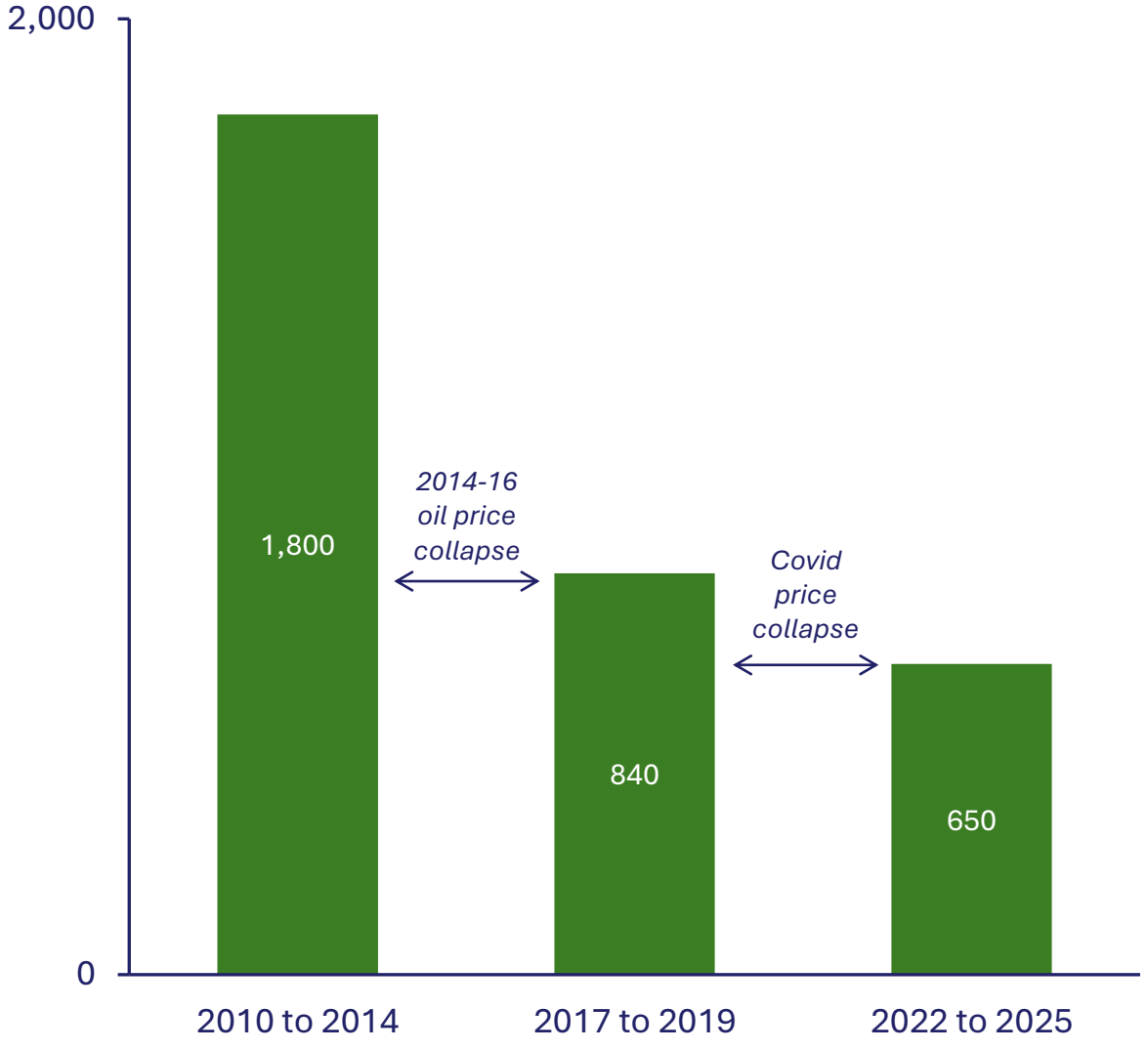
(barrels per day per rig per month)



Source: U.S. Energy Information Administration Drilling Productivity Report as accessed in April 2025

U.S. drilling rig count

(during periods when output was growing at > 1 MMBOE per day)



Source: Rig counts from Baker Hughes' website; Production rates from Energy Institute's website

