Well Completions for Unconventional O&G and Geothermal Resource Development

Greg Leveille

April 15, 2024

SPE workshop

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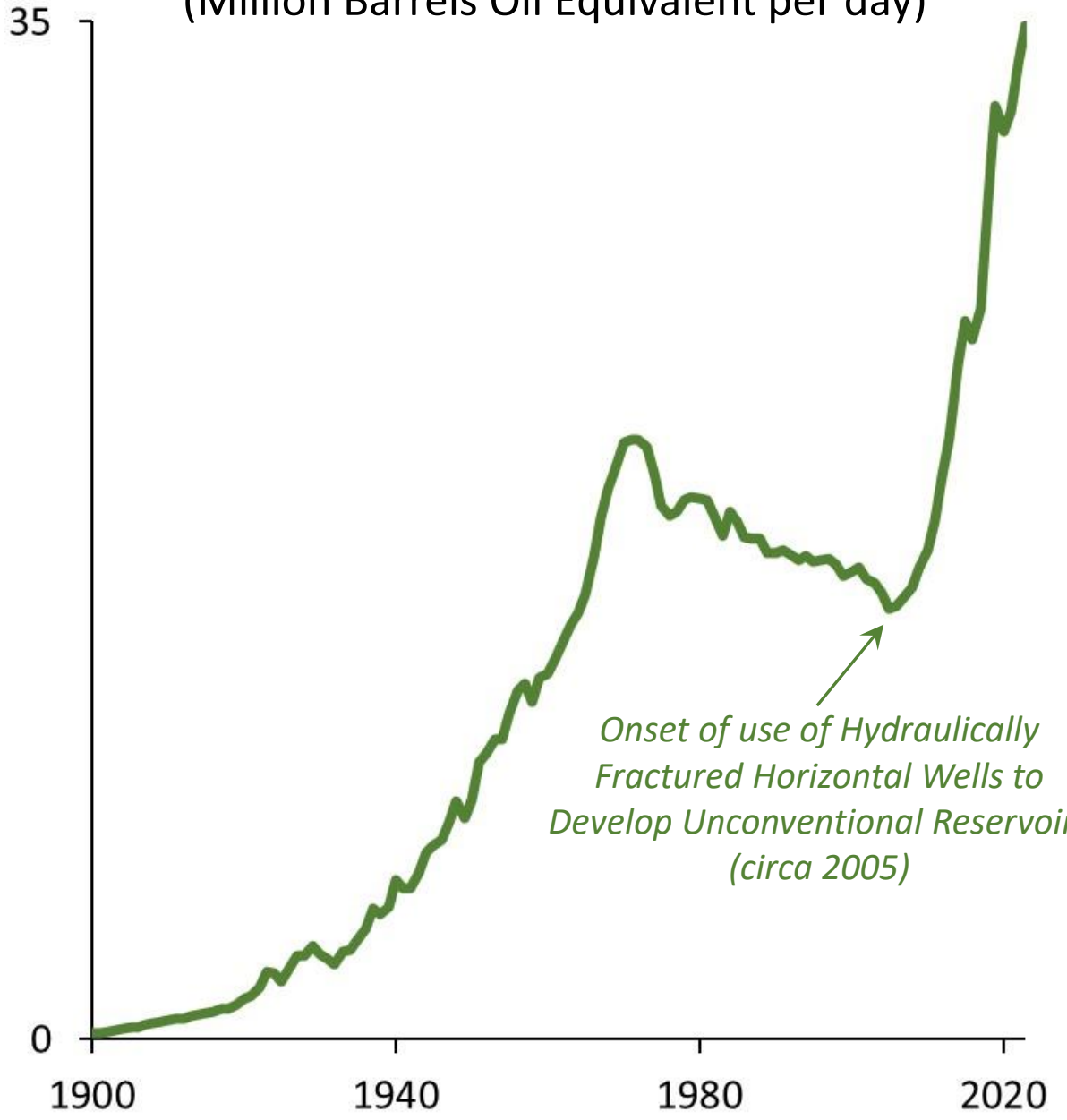
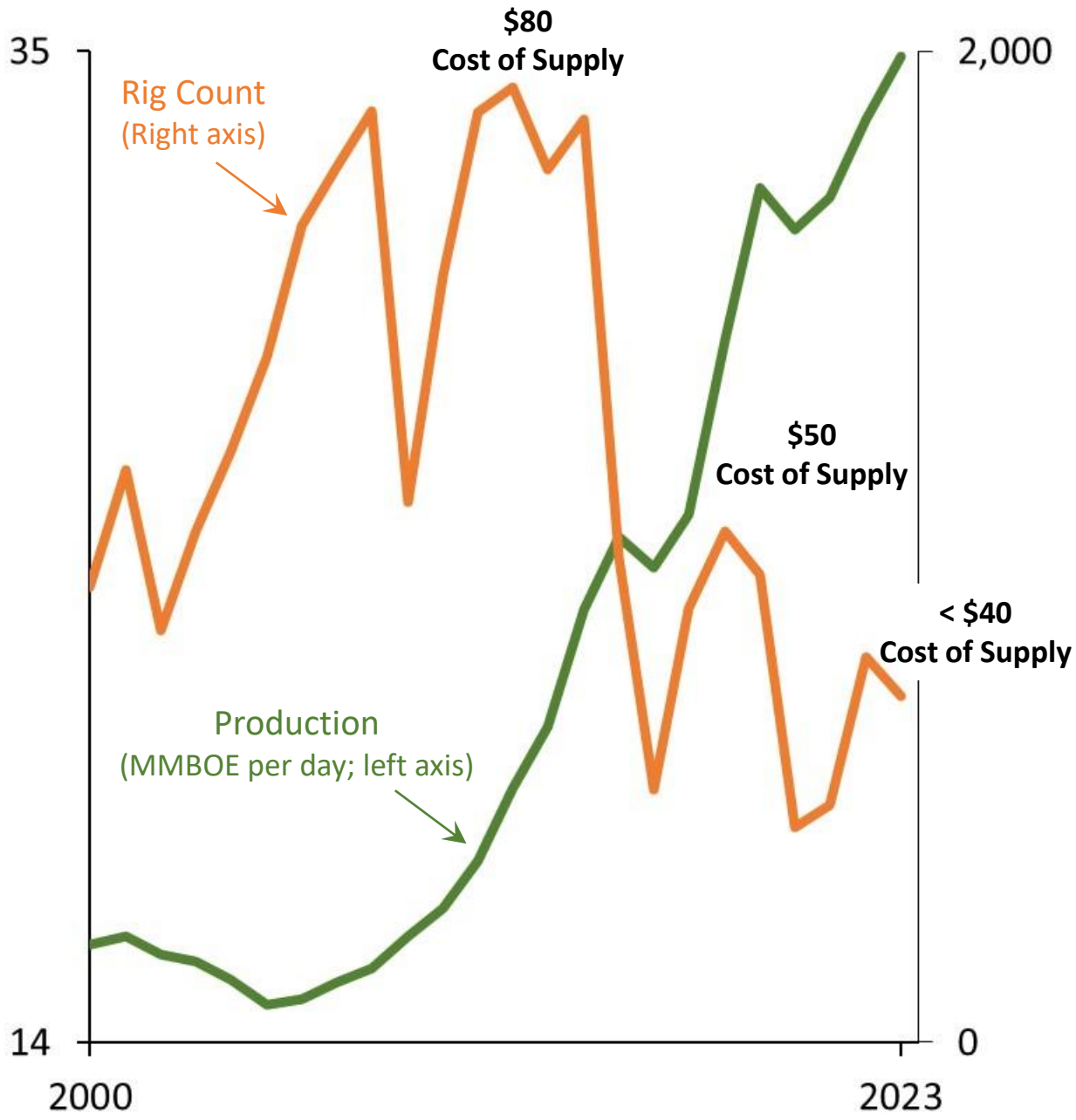
U.S. Hydrocarbon Production

