Enhanced Geothermal Systems (EGS) Opportunity Overview

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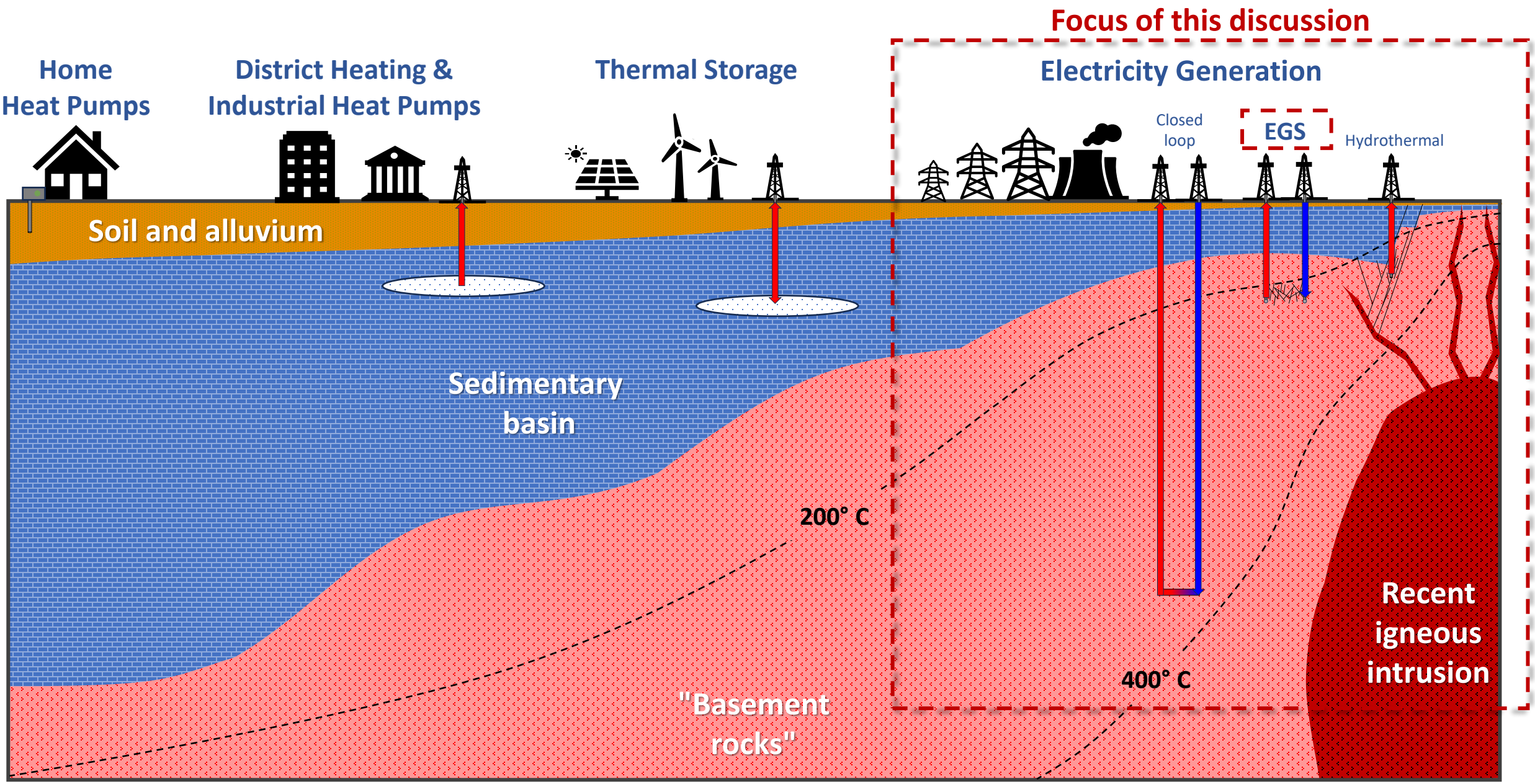
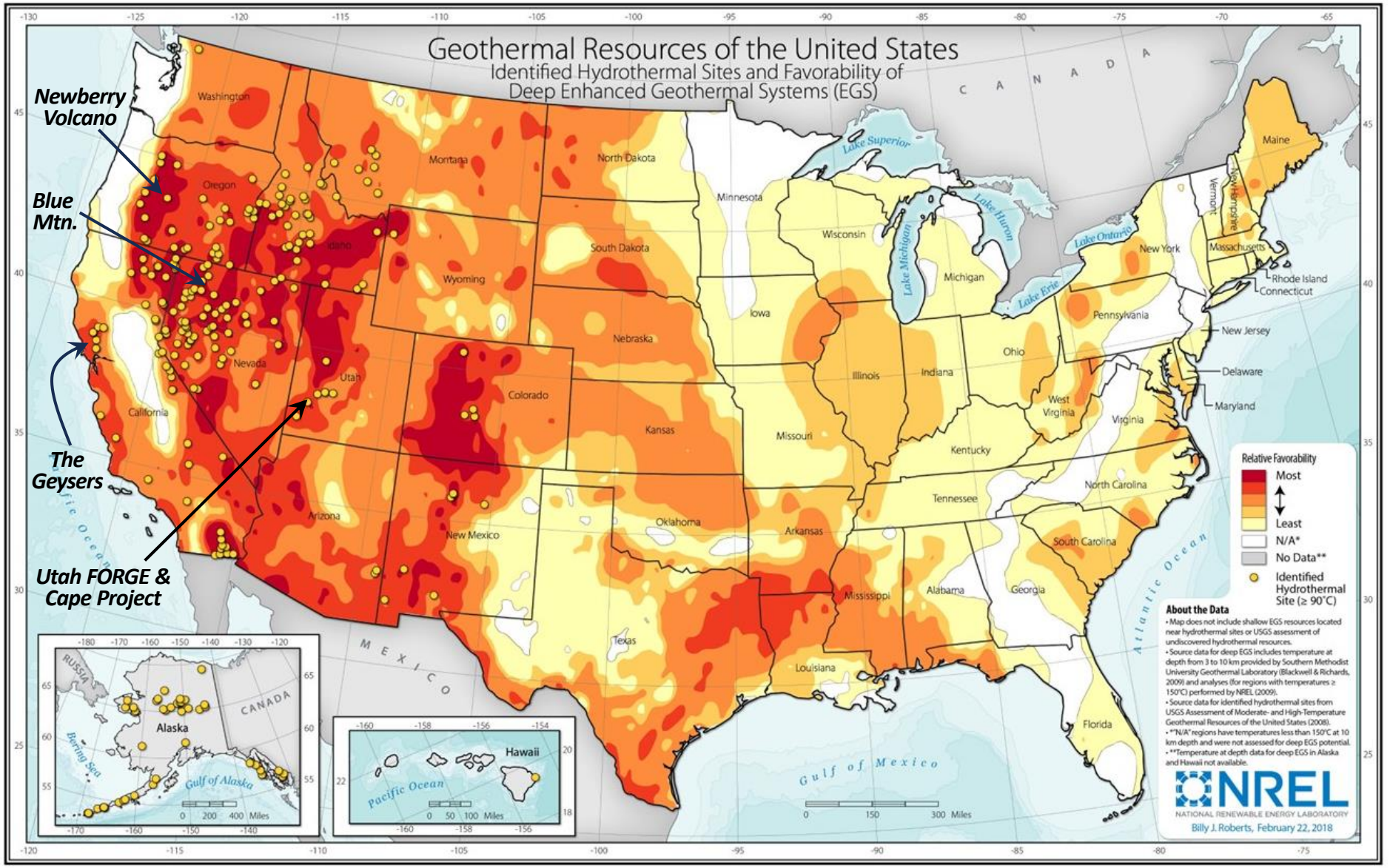
November 2024