Be bold: The time is right for rapid geothermal technological advancements

Imaging faults in basement rocks

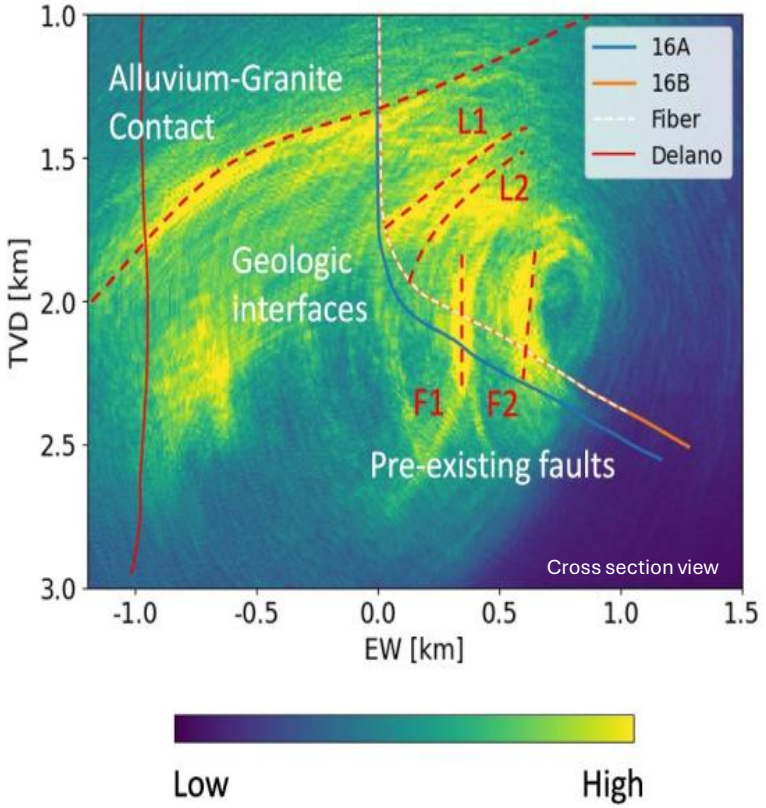


Diagram from Ma et al., 2025, DAS microseismic reflection imaging at Utah FORGE

Drilling dysfunction reduction

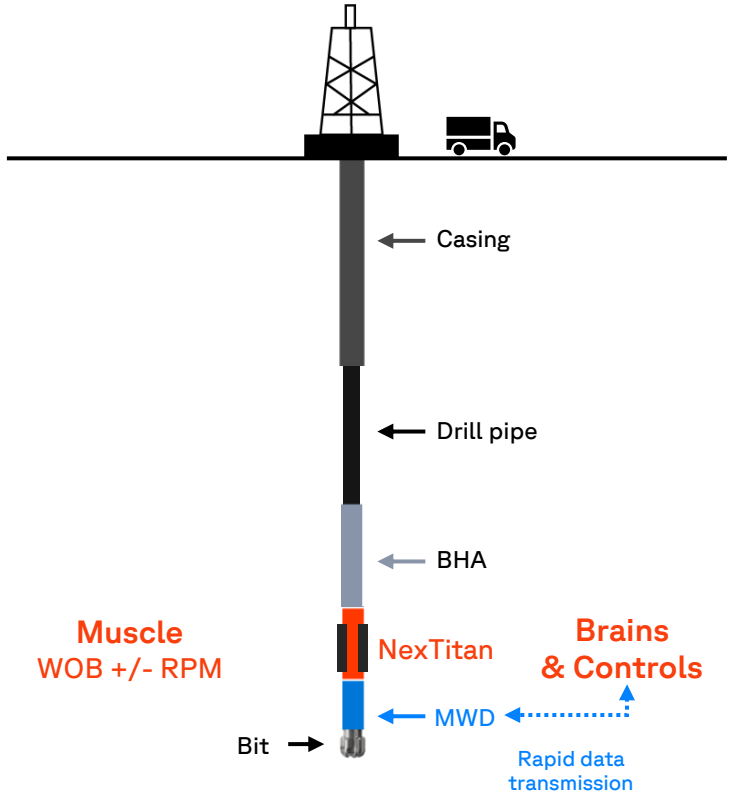
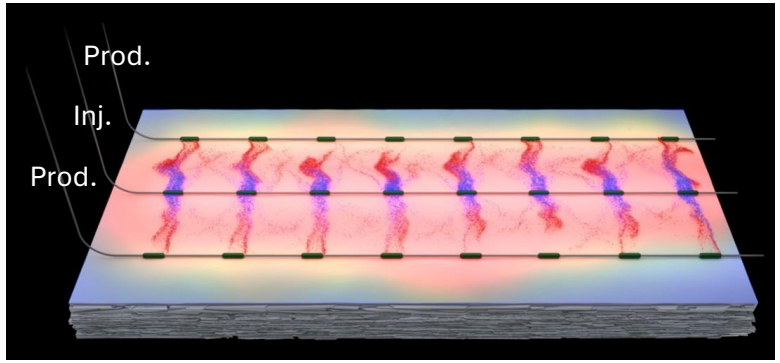
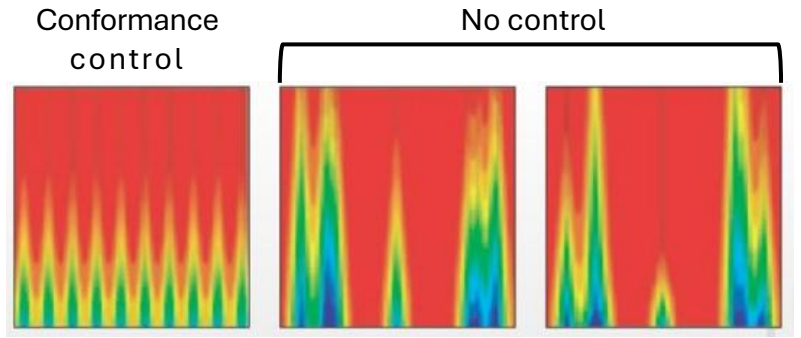


Diagram showing GA Drilling's NexTitan technology platform

Optimizing fracturing & conformance





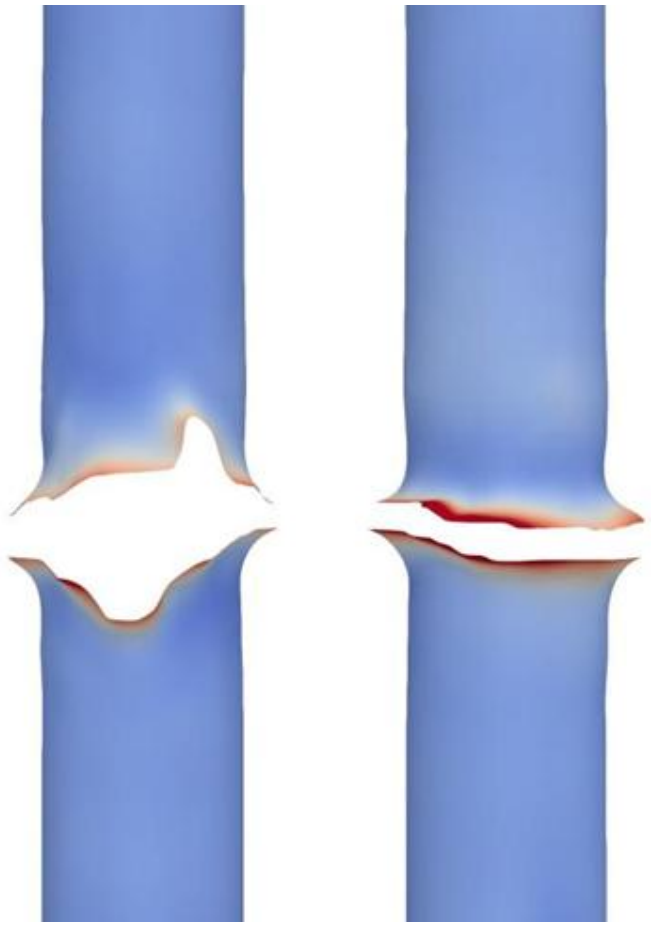
Map view of fractures during production (red = hot; blue = cold)

Top diagram from NCS Multistage website; Bottom from GTO Technologies presentation

The price premium being paid for power by hyperscalers likely won't last forever!

