NETHERLAND, SEWELL & ASSOCIATES, INC.

WORLDWIDE PETROLEUM CONSULTANTS

Technology Trends in Upstream Oil, Gas and Geothermal Energy

Louisiana Energy Conference
May 27, 2025

Rick Talley

Our Company

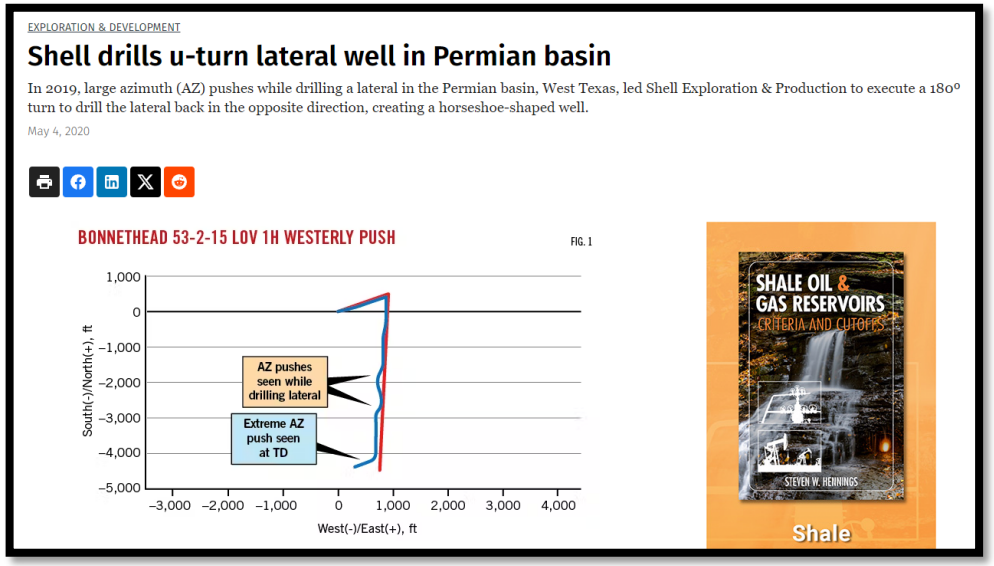
- Established in 1961
- Offices in Dallas and Houston, Texas
- 50+ Engineers, Geologists, Geophysicists, and Petrophysicists
- 60+ Engineering and Geology Analysts
- Expertise in most producing basins worldwide
  - Conventional and Unconventional
  - Domestic and International
- Well known within the oil & gas and financial communities
- Chosen by more companies for their SEC reserves reporting than any other petroleum consulting firm
- Focused on building client relationships and delivering exceptional service

Discussion Topics

- Technology Updates
  - U-Shaped Horizontals
  - Four-mile laterals
  - 20K drilling
  - Artificial Intelligence
- Geothermal Updates

U SHAPED LATERALS

U-Lateral Wellbores


EXPLORATION & DEVELOPMENT

Shell drills u-turn lateral well in Permian basin

In 2019, large azimuth (AZ) pushes while drilling a lateral in the Permian basin, West Texas, led Shell Exploration & Production to execute a 180° turn to drill the lateral back in the opposite direction, creating a horseshoe-shaped well.