There are many ways to extract energy from geothermal resources



Cross section views; not to scale; depiction of the systems used to extract geothermal resources are greatly simplified; EGS = Enhanced Geothermal Systems.

Electricity generated from geothermal energy holds enormous promise



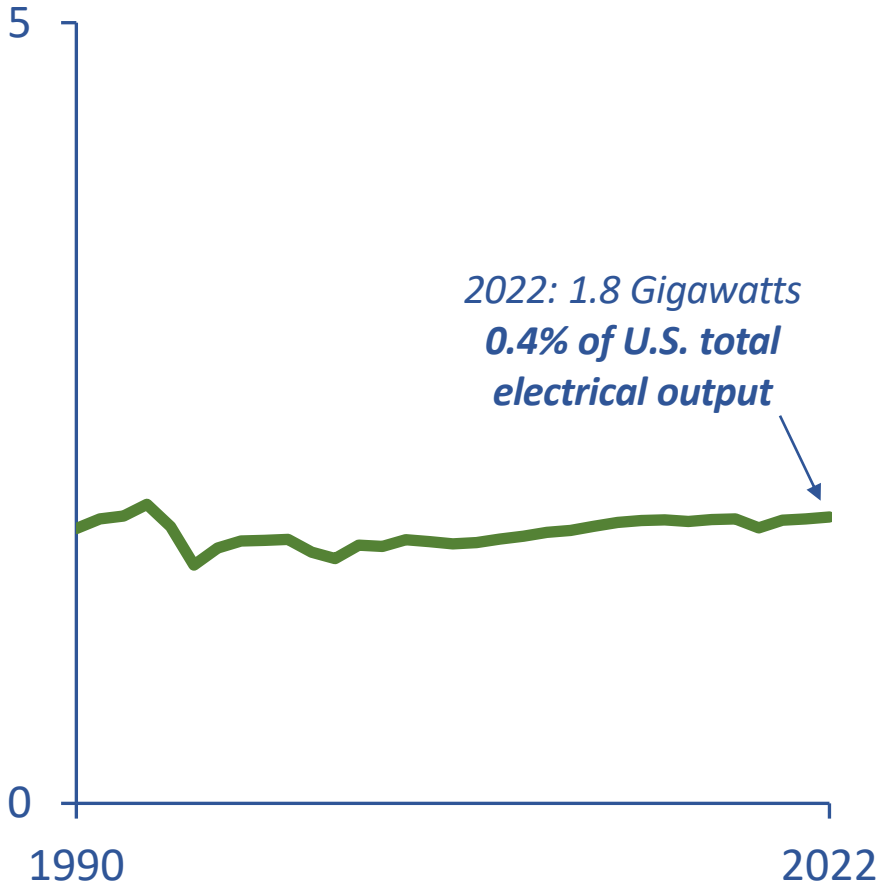
- Near-zero GHG or other emissions
- Firm, dispatchable power (24/7/365)
- Resources sufficient to deliver 1,000s of years of U.S. primary energy consumption
- U.S. is currently the world's largest producer of geothermal power