Unconventional O&G under-appreciated and unexpected challenges

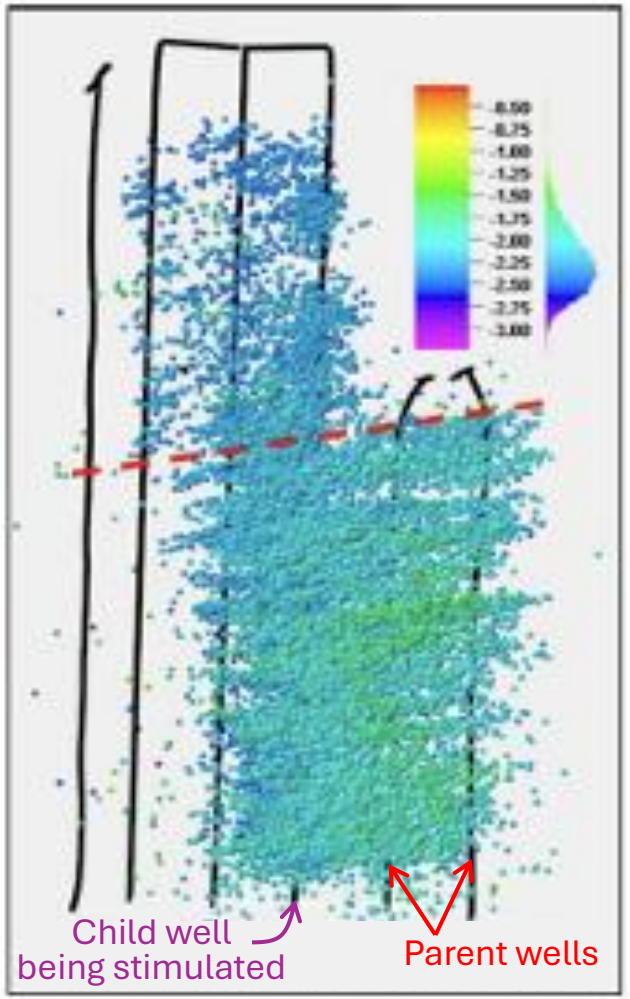
Casing deformation during fracturing



Permian Basin – HFTS 1

Source: GTI Energy Hydraulic Fracturing Test Site 1 (HFTS 1) final report

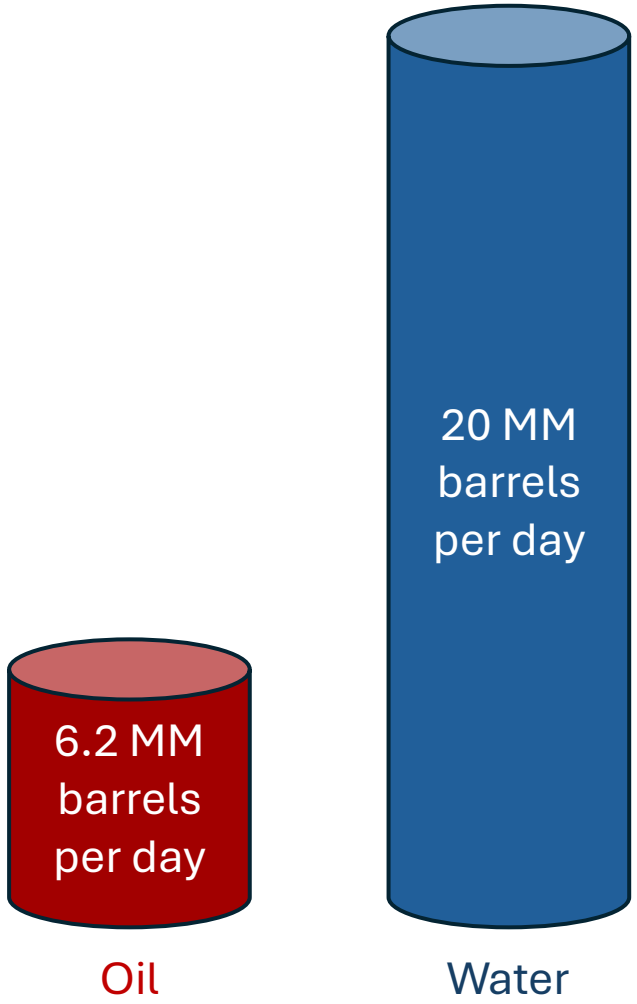
Parent-child production degradation



Permian Basin – HFTS 2

Source: GTI Energy Hydraulic Fracturing Test Site 2 (HFTS 2) final report

Excessive produced water



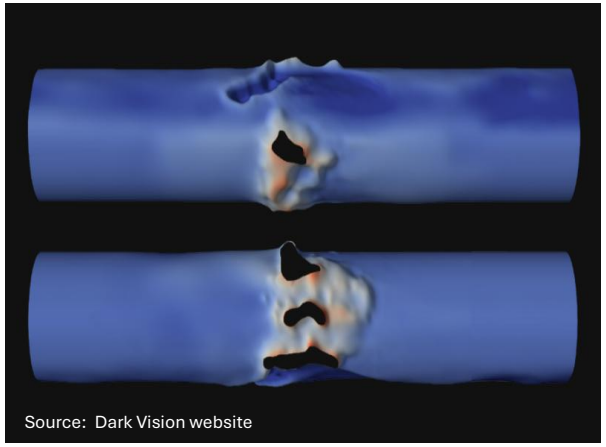
2025 Permian Basin

Oil production data from U.S. EIA; Water data from James Ritchie, ExxonMobil

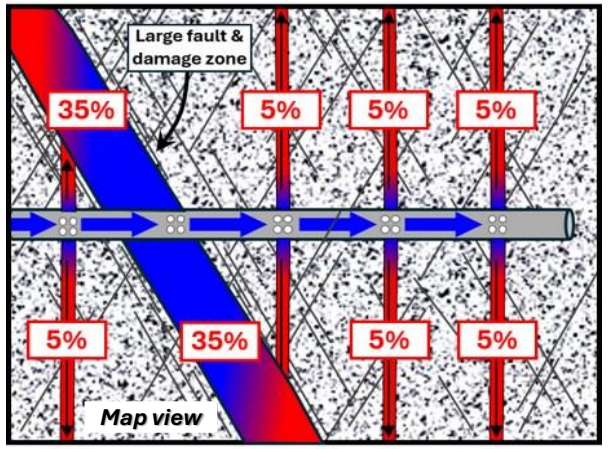
Geothermal under-appreciated and unexpected challenges

Enhanced Geothermal Systems (EGS)

Casing deformation

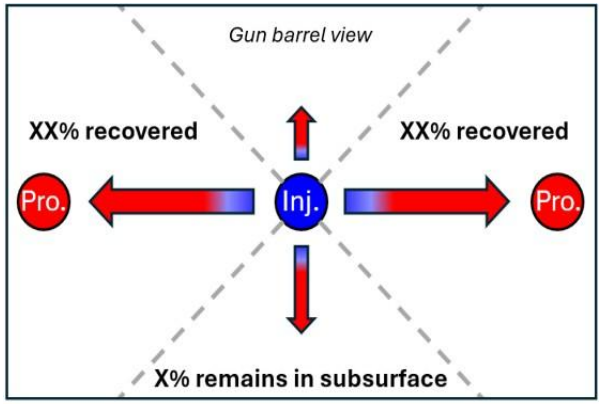


Premature thermal breakthrough



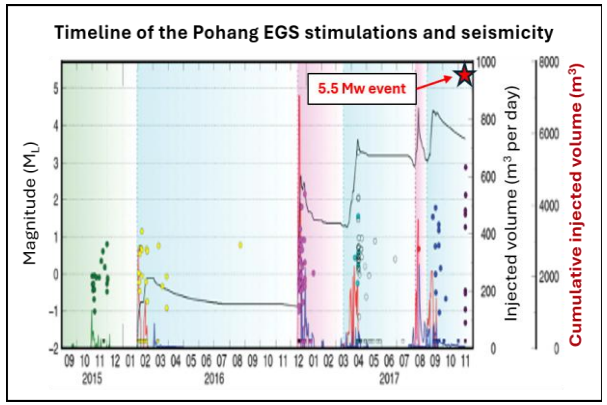
See Leveille and Zoback, 2025, for mitigation options (LINK)

Excessive water losses



See McClure, 2026, for mitigation options (LINK)