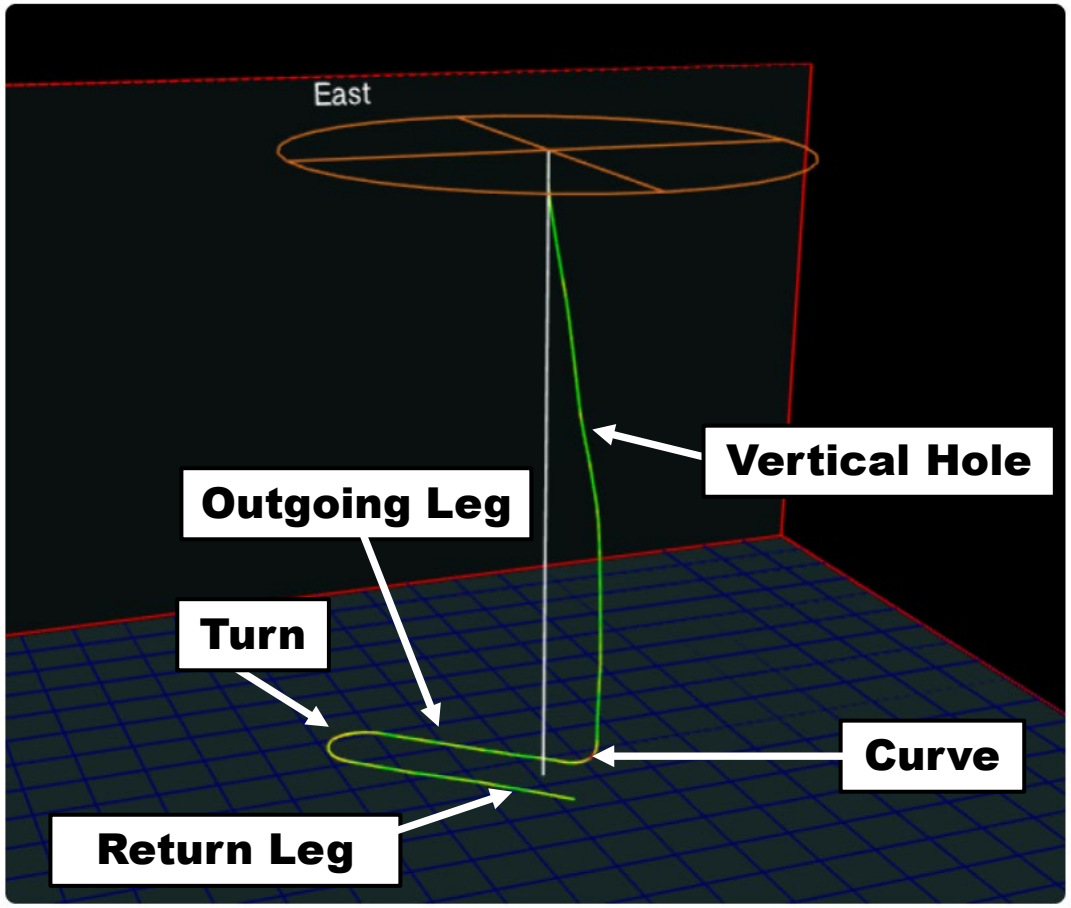
May 4, 2020

BONNETHEAD 53-2-15 LOV 1H WESTERLY PUSH

FIG. 1

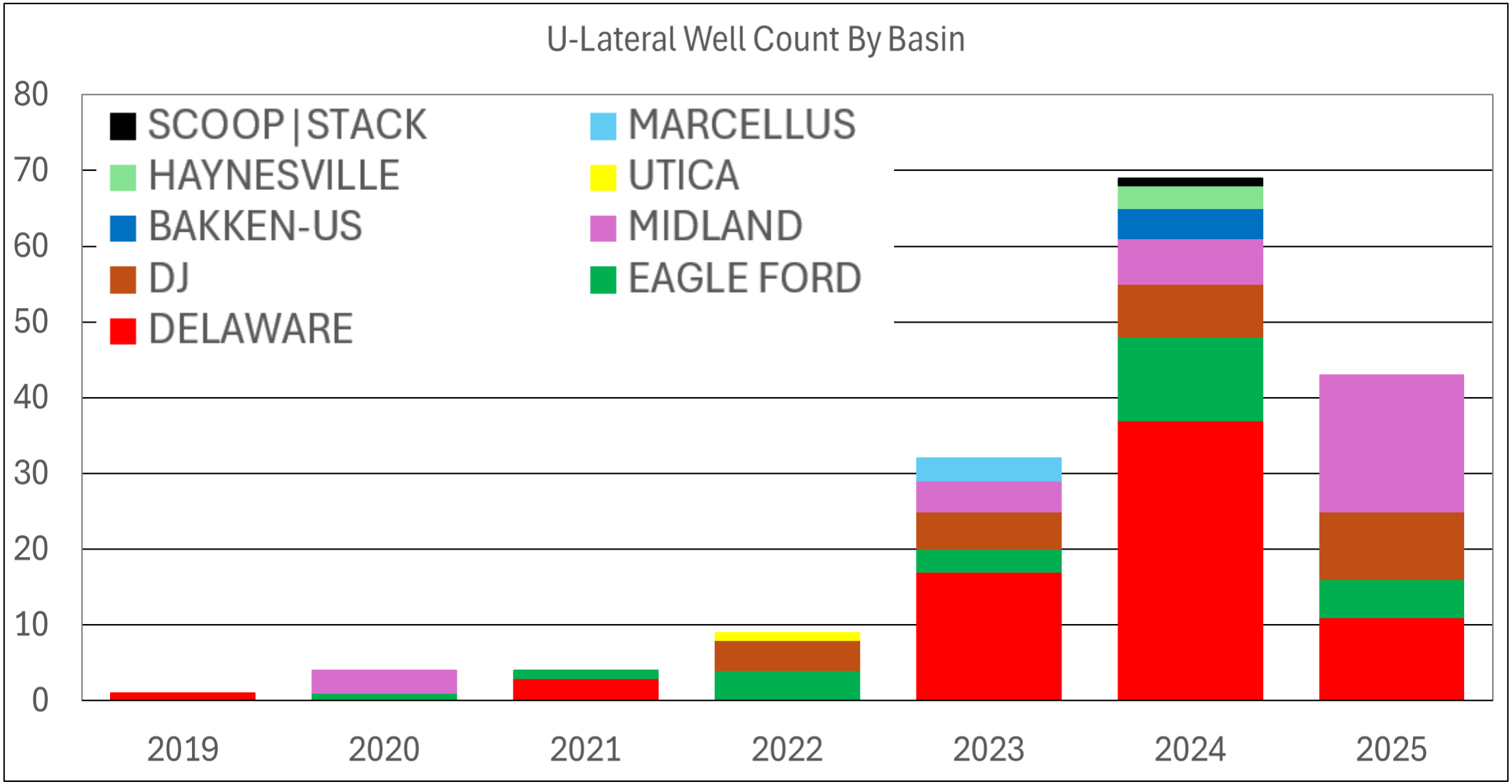
Terminology

- ❑ Vertical Hole – the near-vertical hole
- ❑ Curve – transition from vertical to horizontal
- ❑ Outgoing Leg – lateral drilled away from surface location
- ❑ Turn – reverse lateral azimuth
- ❑ Return Leg – lateral drilled toward surface location

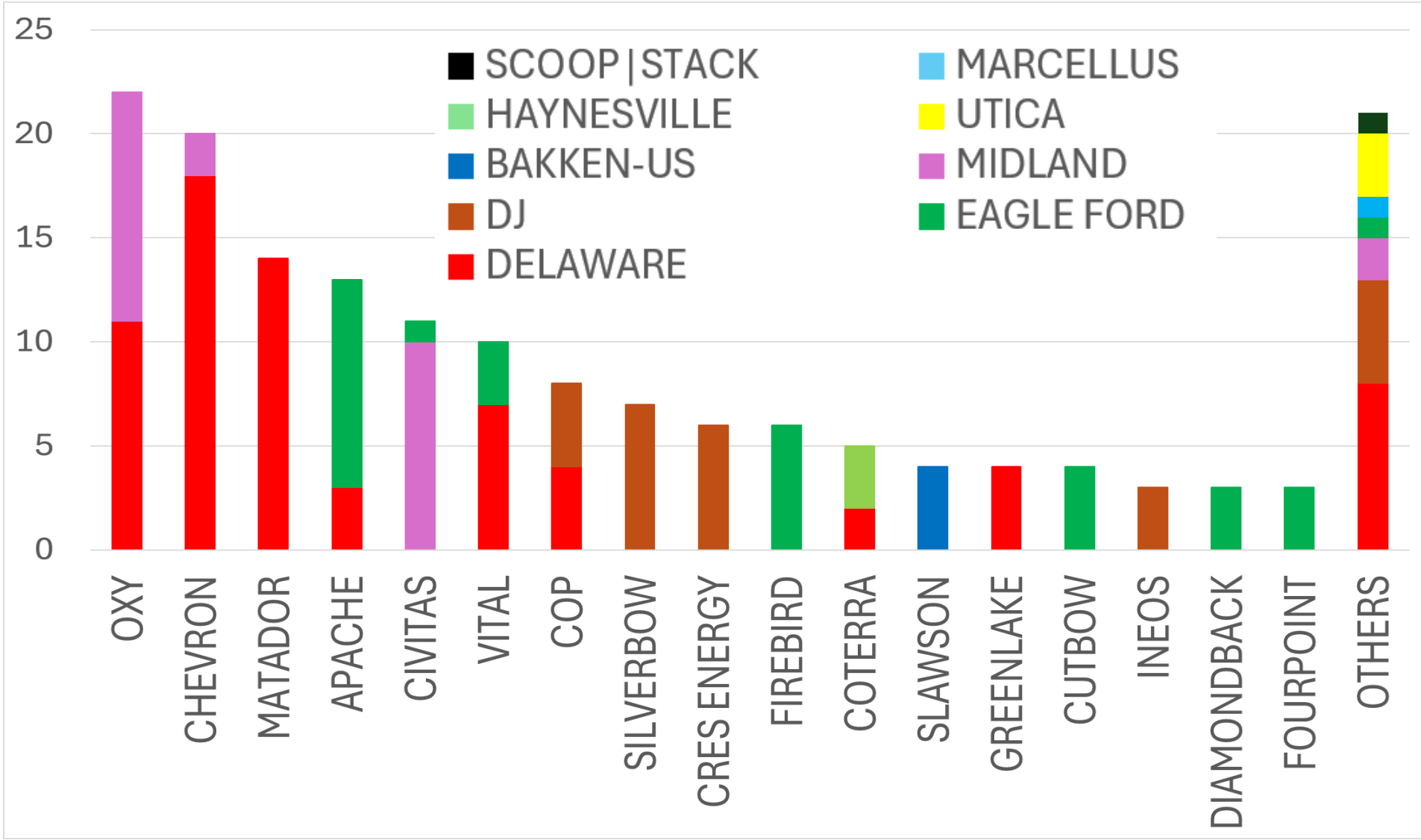


A 3D view of the Neelie 4H well in Loving County, Texas based on publicly available drilling survey data. It is likely to be remembered though as the "horseshoe well" because of its distinctive 180° turn that creates two lateral sections at a depth of more than 11,100 ft. Source: 3Dwellbore.com