Map taken from U.S. NREL website

However, to date, U.S. geothermal power output growth has been negligible

U.S. Geothermal Power Output

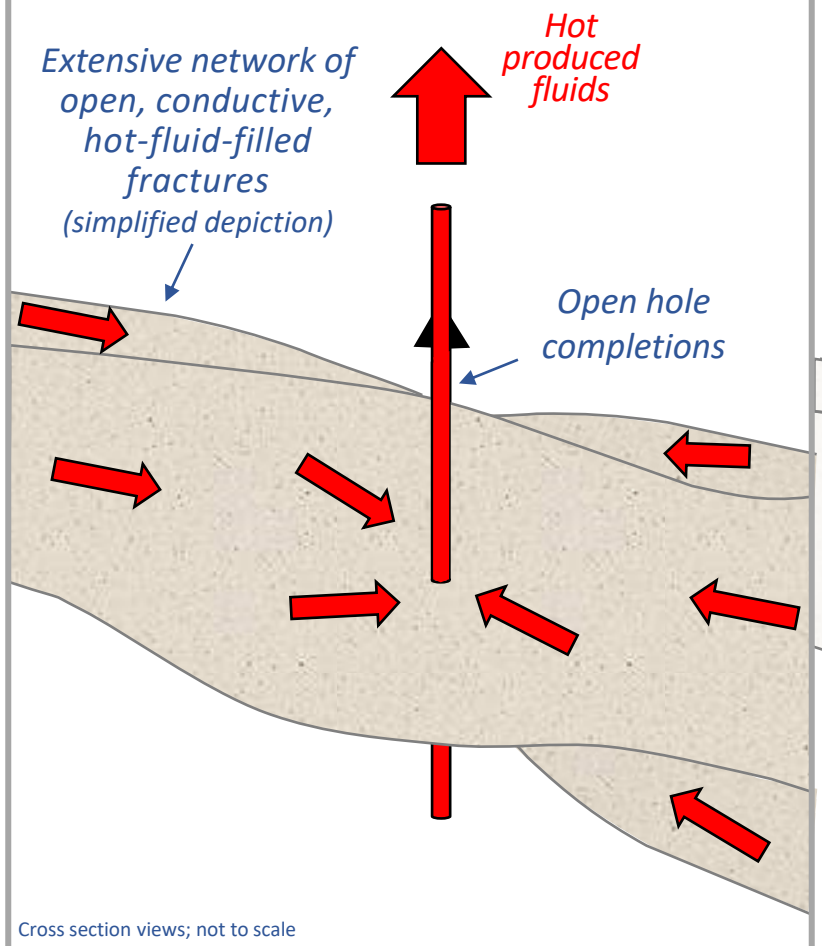
(Average annual GW of instantaneous output)