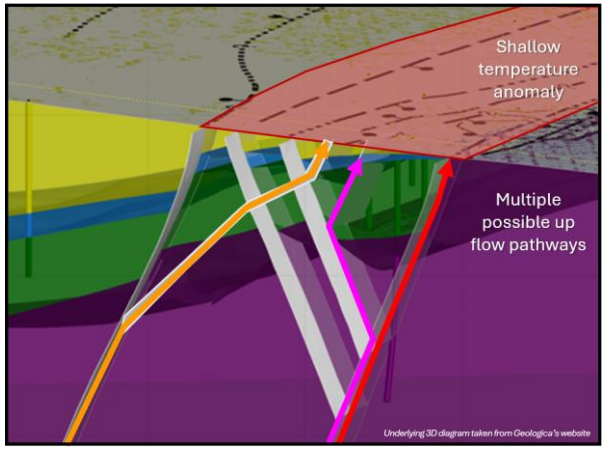
Elevated induced seismicity



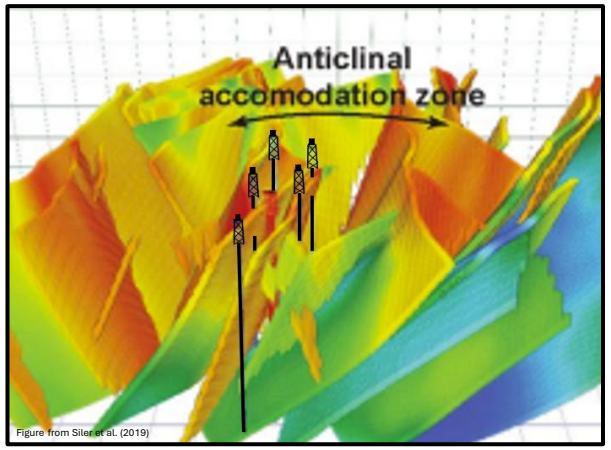
From Leveille and Zoback, 2025; after Ellsworth, et al., 2019

Hydrothermal systems

Well placement given uncertainty



Injector / producer connectivity

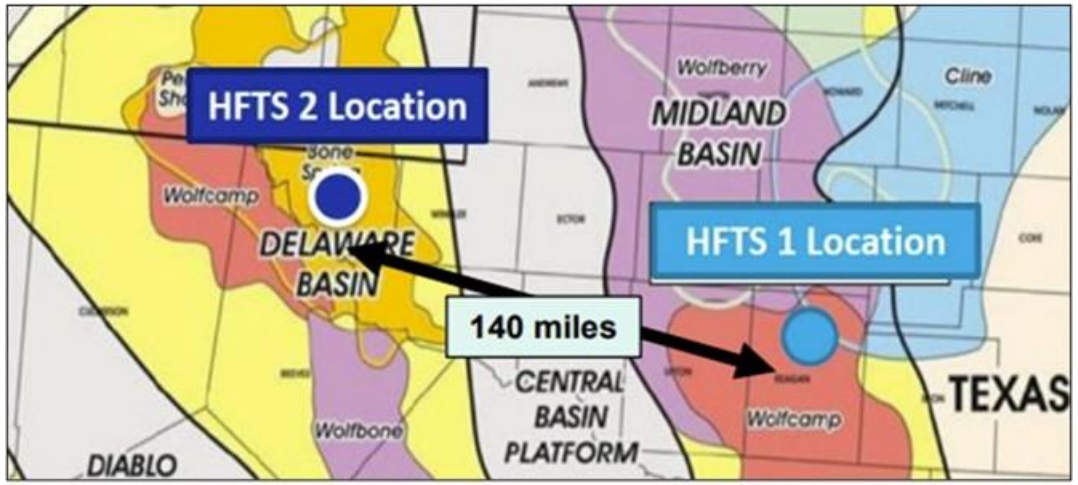


Super hot rocks

Unconventionals: To maximize value creation, build bridges, not moats

Sharing technology development costs

Permian Basin hydraulic fracturing test sites (HFTS)

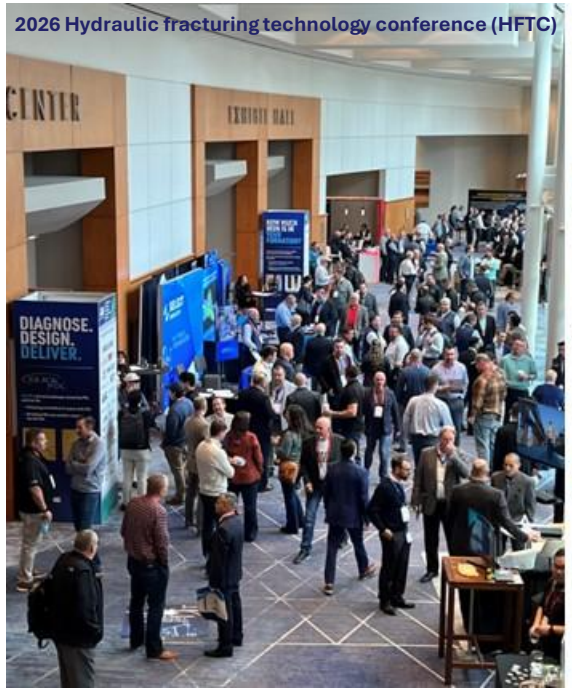


Sharing technical knowledge

Technology leaders promoting collaboration (e.g., URTeC EAB)

bp, Chevron, CONCHO, ConocoPhillips, devon, HESS, PIONEER NATURAL RESOURCES, saudi aramco