(Million Barrels Oil Equivalent per day)



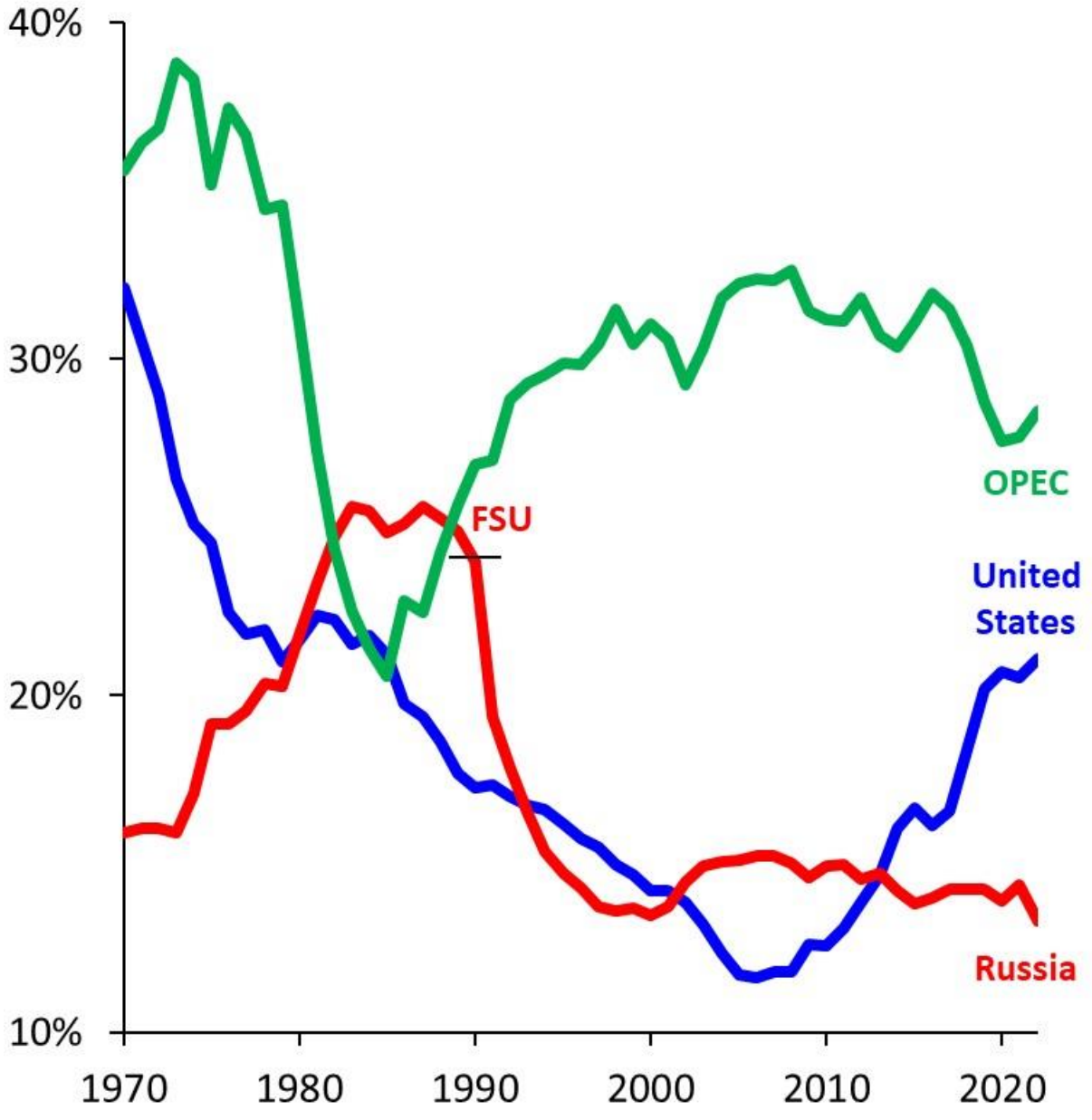
Sources: U.S. EIA, Energy Insights, and BP websites

U.S. Hydrocarbon Production & Rig Count



Sources: U.S. production = U.S. EIA, Energy Insights, and BP websites; Rig count = Baker Hughes

Global Hydrocarbon Production Market Share



Sources: Energy Insights and BP websites

The U.S. is the World's Largest O&G Producer:

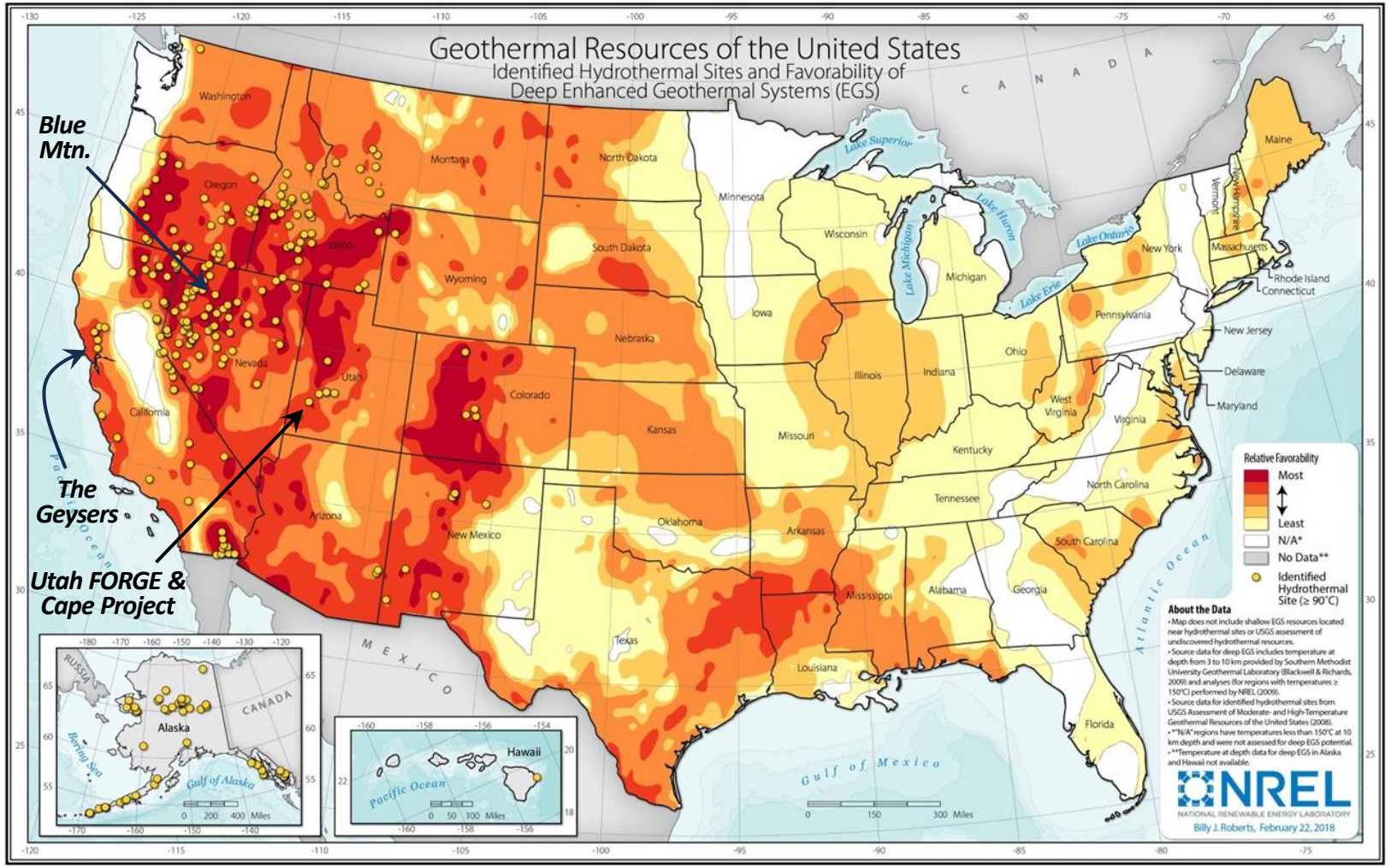
- Oil – Condensate – NGLs – Natural Gas
- > 22% of total global production
- Approaching OPEC's level of output
- ≈20 MMBOEPD > Saudi Arabia's output
- ≈15 MMBOEPD > Russia's output

America's Unconventional Revolution has:

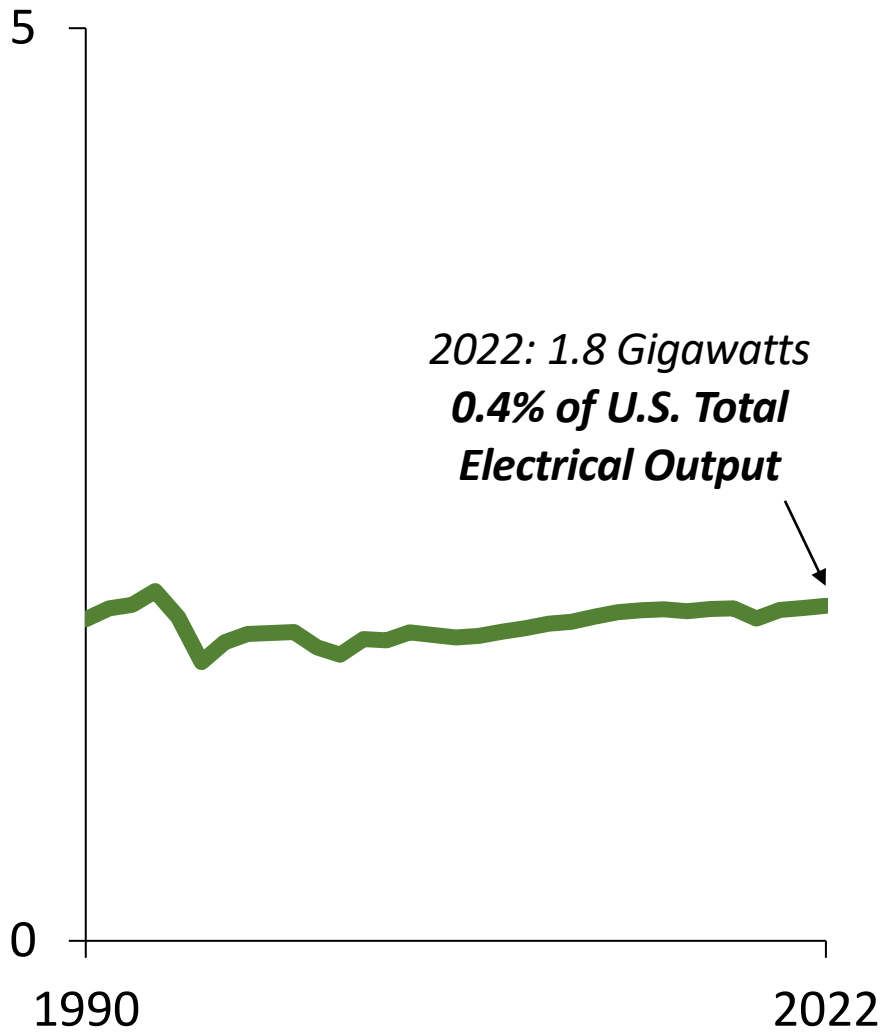
- Enhanced U.S. energy security
- Invigorated economic growth
- Shrunk America's trade deficit
- Reduced GHG emissions

Hydraulically fractured horizontal wells are what enabled these results to be achieved