Source: U.S. EIA ; plot shows annual average instantaneous electricity output

NEGLIGABLE GROWTH DESPITE CONSIDERABLE INVESTMENT

Hydrothermal Systems

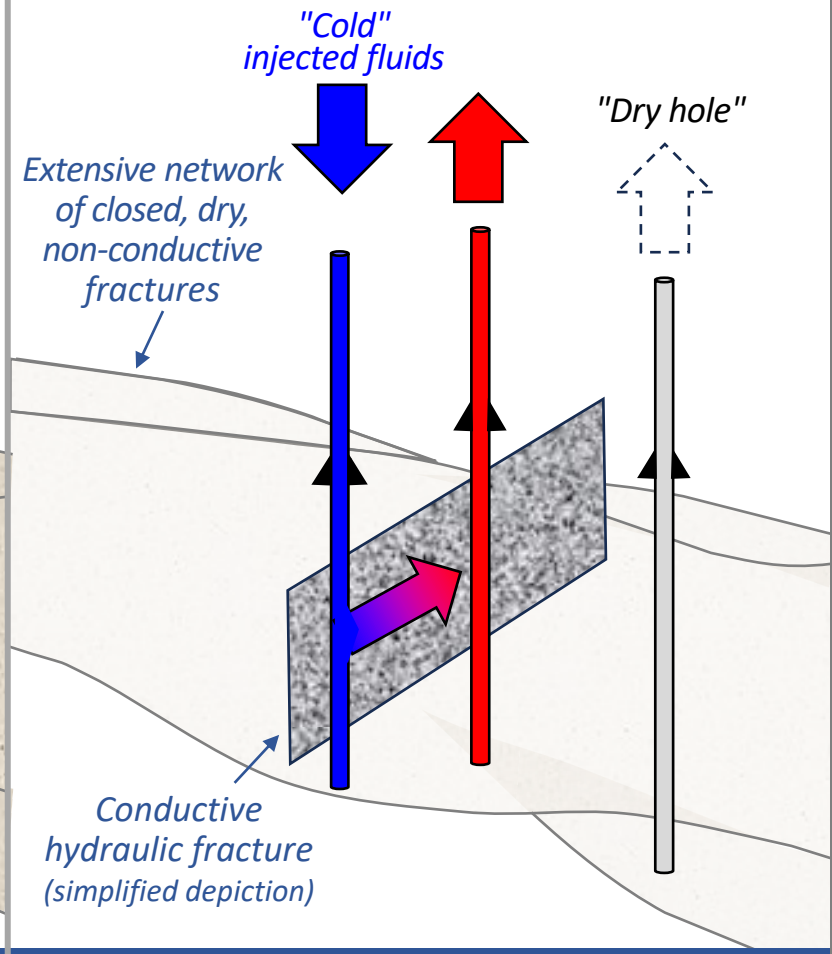


Cross section views; not to scale

EXCEEDINGLY RARE

Example: The Geysers, California