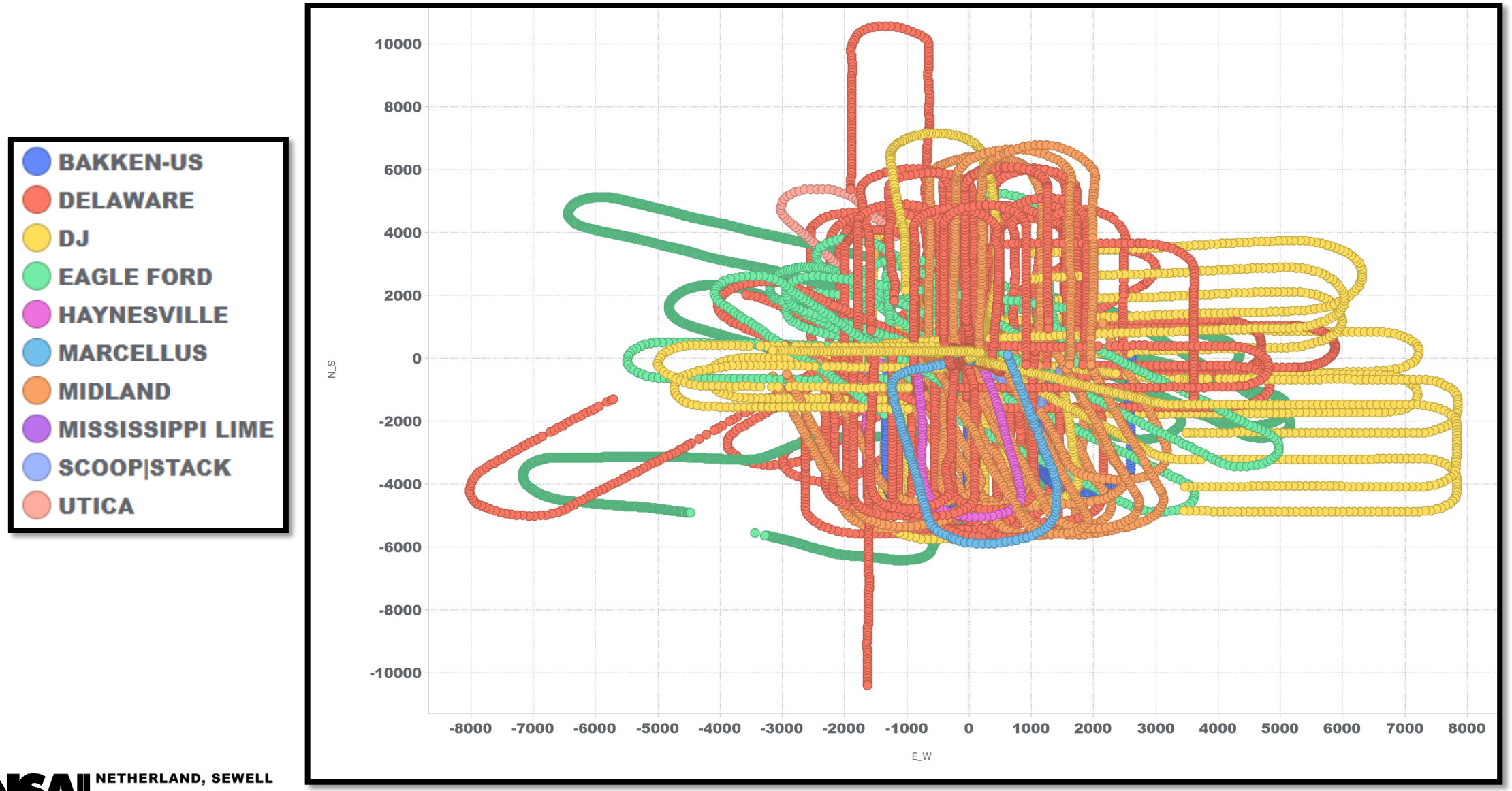
U-Lateral Activity by Year by Basin



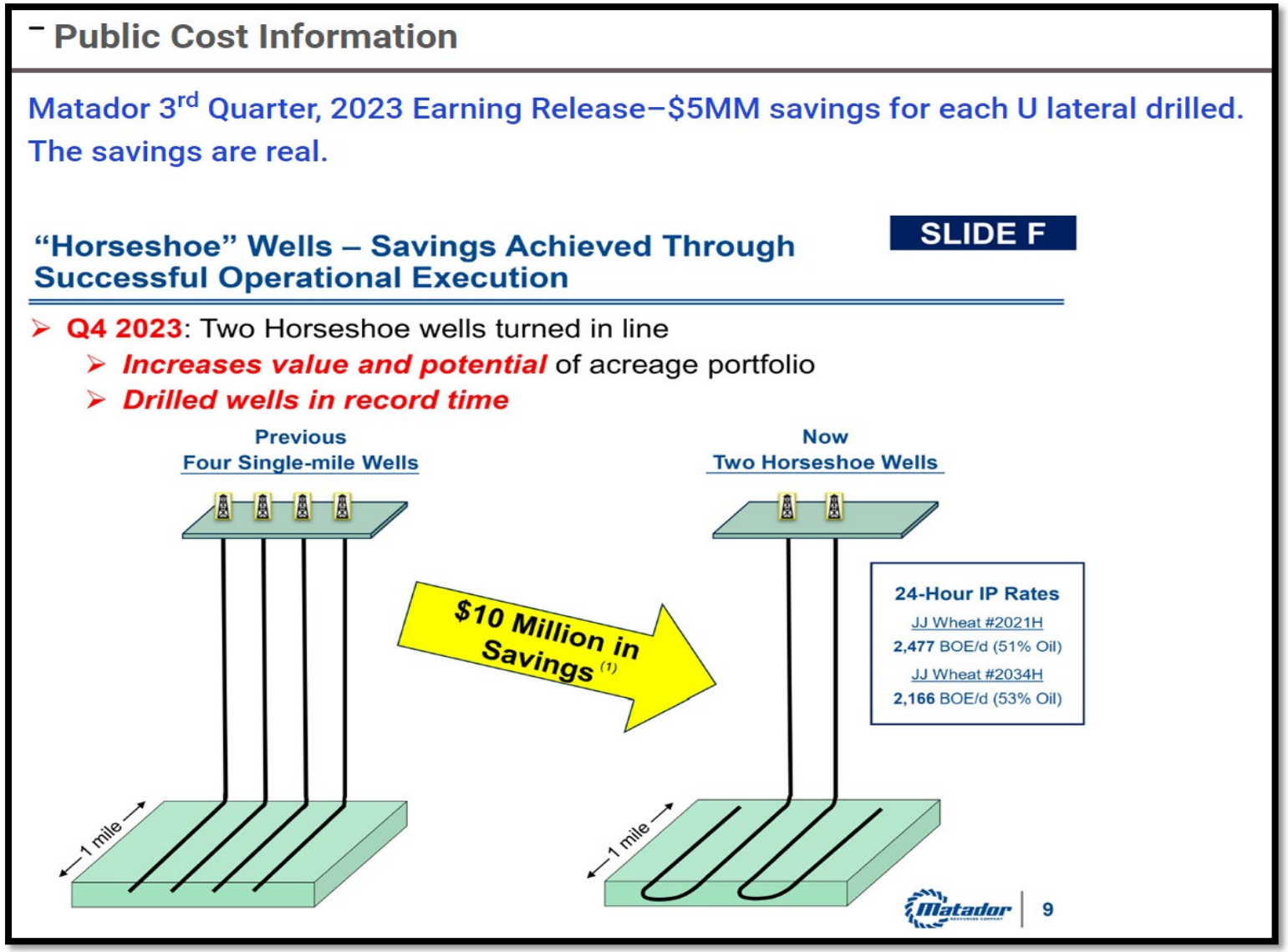
U-Lateral Activity by Operator and Basin



U-Lateral Well Paths



U-Lateral Economics



Economics drives drilling U-laterals in stranded sections.

In the Delaware Basin, where the most have been drilled, a 25-40% increase in ROR is realized by replacing one-mile laterals with U-laterals.