Geothermal Resources Represent a Nearly Inexhaustible Supply of Energy



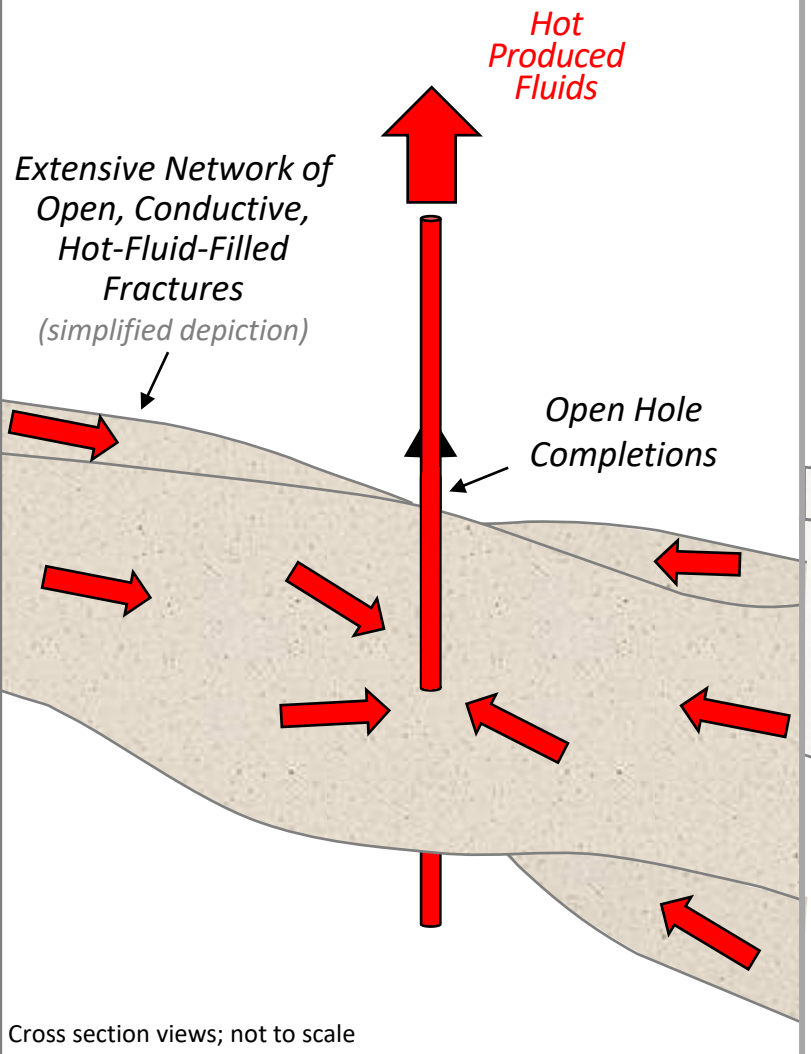
But U.S. Electricity Output from Geothermal is Negligible



Mao taken from U.S. NREL website

Source: U.S. EIA

Hydrothermal Systems



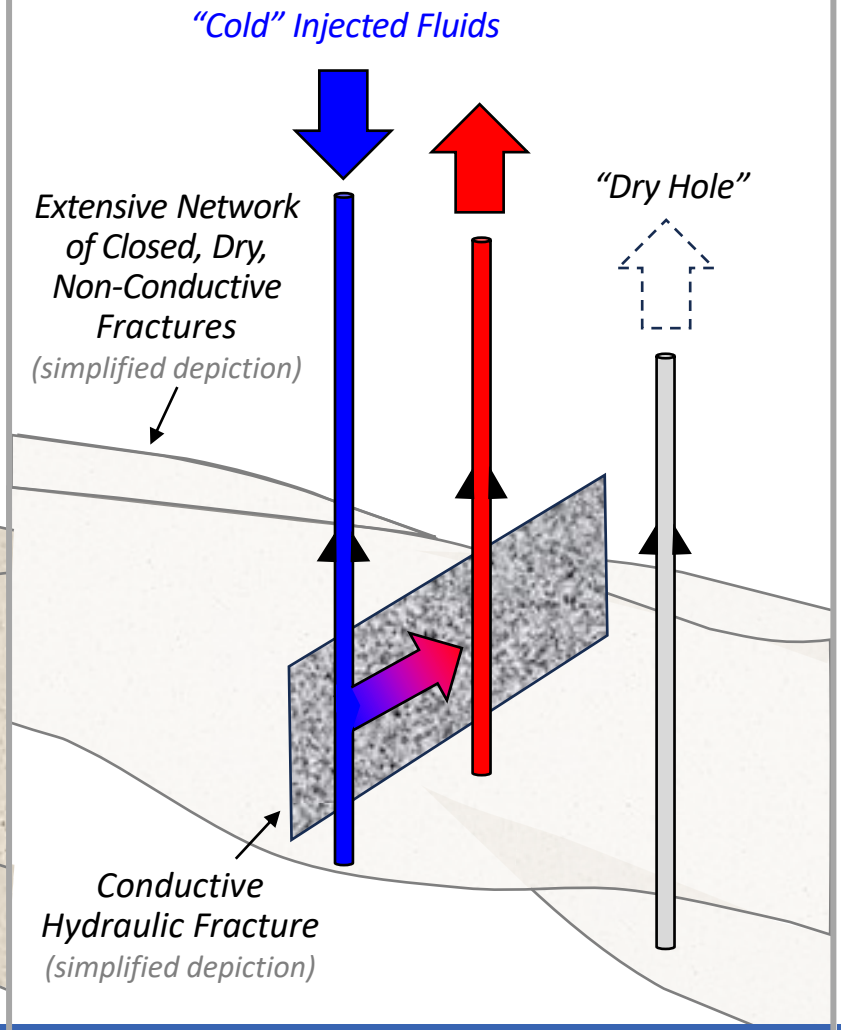
Cross section views; not to scale

EXCEEDINGLY RARE

Example: The Geysers, California

Enhanced Geothermal Systems (EGS)