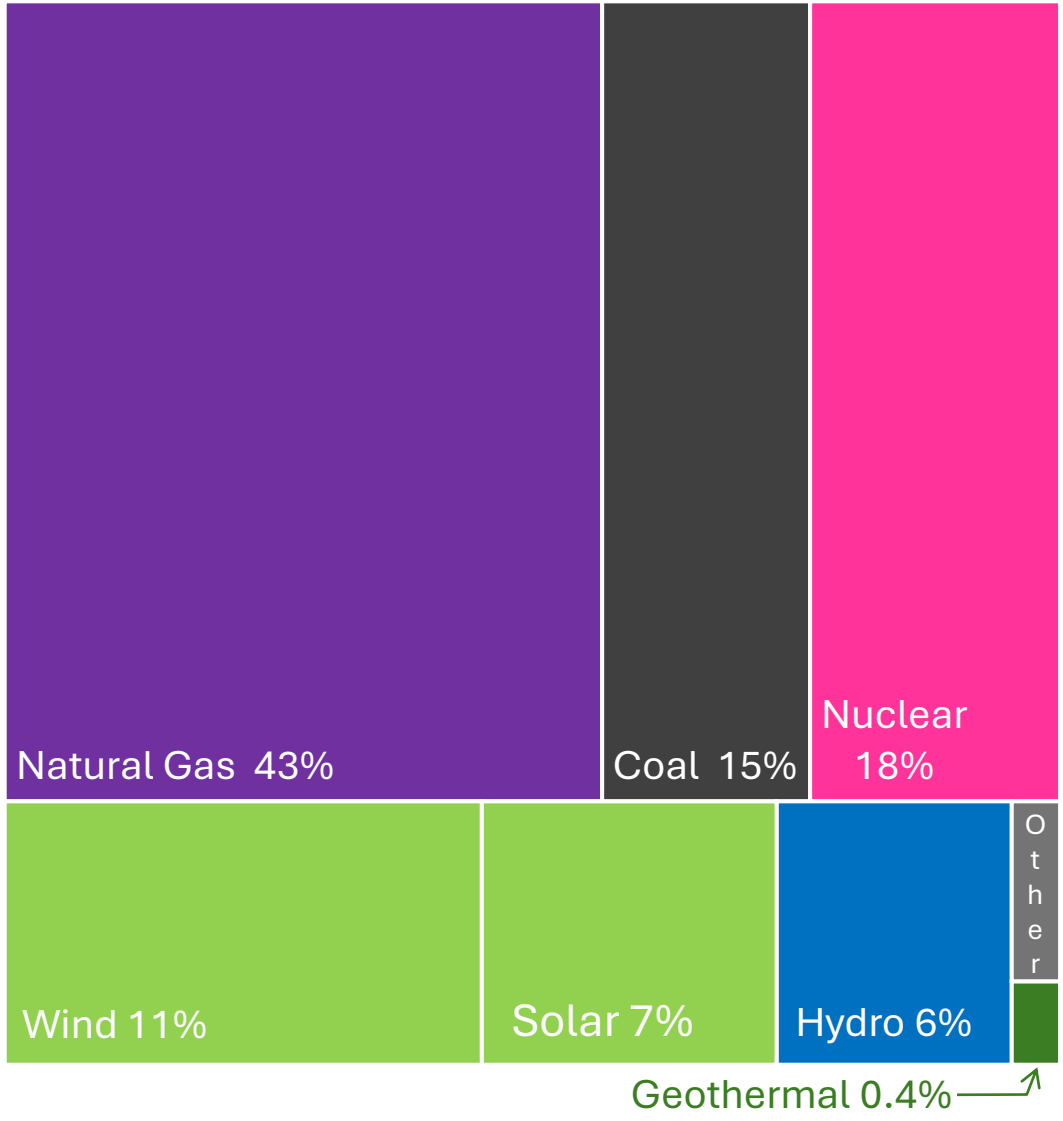
URTeC EAB = Unconventional resources technology conference executive advisory board



2026 Hydraulic fracturing technology conference (HFTC)

For geothermal to maximize value creation, build bridges, not moats

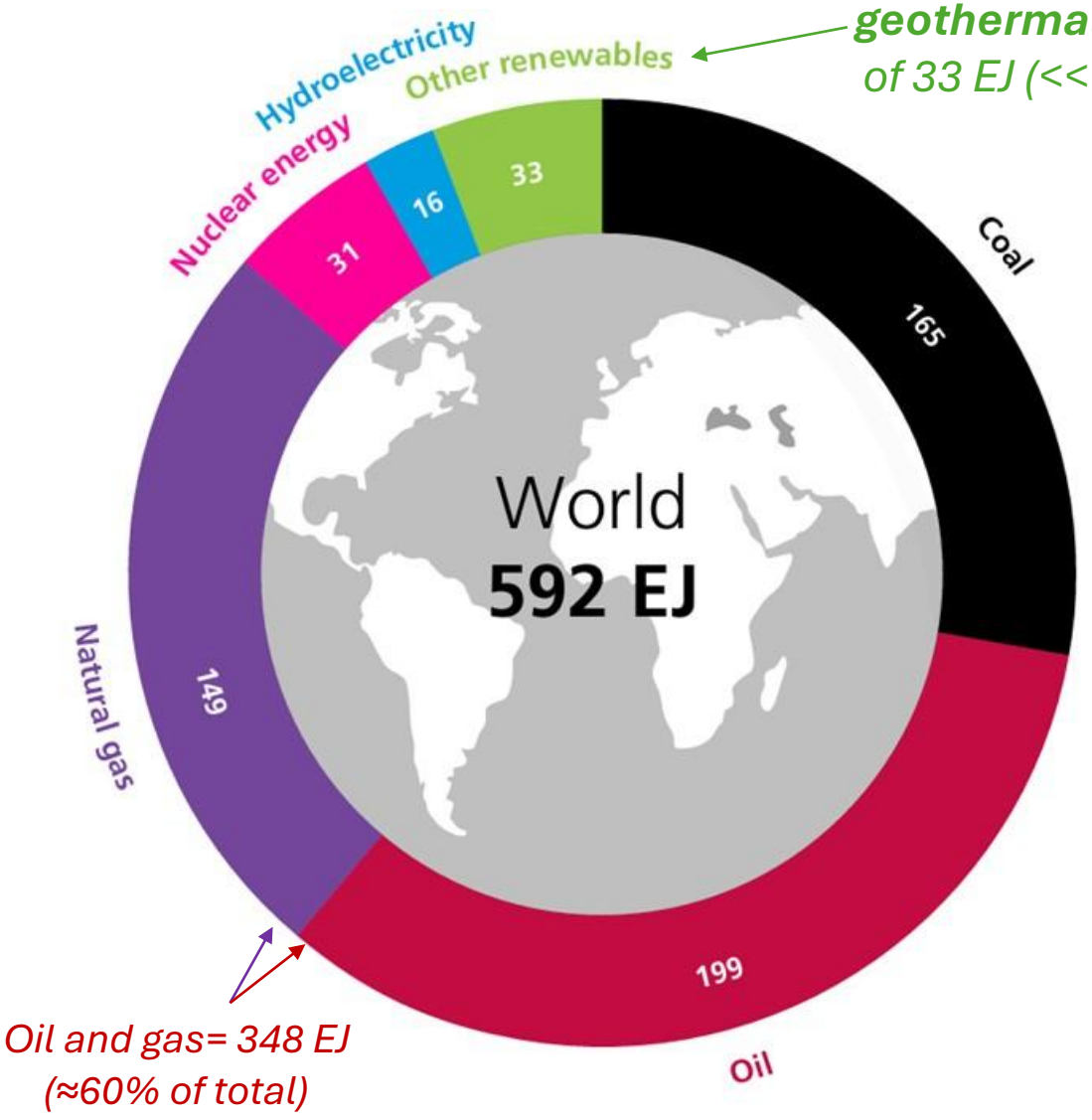
Sources of power generated in the U.S.
(2024)



Source: U.S. Energy Information Administration

Sources of energy
(2024 Exajoules)