Adapted from udriller.com

FOUR-MILE LATERALS

Why Longer Laterals? Challenges…

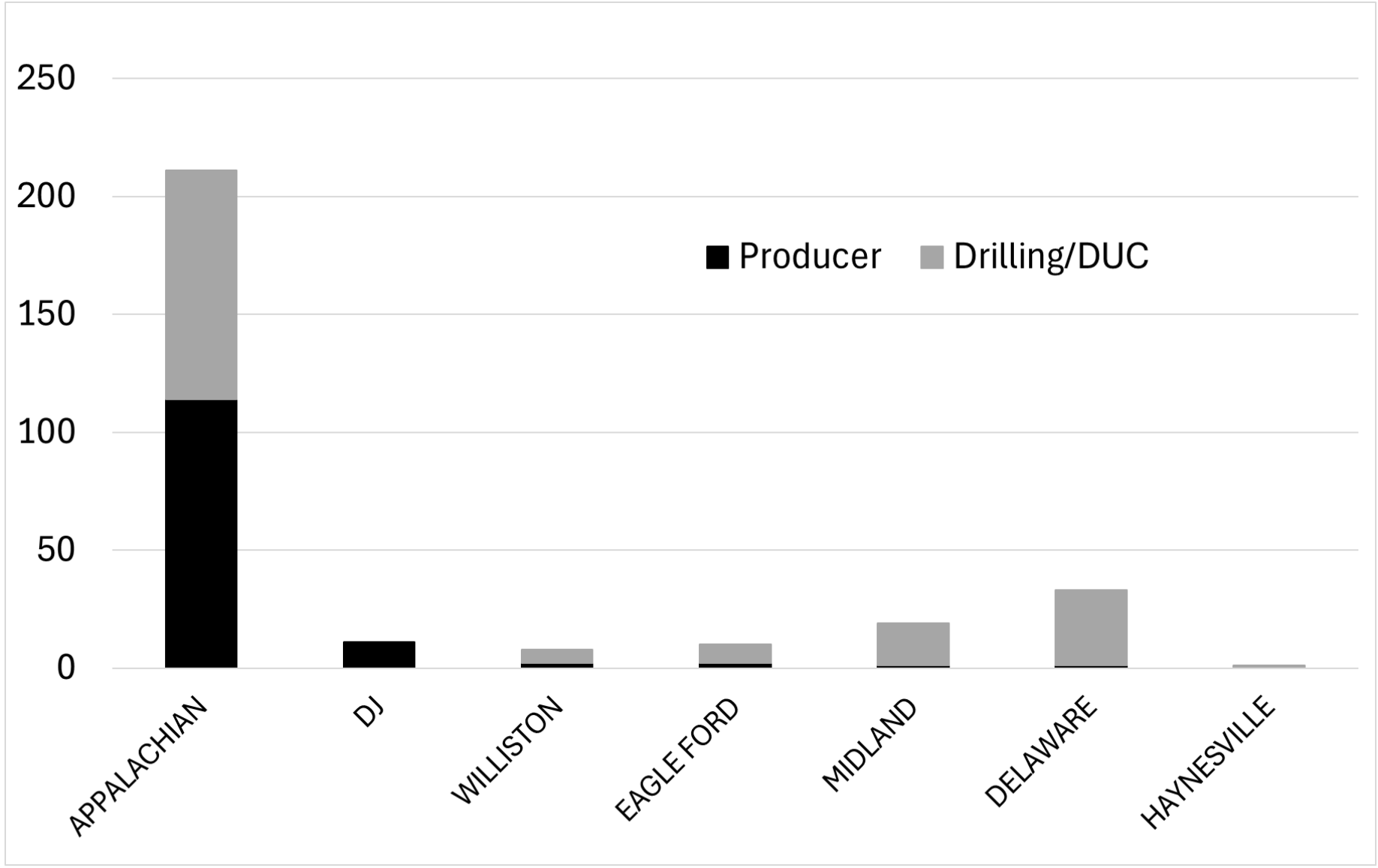
Advantages

- Reduced surface infrastructure costs
- Increased production rates
- Higher ultimate recovery (not in per-foot recovery)
- Reduction in number of rigs
- Cost savings

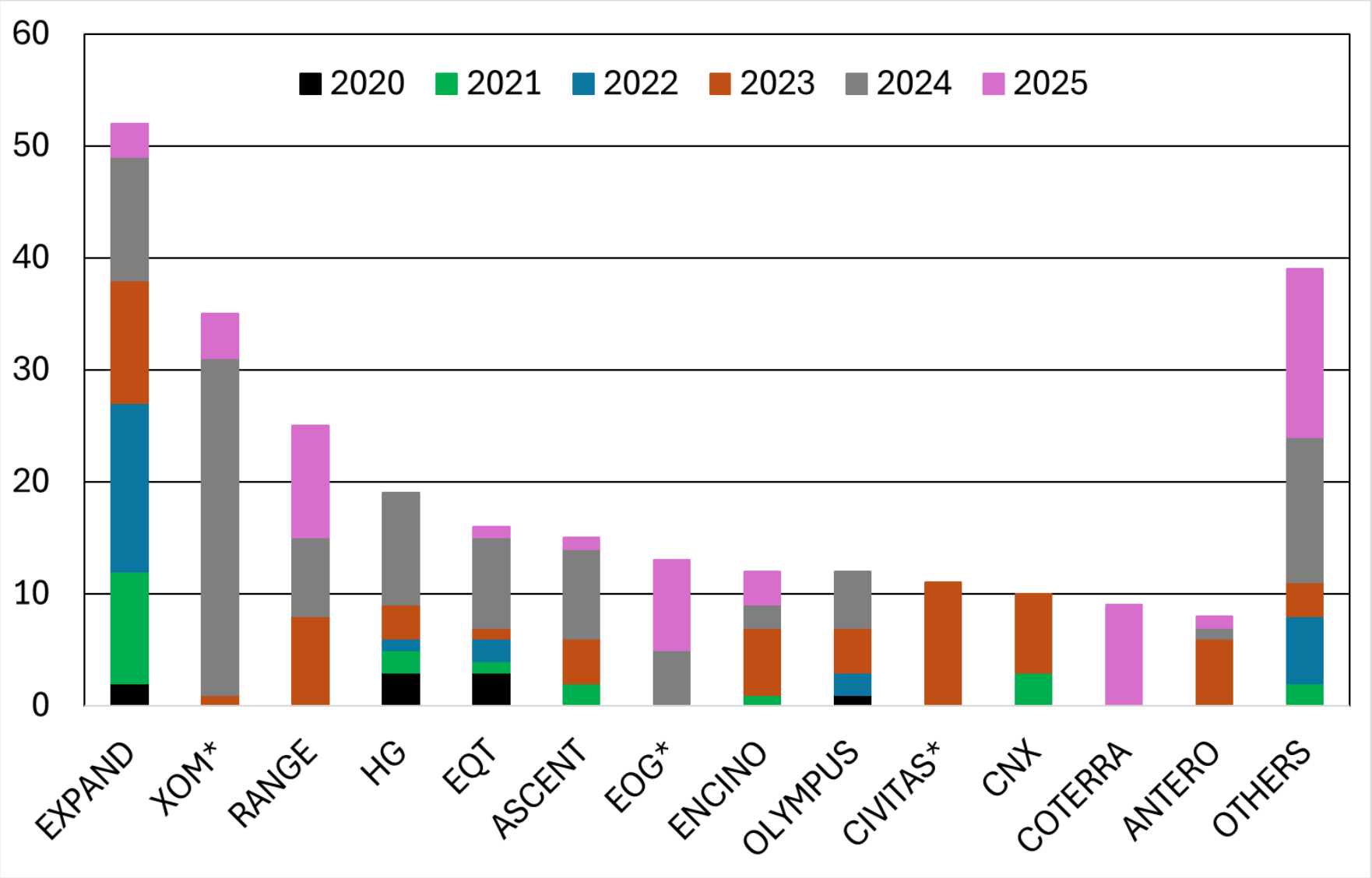
Technical Challenges

- Drilling Torque & Drag, Hole Cleaning
- Maintaining lateral in zone
- Casing
- Completions
- Reservoir Quality Risks

Four-mile laterals by Basin



Four-mile wells by Operator and Vintage



* Non-Appalachia Wells

20K TECHNOLOGY

What is 20K Technology?

- The equipment and processes capable of handling pressures of up to 20,000 psi in offshore oil and gas production
- Designed for ultra-deepwater operations where depth and pressure create significant engineering challenges
- HPHT reservoirs have been identified particularly in the Lower Tertiary and Jurassic Norphlet Formations; they are found at significant depths and extreme pressures (>15000 psi) and/or temperatures (>350F) (wellhead)

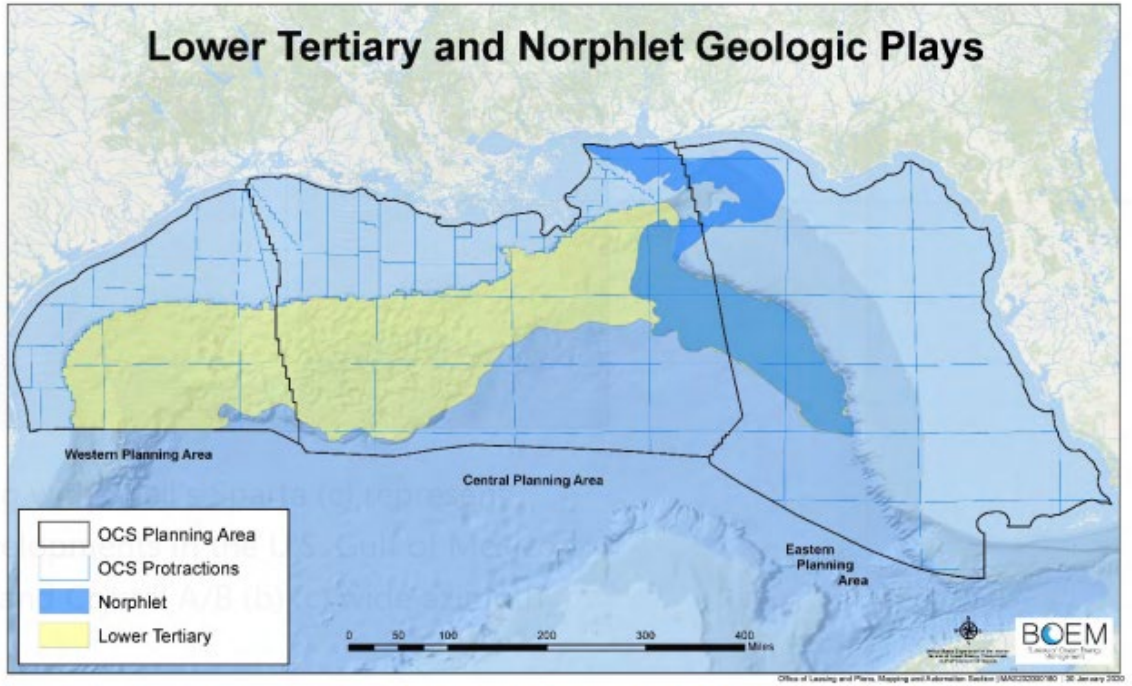


Figure 2. Lower Tertiary and Norphlet Formations in the Gulf of Mexico.