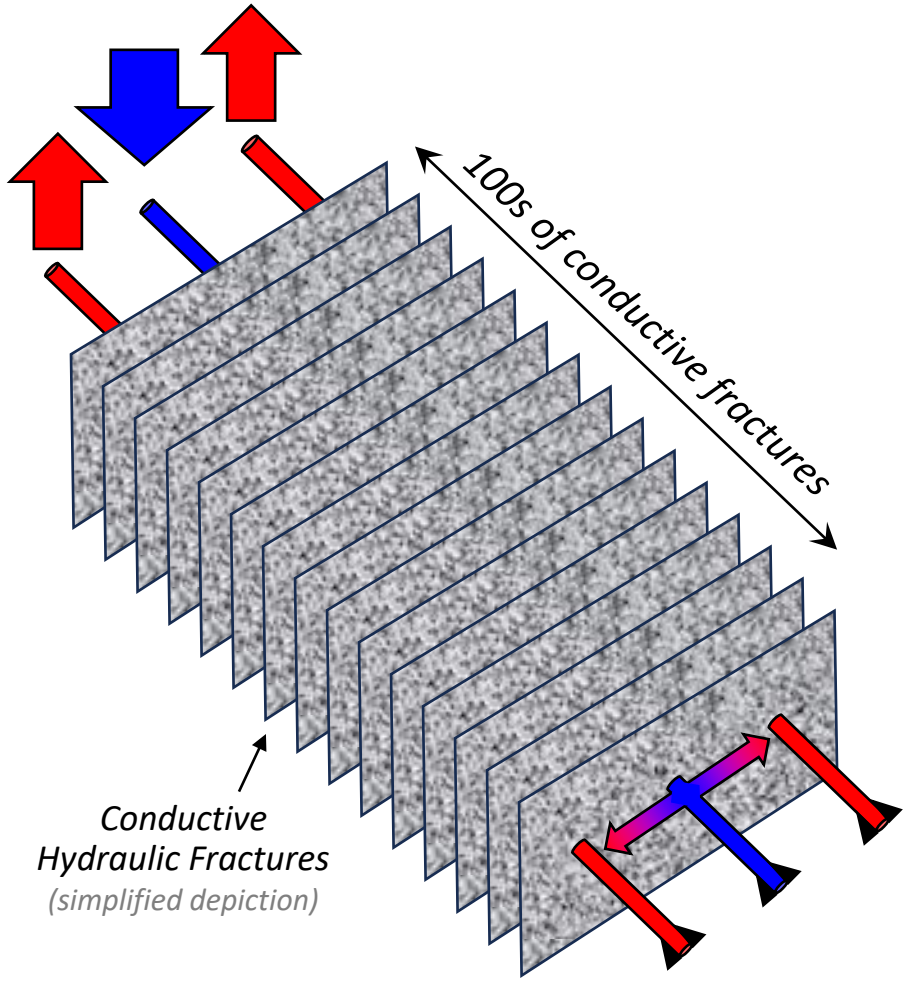
Vertical Wells



EXCEEDINGLY DISAPPOINTING

Example: Most EGS projects 1970-2023

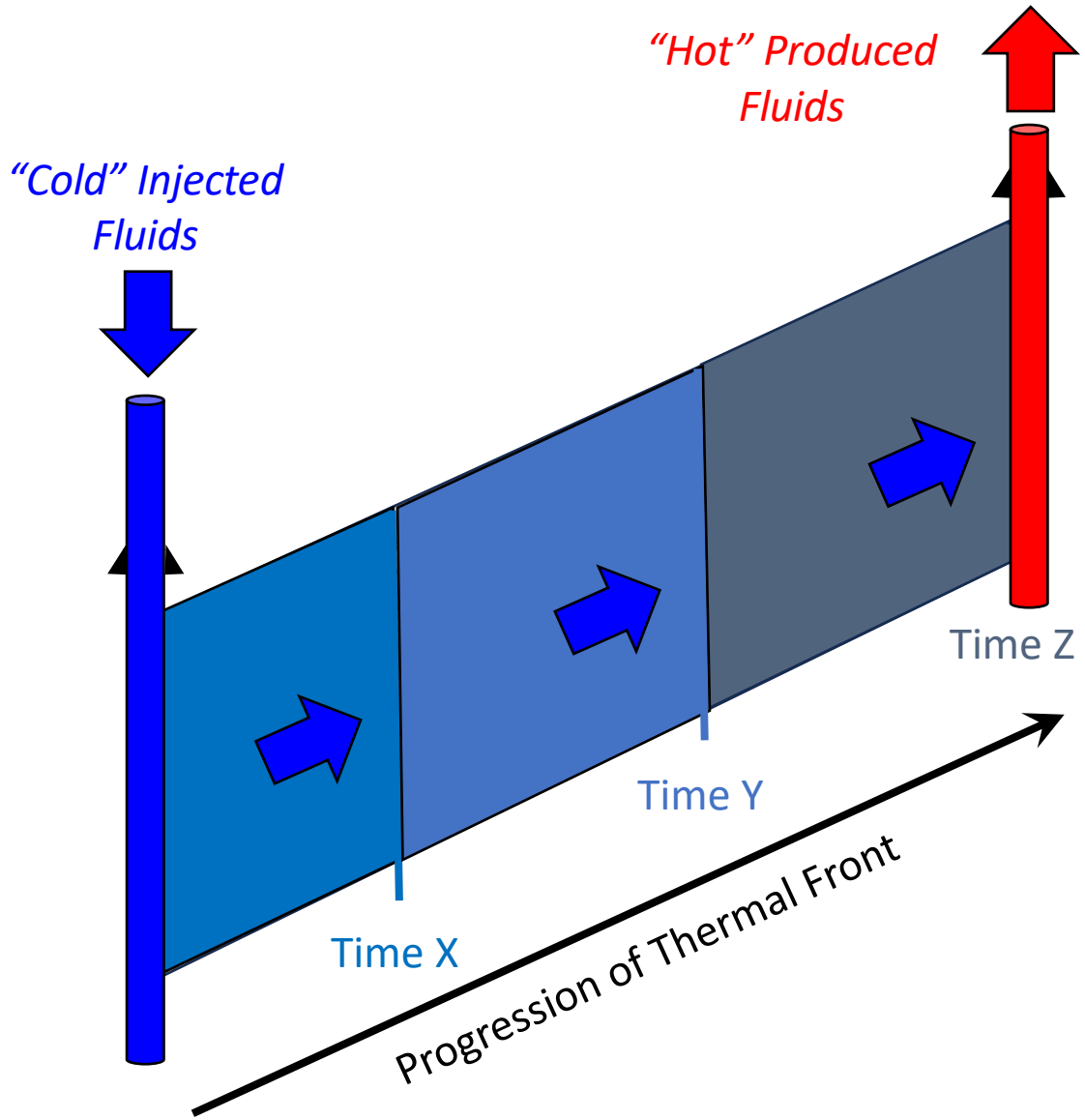
Horizontal Wells



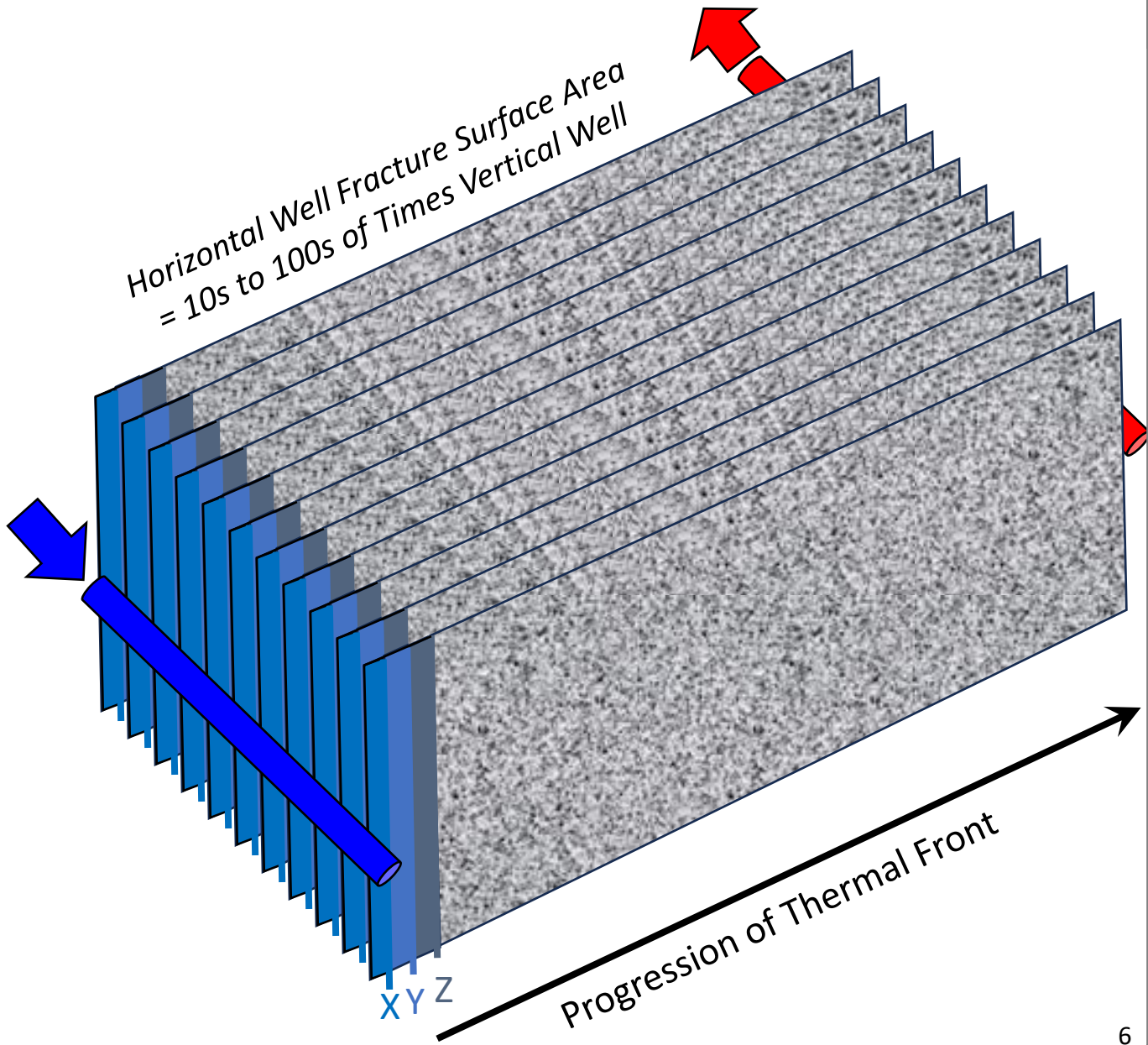
THE RIGHT TOOL FOR THE JOB

Examples: Fervo and Utah FORGE

EGS with Vertical Wells



EGS with Horizontal Wells



Cross section views; simplified depiction of hydraulic fractures; diagrams are not to scale