Old Style EGS

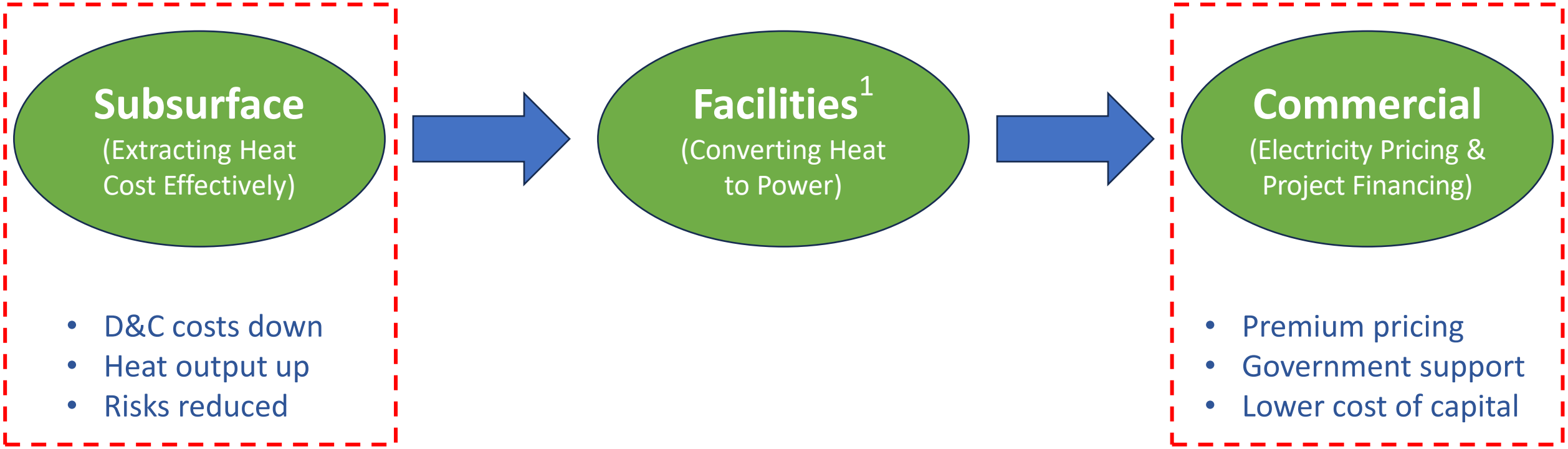


EXCEEDINGLY DISAPPOINTING

Example: Most EGS projects 1970-2023

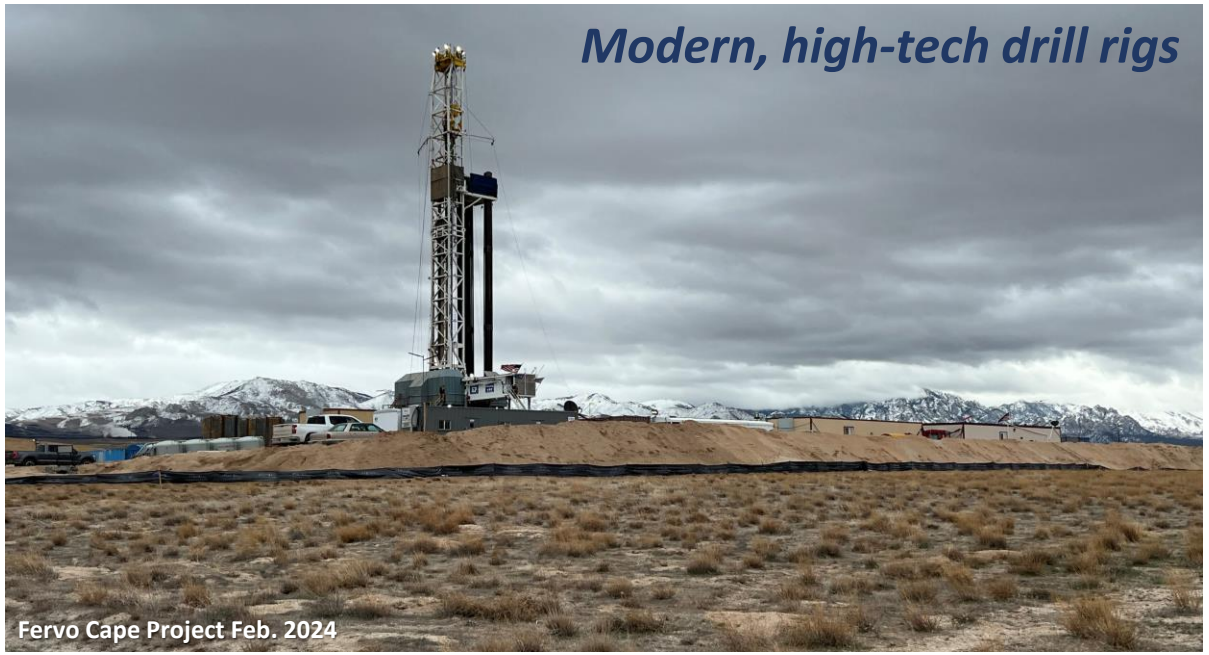
Two of three high-level “critical drivers" of EGS economics have recently changed substantially for the better