https://www.boem.gov/sites/default/files/documents/about-boem/HPHT-Production-in-the-GOM.pdf

20K Examples

- Chevron's Anchor field was the first field to be developed using 20K technology and started flowing August 2024
- It is estimated to contain 440 million barrels of oil equivalent reserves with a daily capacity of 75,000 barrels of oil and 28 million cubic feet of gas

Transocean's first 20,000-psi drillship

https://www.hartenergy.com/exclusives/first-20000-psi-drillship-headed-gom-203558

https://www.ogj.com/drilling-production/drilling-operations/article/55233432/chevron-anchor-pioneers-20k-subsea-development

Additional Projects

- Future projects include
  - BP's Kaskida
  - BP's Tiber
  - Beacon Offshore's Shenandoah
  - Shell's Sparta

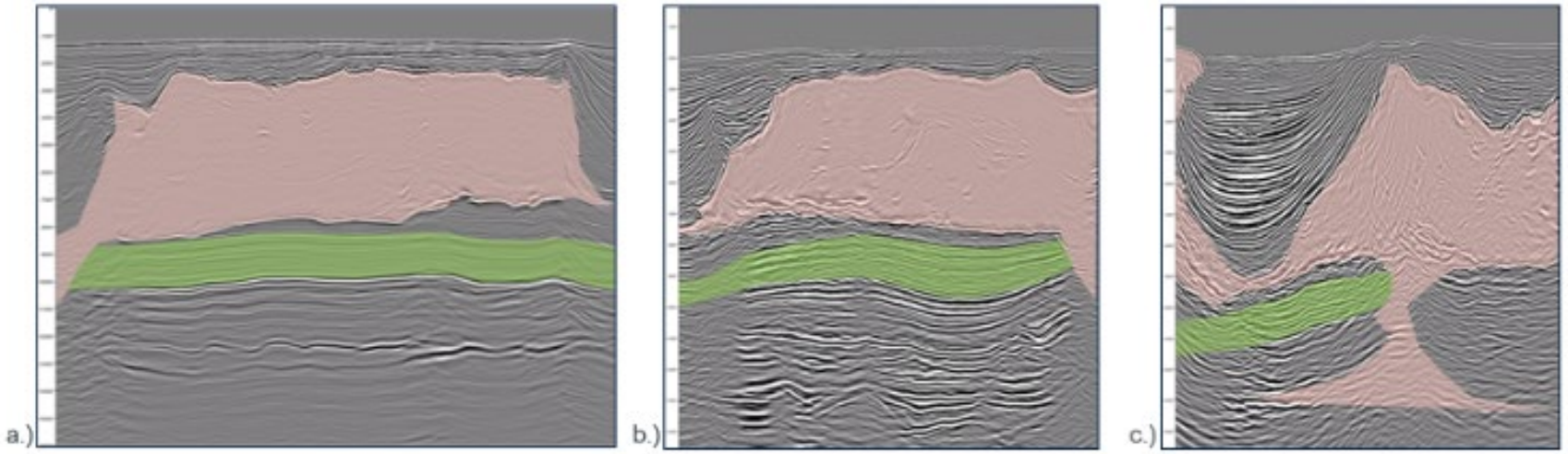


Figure 1. BP's Tiber (a) and Kaskida (b) along with Shell's Sparta (c) represent upcoming high pressure Paleogene Oil developments in the U.S. Gulf of Mexico. These fields are covered by TGS' Triton (a) and Crystal A/B (b) (c) wide azimuth seismic datasets.

https://www.linkedin.com/pulse/innovations-20k-technology-subsurface-imaging-propel-gulf-mexico-4rvnc

ARTIFICIAL INTELLIGENCE

Artificial Intelligence – Use examples

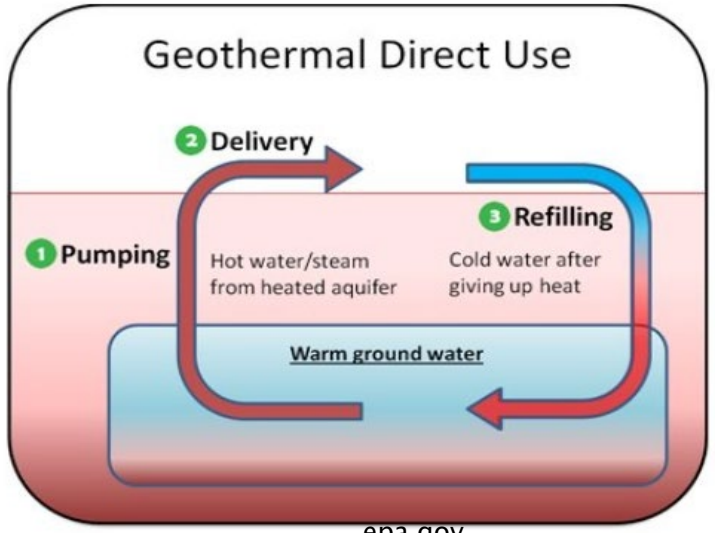
- Predictive Maintenance
- Safety & Environmental Monitoring
- **Decision-Making Support (development planning)**
- Reducing Well & Equipment Downtime
- Inventory Management
- Laboratory
- Surface Analysis/Geological Assessment
- **Reservoir Modeling**
- **Auto Forecasting of well-by-well production**
- **Proved Undeveloped Reserves prediction**

GEOTHERMAL

What is Geothermal used for?

Direct Utilization

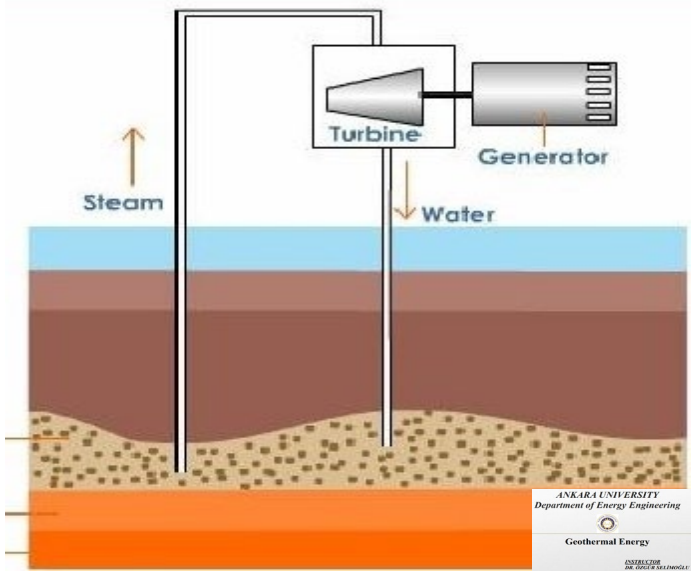
- Space heating/Heat pumps
- Industrial processes
- Drying crops
- Hot water (de-icing, fish)