Fervo Blue Mountain Nevada Demonstration Project

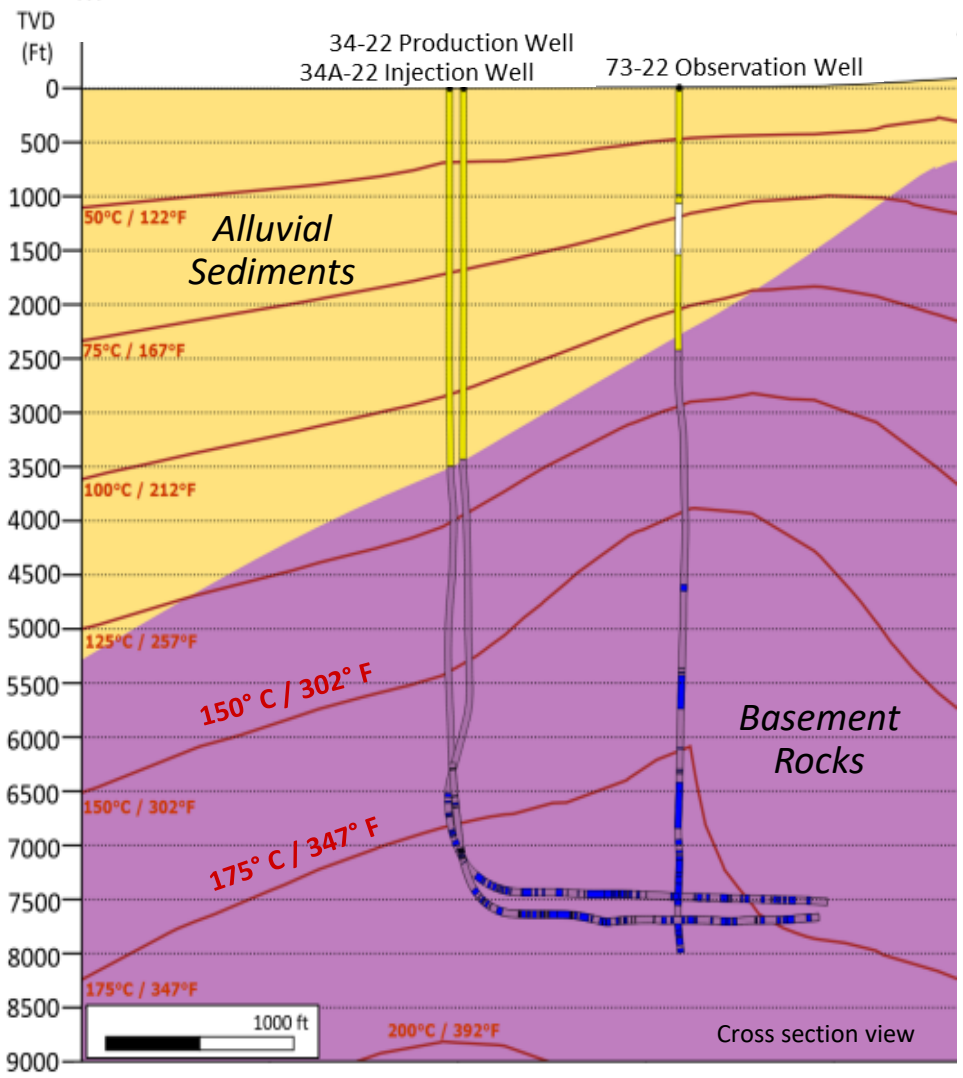


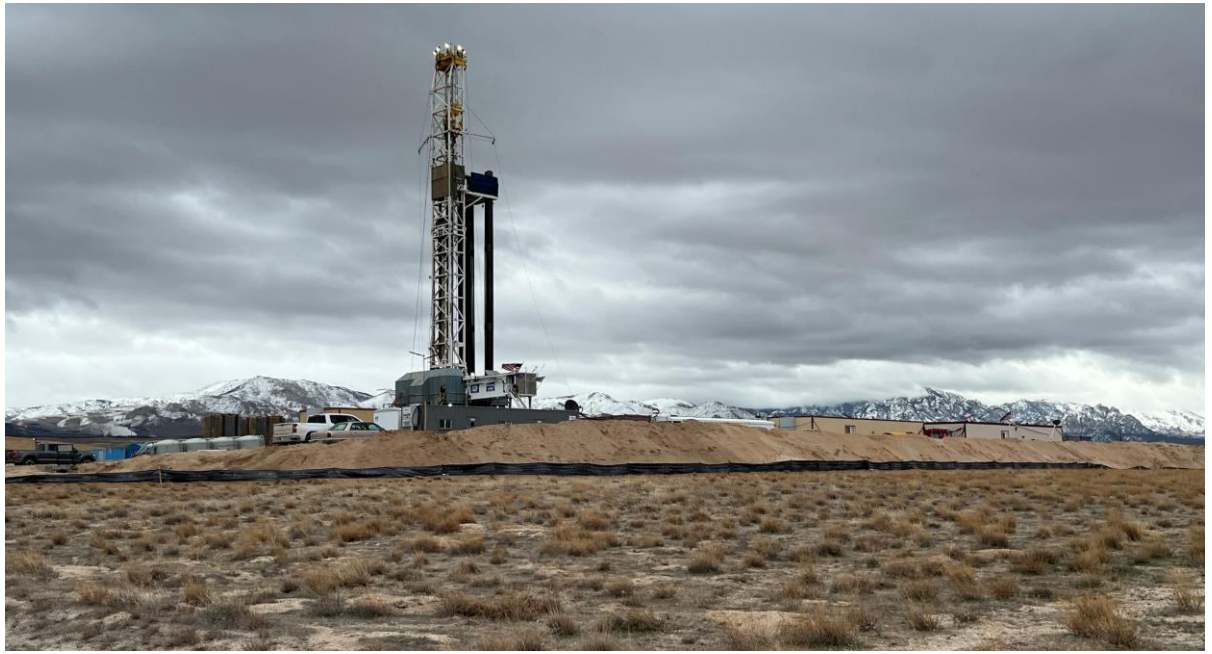
Diagram taken from 2023 paper by Jack Norbeck and Tim Latimer

Fervo Accomplishments to Date[1]

- Ability to drill horizontally in hot, hard rocks
- Viability of plug & perf completions at > 375° F
- Establishment of connectivity between horizontal injectors and producers
- Record setting EGS production rates
- Consistent placement of injected fluid across > 3,000’ of horizontal section
- Numerous sources suggest thermal longevity greater than a decade in duration is achievable
- Drilling time: from ≈ 150 days to < 25 days[2]

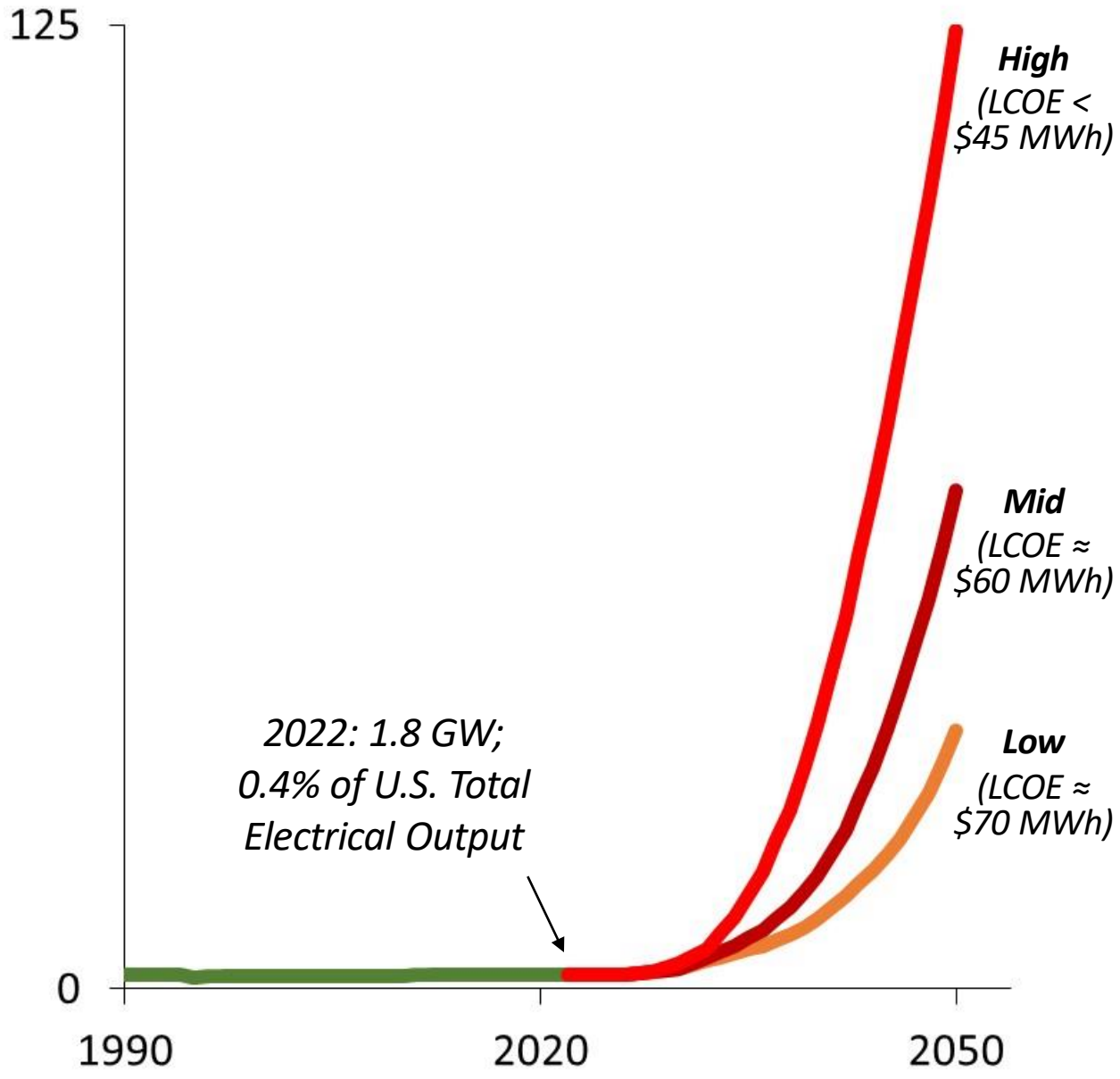
[1] Includes results from both Fervo’s Blue Mountain Nevada demonstration project and their Cape Project commercial development in SW Utah
[2] For a 10,000’ MD well drilled predominantly through hot, hard, abrasive basement rocks