*Biomass and **geothermal** ≈ 3 EJ of 33 EJ (<< 0.5%)*

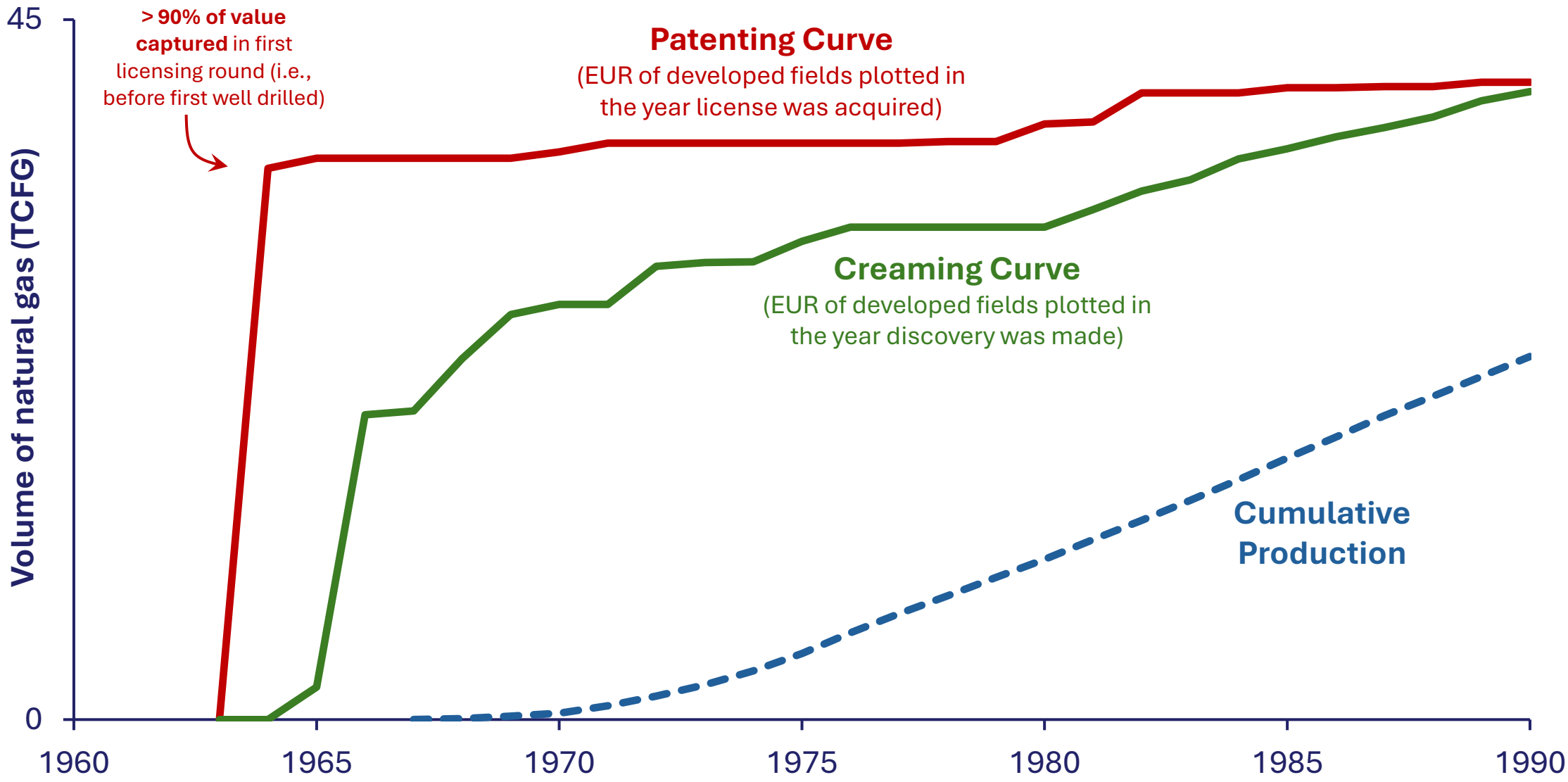


Oil and gas= 348 EJ (≈60% of total)

Source: Energy Institute; EJ = Exajoule

Land is the source of all wealth: Securing a bullet proof patent

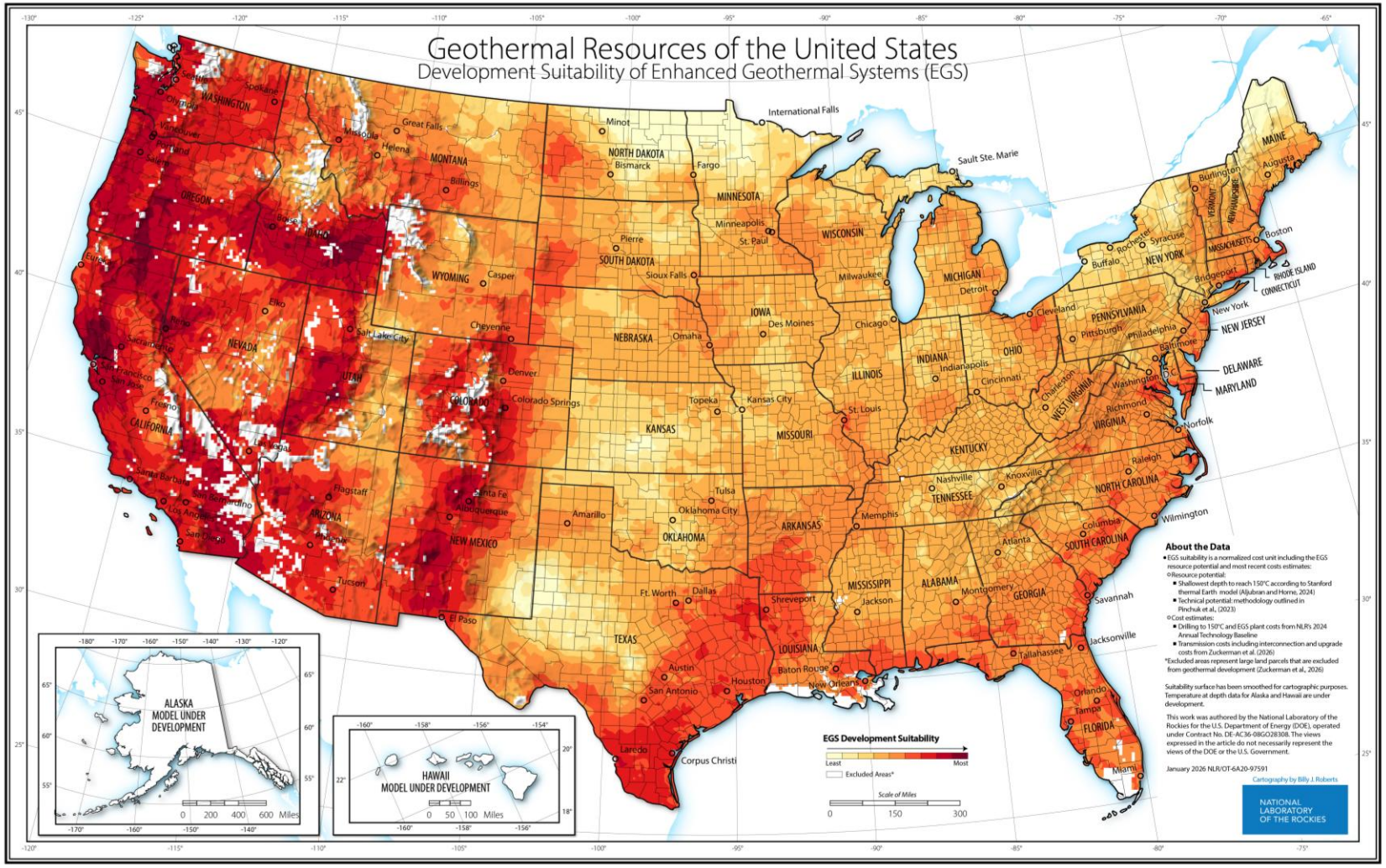
Example from the Rotliegendes natural gas play, U.K. Southern North Sea