epa.gov

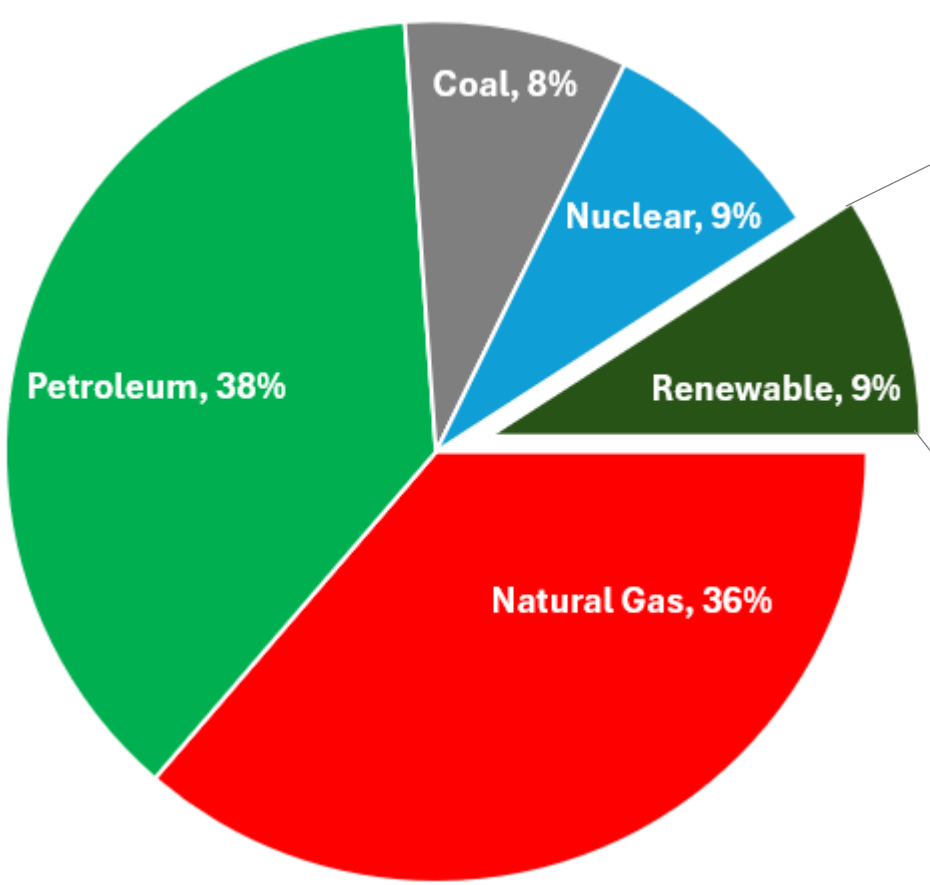
Indirect Utilization

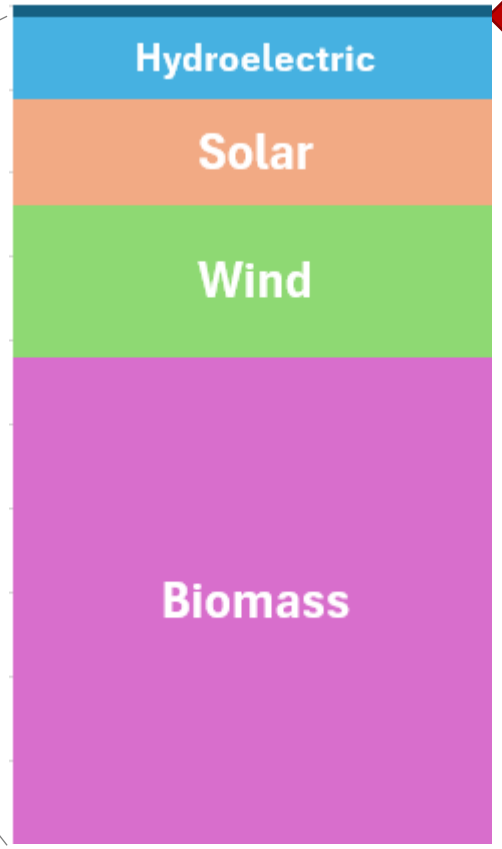
- Electricity generation



Geothermal Share of Energy in the U.S.

US primary energy consumption by energy source, 2024
Total = 94.207 quadrillion BTUs





Geothermal
1% of 9%

Renewable=
8.581 QBTU

Source: EIA Monthly Energy Review (April 2025) www.eia.gov/mer

How hot is hot enough?

- Generally cited temperature thresholds for various exploitation methods are:

<u>Low Grade (Direct Utilization)</u>

10-150 degrees C

(50-302 degrees F)

<u>Mid Grade (Indirect Utilization)</u>

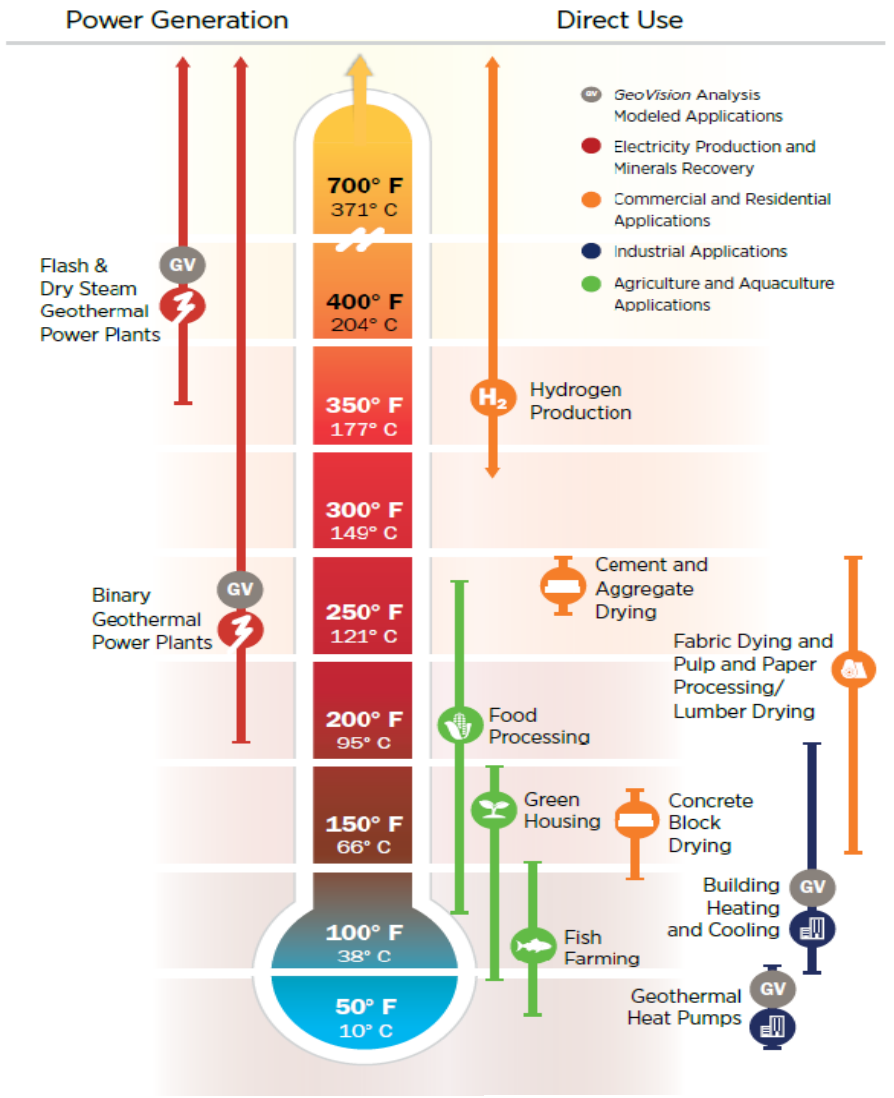
150-200 degrees C

(302-392 degrees F)

<u>High Grade (Indirect Utilization)</u>

200+ degrees C

(392+ degrees F)



Continuum of Geothermal applications
DOE GeoVision, 2019

Hot vs Not

There are a number of favorable aspects of GT-based energy but, as with any solution, there are trade-offs