Well Completion Core Competencies will be Critical for the Success of EGS



U.S. Electricity Output from Geothermal

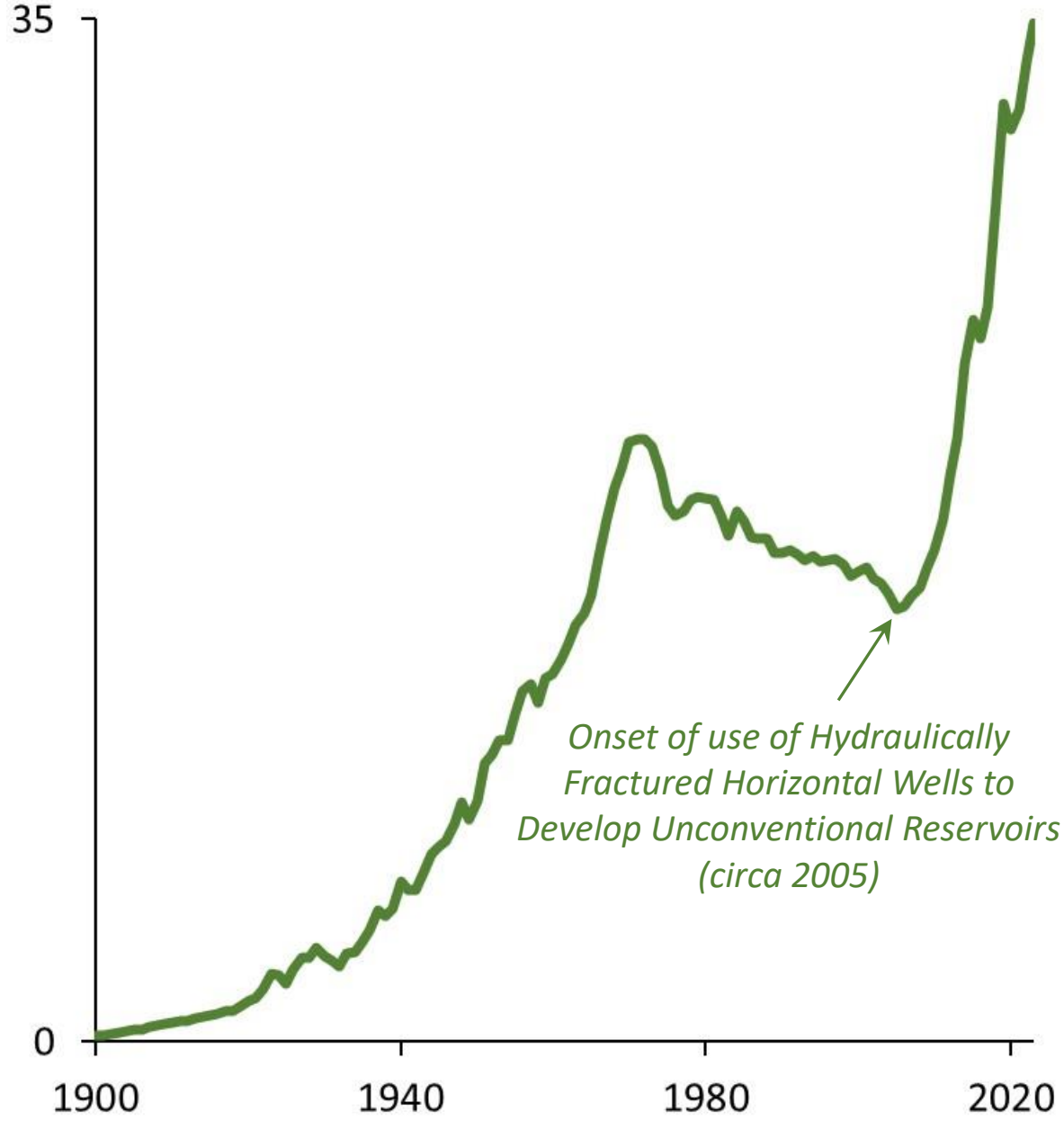
(Gigawatts)



Sources: U.S. EIA for 1990 to 2022; Author projections from 2023 to 2050; Total U.S. Consumption 2022 = 482 GW; 2050 DOE Estimate = 630 GW

U.S. Oil & Natural Gas Production

(Million Barrels of Oil Equivalent per Day)



Sources: U.S. EIA, Energy Insights, and BP websites

Key Take-Away Messages

- The Wells Completion Community has delivered heroic levels of optimization in O&G over the past twenty years
- This has produced enormous benefits for America, the O&G industry, and humankind
- The same skills, equipment, and people who achieved this result will be needed to optimize EGS development
- By delivering dramatic improvements in EGS performance, your community will once again positively impact our nation's and our planet's future

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Selected Key References

Horizontal EGS Demonstration Project Results

- Jack Norbeck & Tim Latimer, 2023, ***Commercial-Scale Demonstration of a First-of-a-Kind Enhanced Geothermal System*** (LINK)
- Mark McClure, 2023, ***Fervo Energy's 'Project Red' Results are a Historical Breakthrough for Geothermal – What Comes Next*** (LINK)
- Kareem El-Sadi, Brittany Gierke, Elliot Howard, Christian Gradl, 2024, **Review Of Drilling Performance In A Horizontal EGS Development** (LINK)
- Duane Winkler and Leroy Swearingen, 2021, ***Summary of Drilling Activities: Well 16A(78)-32***, Utah Forge U.S. DOE website (LINK)
- Fred Dupriest and Sam Noynaert, 2022, ***Drilling Practices and Workflows for Geothermal Operations*** (LINK)

Fully Coupled Hydraulic Fracturing and Reservoir Simulation Key Insights

- 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)

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)