Data from various sources including publications, presentations, and UK government databases; Cum. Prod. Estimated from multiple sources; SNS = southern North Sea; EUR = estimated ultimate recovery (from producing fields within play); TCFG = trillion cubic feet of gas

Geothermal acreage acquisition – the ultimate competitive advantage

Vast areas in the western and south-central United States are favorable for geothermal power development, but lease costs are rising and the best acreage will go quickly



April 2022 (≈ $36 per acre)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

BLM geothermal leases in Utah sale net $0.79 million

April 2025 (≈ $111 per acre)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

BLM geothermal leases in Utah sale net over $5.6 million

August 2026 (≈ $341 per acre)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Record $24 million in winning bids for Utah geothermal leases

Six useful unconventional reservoir revolution lessons learned

1. To achieve exceptional economics, find a powerful lever
2. A technology revolution opens multiple pathways to success
3. Be bold to avoid "good enough" becoming the enemy of "great"
4. There will be under-appreciated and unexpected challenges
5. Build bridges, not moats to maximize value creation
6. Land is the source of all wealth

SPE International

Geothermal TS

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September 2026

Slides available at: https://tidalwavetechnologies.com/publications-presentations/

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SEPTEMBER 24TH | 10:00 AM – 11:00 AM | US CENTRAL TIME | ZOOM WEBINAR

GREG LEVEILLE

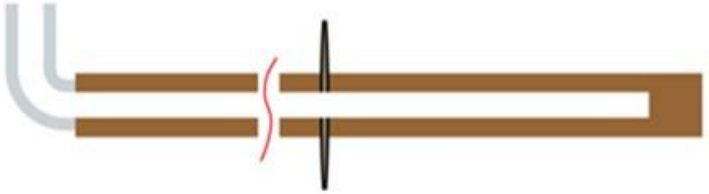
CEO AT TIDAL WAVE TECHNOLOGIES LLC

Examples of technological advancements that helped improve unconventional economics

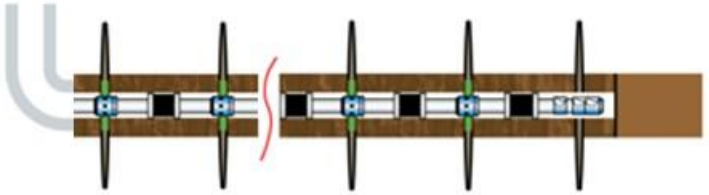
Improved economics over time

Hydraulic fracturing techniques

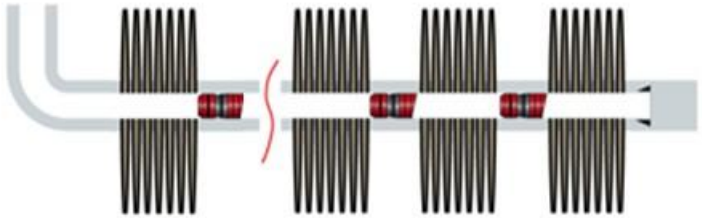
Pump-n-pray



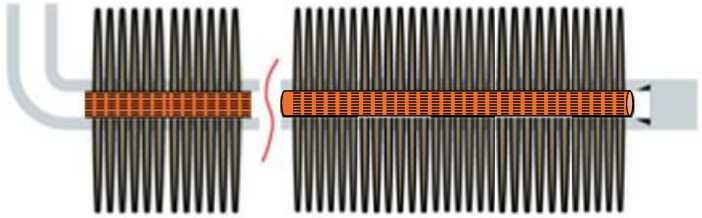
Open hole swell packers with sleeves



Cemented plug-n-perf

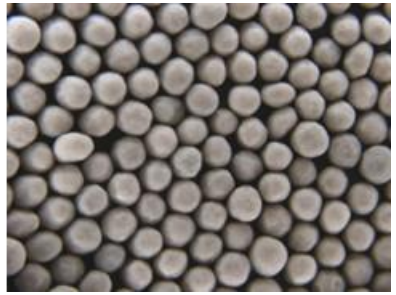


Cemented frac sleeves

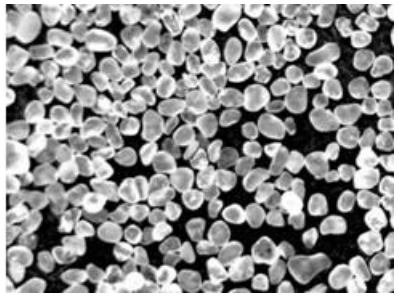


Proppant

Man-made ceramic proppant



High-quality sand mined at remote locations



Sand mined at local sites

Additional examples of important technological advancements

Highly automated, mobile drilling rigs

1 hour on average for well-to-well "rig walks"

PDC drill bits and physics-based optimization

Increased ROP; Minimal non-productive time

PDC = Polycrystalline Diamond Compact; ROP = Rate of penetration

Additional examples of important technological advancements

Highly efficient, upscaled fracturing operations

More water, more proppant, zipper fracs

Hydraulic completion units replaced coiled tubing

HCUs enabled cleanout of ultra-long laterals

Key papers, posts and presentations (Enhanced geothermal systems; 1 of 2)

- Mark McClure, 2026, **The influence of well configuration on water loss in Enhanced Geothermal Systems** (LINK)
- Leveille, 2026, **Geothermal Power – a super-hot, international industry primed to scale rapidly** (LINK)
- Leveille, 2026, **Geothermal Power Surge at the Massachusetts Institute of Technology** (LINK)
- Fervo, 2026, **Enhanced Geothermal Has Been Proven at Scale. Here's What Two Years of Production Data Show** (LINK)
- Bonneville et al., 2026, **A Major Milestone at Newberry, Oregon: Advancing Toward a Superhot Rock EGS Reservoir** (LINK)
- Grubac et al., 2026, **Implementation of the World's First Greater than 300 °C Propped EGS Reservoir** (LINK)
- Gonzalez et al., 2026, **Twinned at 300°C+: High-Performance Geothermal Drilling — Newberry Case Study** (LINK)
- Chandrasekhar and Suryanarayana, 2026, **Thermal Decline and Management in Energy Generation from Fractures in Super Hot Rock Formations** (LINK)
- Dichter et al., 2026, **Concept of a High-Temperature EGS Plant in Central Oregon** (LINK)
- Fervo, 2026, **Fervo Energy Drills Hottest Well to Date at New Giga-Scale Geothermal Project Site** (LINK)
- Kim et al., 2026, **Evidence of Direct Fluid Connections between Hydraulic Fractures and Pre-existing Faults at the Cape Station EGS Project** (LINK)
- Leveille and Zoback, 2025, **Impacts of Shear Zones on Enhanced Geothermal Systems (EGS): Best Practices for Avoiding Induced Seismicity, Premature Thermal Breakthrough, and Excessive Leakoff** (LINK); (LINK to slide deck).
- Project Innerspace, 2025, ***The Geothermal Exploration Opportunities Map Beta*** (GeoMap™) (LINK)