ADVANTAGES

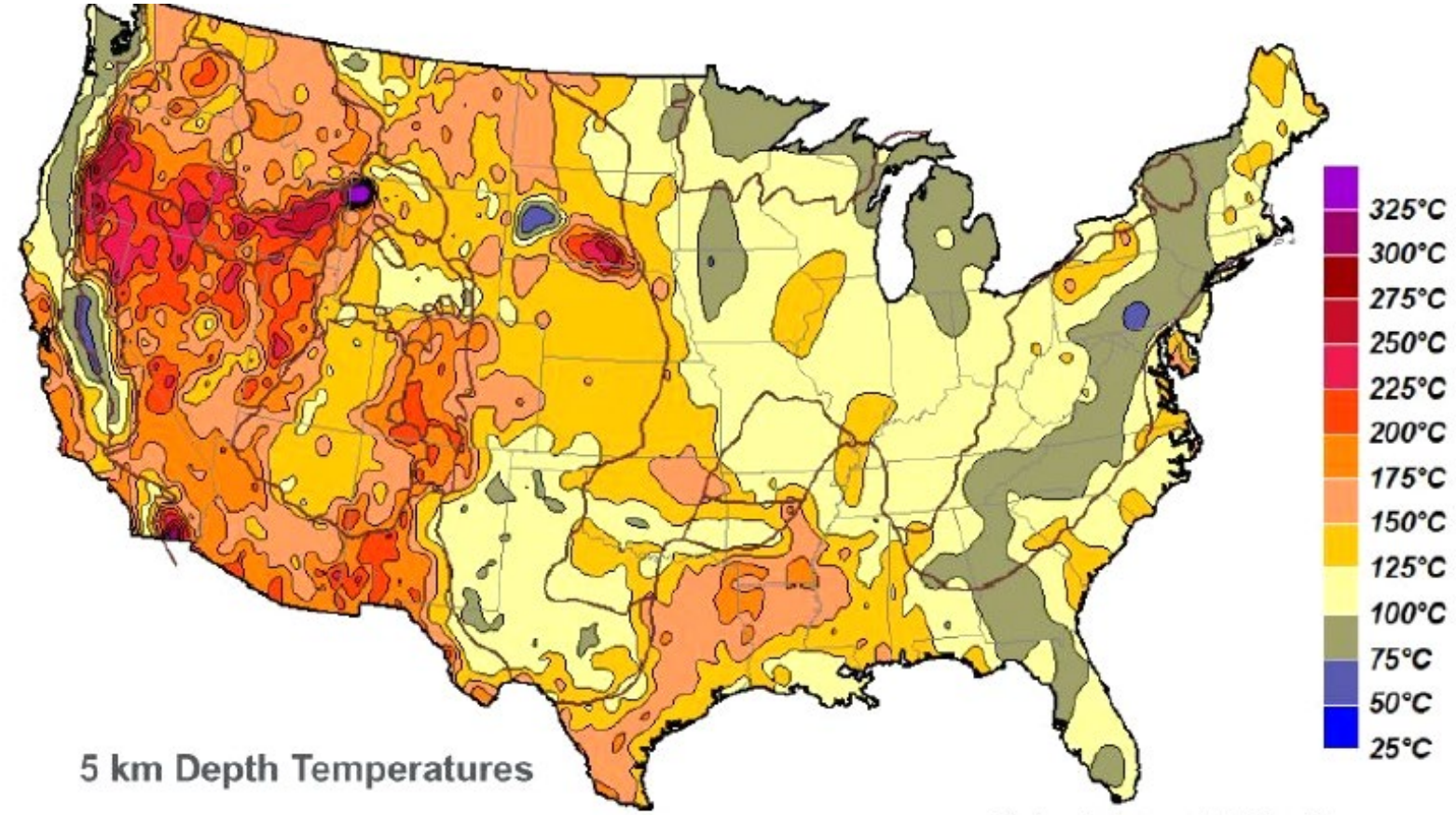
- Continuous baseload
- Operation & maintenance costs low
- Developments can be self-powered (no need for external fuel)
- “Infinite” supply
- Lower exploration/drilling risk
- ESG & Tax benefits
- It’s not hydrocarbons (?)

DISADVANTAGES

- High up front cost (drilling/facilities)
- Higher initial energy cost (decreases w/ scale)
- Challenges associated w/ new technology (learning curve, govt, investors, infrastructure)
- Binary project viability: complete success or complete failure
- Requires drilling wells (social/environmental push-back)

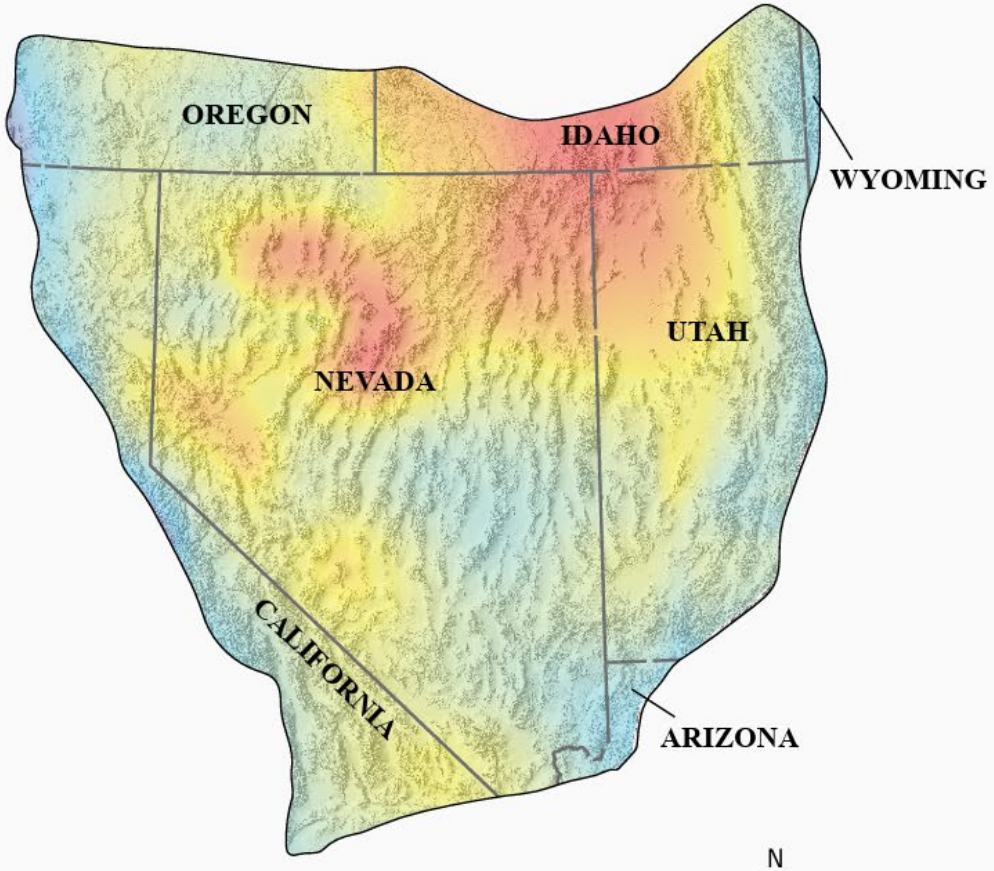
Domestic Temperature at Depth

- At the current requirement of 150 degC, a substantial portion of the country falls within that window at a depth of 5 km
- Advancements in exploitation methods could lower that temperature threshold, opening up a wider area for potential future project development



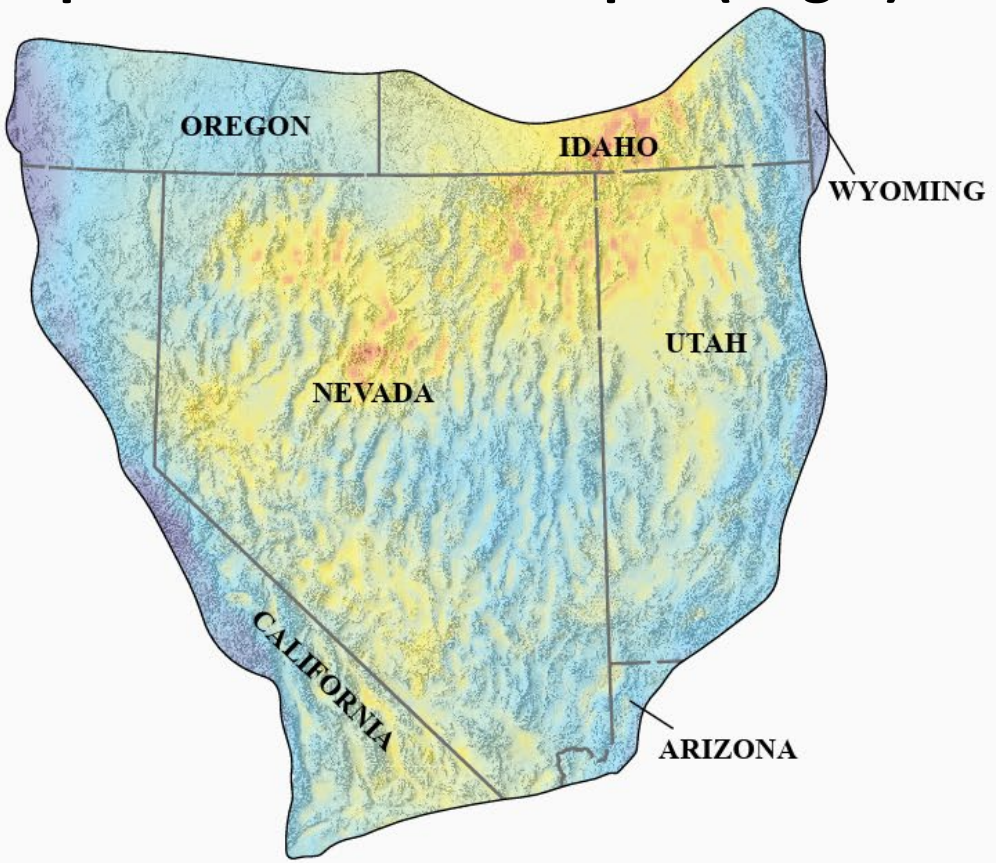
Enhanced Geothermal Systems Electric-Resource Assessment for the Great Basin, Southwestern United States (USGS, May 22, 2025)

Heat Flow Map (mW/m³)



Heat flow map from https://doi.org/10.5066/P9BZPVUC

Temperature at 6 km depth (deg C)



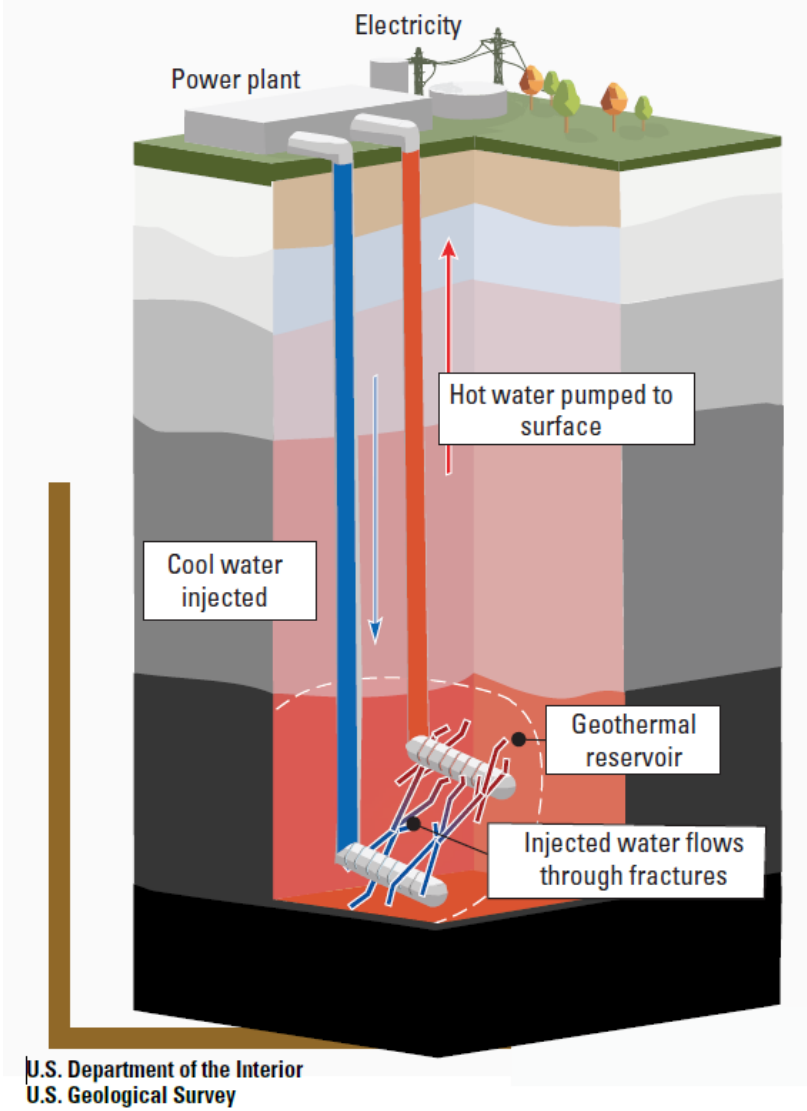
Shaded relief from National Atlas of the United States, 2012. https://purl.stanford.edu/zz186ss2071

Temperatures at 6 km from https://doi.org/10.5066/P149FR54

Source: USGS May 2025

Enhanced Geothermal Systems Electric-Resource Assessment for the Great Basin, Southwestern United States (USGS, May 22, 2025)

- Assessment of low permeability rock formations in Great Basin (Enhanced Geothermal Systems – EGS)
- Potential for 135 gigawatts (GW) electric available from "upper 6 km of Earth's crust"
- Increase from 1% to 10% of current US power production
- EGS require creating open fractures



Source: USGS May 2025

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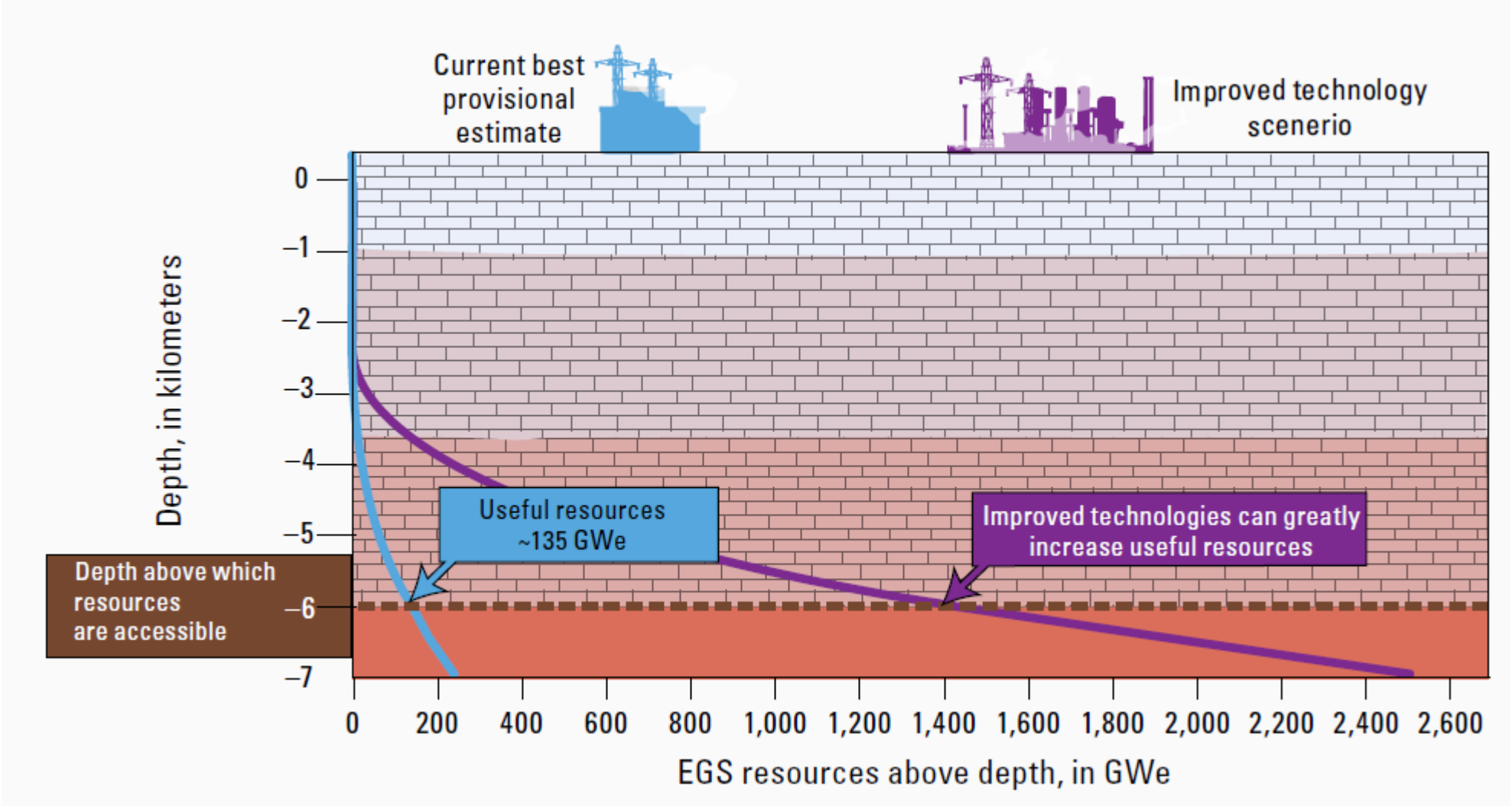

Source: USGS May 2025

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NETHERLAND, SEWELL & ASSOCIATES, INC.

WORLDWIDE PETROLEUM CONSULTANTS

Dallas: 214-969-5401
Houston: 713-654-4950

www.netherlandsewell.com
info@nsai-petro.com