Key papers, posts and presentations (Enhanced geothermal systems; 2 of 2)

- Fercho et al., 2025, ***Update on the Geology, Temperature, Fracturing, and Resource Potential at the Cape Geothermal Project Informed by Data Acquired from the Drilling of Additional Horizontal EGS Wells*** (LINK)
- Dadi, 2025, **Insights from Microseismic Monitoring of Enhanced Geothermal Systems: Case Study from Cape Modern, Utah, USA** (LINK)
- Jurick et al., 2025, ***Improving the Connectivity Between Injection and Production Wells in Enhanced Geothermal Systems Using Fiber Optic Data*** (LINK)
- Ertas, 2025, ***EGS Reservoir Characterization Through Injectivity and Steady-State Circulation Tests*** (LINK)
- Norbeck, Gradl, and Latimer, 2024, ***Deployment of Enhanced Geothermal System technology leads to rapid cost reductions and performance improvements*** (LINK)
- El-Sadi et al., 2024, ***Review Of Drilling Performance In A Horizontal EGS Development*** (LINK)
- Moore, 2024, ***Current Activities at Utah FORGE*** (LINK)
- Norbeck and Latimer, 2023, ***Commercial-Scale Demonstration of a First-of-a-Kind Enhanced Geothermal System*** (LINK)
- McClure, 2023, ***Fervo Energy's 'Project Red' Results are a Historical Breakthrough for Geothermal – What Comes Next*** (LINK)
- Dupriest and Noynaert, 2022, ***Drilling Practices and Workflows for Geothermal Operations*** (LINK)

Key papers and publications (Hydrothermal systems)

- Faulds et al., 2026, **Favorable Structural Settings for Geothermal Systems in the Great Basin Region, Western USA: A Critical Regional Dataset and Harbinger for Hidden Geothermal Resources** (LINK)
- Kim et al., 2026, **Evidence of Direct Fluid Connections between Hydraulic Fractures and Pre-existing Faults at the Cape Station EGS Project** (LINK)
- Zheng et al., 2026, **Thermal Gradient Signatures of Fault-Controlled Hydrothermal Systems: Insights from Conceptual Models and Field Data** (LINK)
- Leveille, 2025, **Horizontal Hydrothermal Wells: An Idea Whose Time Has Come** (LINK)
- Leveille, 2025, Slide deck accompanying paper "**Horizontal Hydrothermal Wells: An Idea Whose Time Has Come**" (LINK)
- Dadi, 2025, **Insights from Microseismic Monitoring of Enhanced Geothermal Systems: Case Study from Cape Modern, Utah, USA** (LINK)
- Edwards et al., 2025, **A Look Into Geothermal Discoveries Across the Western United States** (LINK)
- Grujic et al., 2025, **GeoCore: An Efficient and Scalable Framework to Optimize Geospatial Machine Learning** (LINK)
- Hermantet al., 2025, ***Using Deep Learning to Map Quaternary Faults in Western USA*** (LINK)
- Hart-Wagoner et al., 2024, **Preliminary regional play fairway workflow for the Great Basin region, USA** (LINK)
- Macrossie Smith, 2021, **Machine Learning Techniques Applied to the Nevada Geothermal Play Fairway Analysis** (LINK)
- Pollack, 2020, **Quantifying Geological Uncertainty and Optimizing Technoeconomic Decisions for Geothermal Reservoirs** (LINK) – see especially sections four and five of this document (pages 71 – 154)

Other key geothermal power production papers and publications

- NOAA Global Monitoring Laboratory, 2026, ***Trends in CO2 and CH4*** (LINK)
- Roland Horne, 2026, ***History of closed loop geothermal power systems*** (LINK)
- United States Energy Information Administration, 2025, ***Crude Reserves and Production*** (LINK) ***& Natural Gas Gross Withdrawals and Production*** (LINK) ***& Electricity Net Generation by Energy Source*** (LINK)
- Lazard, 2024, ***Levelized Cost of Energy Comparison*** (LINK)
- CATF, 2024, ***Gaps, Challenges, and Pathways Forward for Superhot Rock Energy Summary Reports*** (LINK; LINK; LINK)
- United States Department of Energy, 2024, ***Pathways to Commercial Liftoff: Next-Generation Geothermal Power*** (LINK)
- Mark McClure, 2023, ***Thermoelastic fracturing and buoyancy-driven convection – Surprising sources of longevity for EGS circulation*** (LINK)
- Mark McClure, 2023, ***Technical barriers for deep closed-loop geothermal*** (LINK)
- CATF, 2022, ***Superhot Rock Energy - A Vision for Firm, Global Zero-Carbon Energy*** (LINK)
- McClure, M., 2021, ***Why Deep Closed-Loop Geothermal Is Guaranteed To Fail*** (LINK)

Key electricity demand and O&G fracture stimulation papers and publications

Demand for Clean Firm Electricity and High-Tech Companies' Net Zero Goals

- Sam Altman, 2024, ***Age of AI will require an 'energy breakthrough'*** (LINK)
- Microsoft, 2020, ***Microsoft will be carbon negative by 2030*** (LINK)
- Google, 2024, ***Google Commitment to net-zero carbon*** (LINK)
- Google, 2024, ***A new initiative with Microsoft and Nucor to accelerate advanced clean electricity technologies*** (LINK)
- Meta, 2024, ***Climate: We commit to reaching net zero emissions across our value chain in 2030*** (LINK)
- Amazon, 2024, ***Amazon's Climate Pledge – Net zero by 2040*** (LINK)
- Nvidia, 2024, ***NVIDIA Corporate Responsibility Report - Fiscal Year 2023*** (LINK)
- Scientific American, 2023, ***The AI Boom Could Use a Shocking Amount of Electricity*** (LINK)

Insights from Oil & Gas Horizontal Well Hydraulic Fracturing Characterization Projects

- Kevin T. Raterman et al., 2017, ***Sampling a Stimulated Rock Volume: An Eagle Ford Example***, URTeC paper 2670034 (LINK)
- Kevin T. Raterman, Yongshe Liu, and Logan Warren, 2019, ***Analysis of a Drained Rock Volume: An Eagle Ford Example***, URTeC paper 2019-263-MS, (LINK)
- Caner Karacaer et al., 2021, ***Multi-well Modeling in the Eagle Ford: An Investigation of Redevelopment, Infill and Refrac Opportunities***, URTeC paper 2021-5066-MS (LINK)
- Jordan Ciezobka and Debotyam Maity, 2023, **HFTS-1 Final Report** (LINK)
- Jordan Ciezobka and Debotyam Maity, 2022, **HFTS-2 Final Report** (LINK)