Focus of this Presentation



[1] Potential for significant cost reductions for larger scale projects

Technology transfer from the oil & gas industry is transforming EGS economics



Drill bit design

Roller Cone

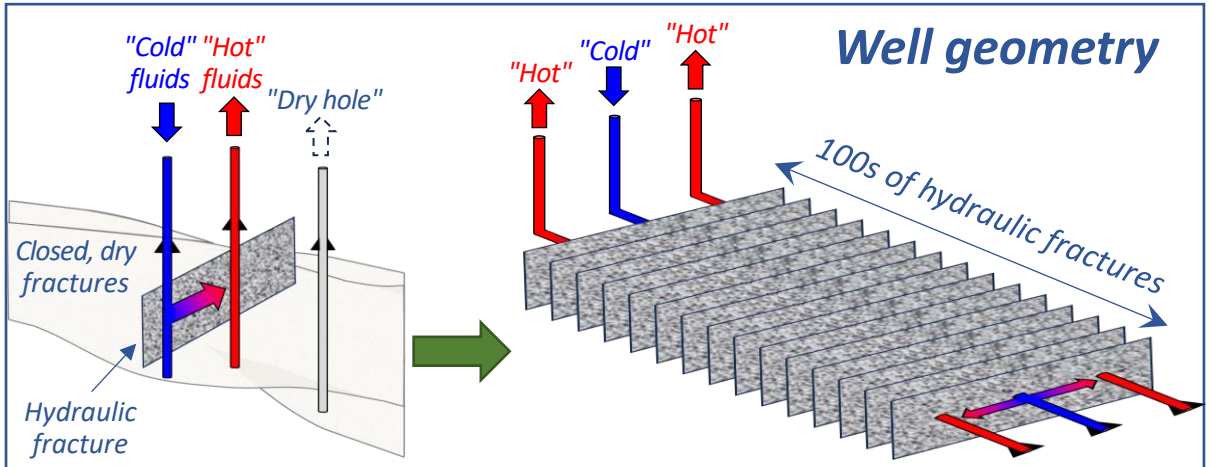
PDC

Physics-based drilling

Fred Dupriest
& Sam Noynaert

Texas A&M University

Well geometry

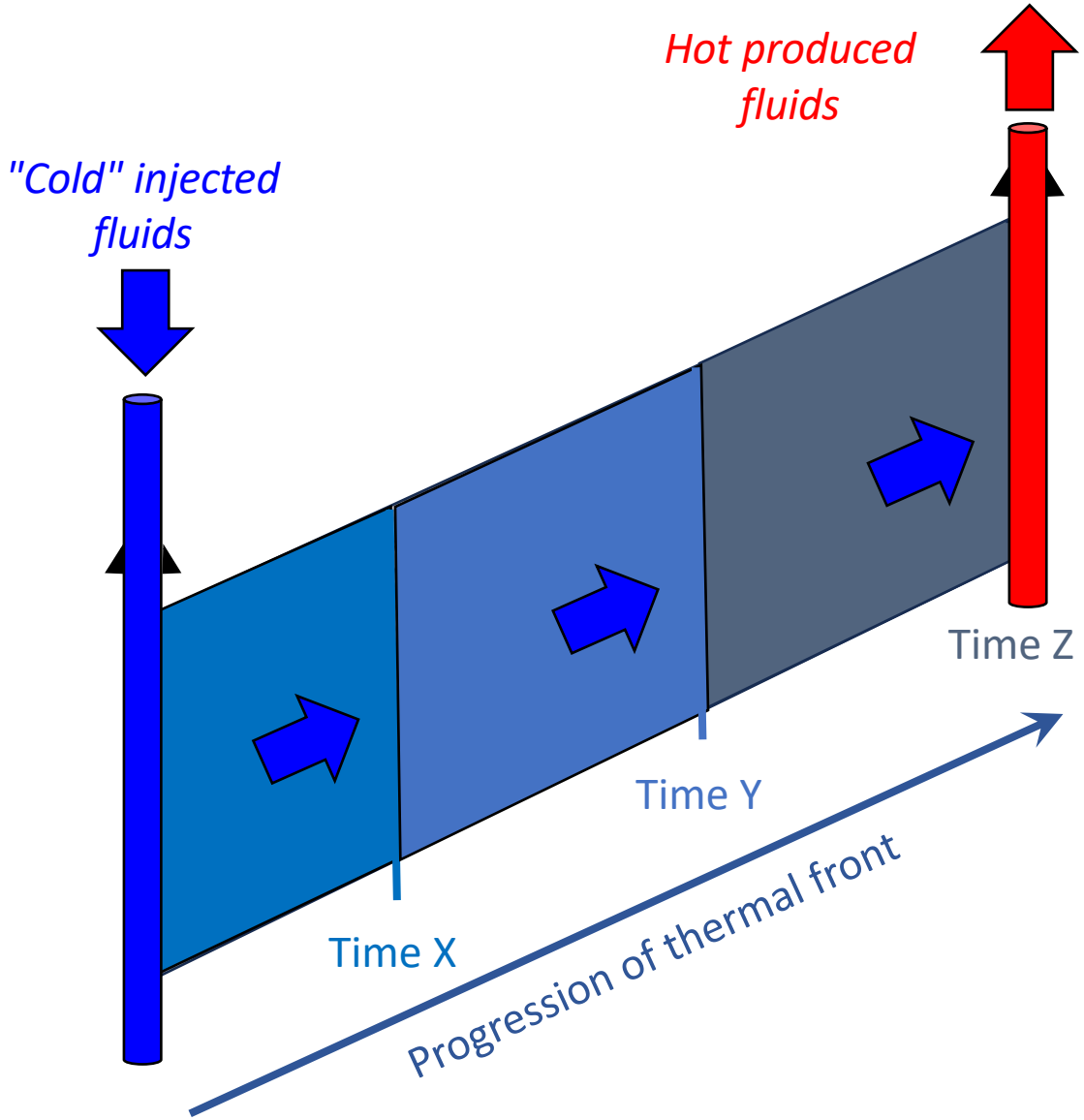


Vertical Wells

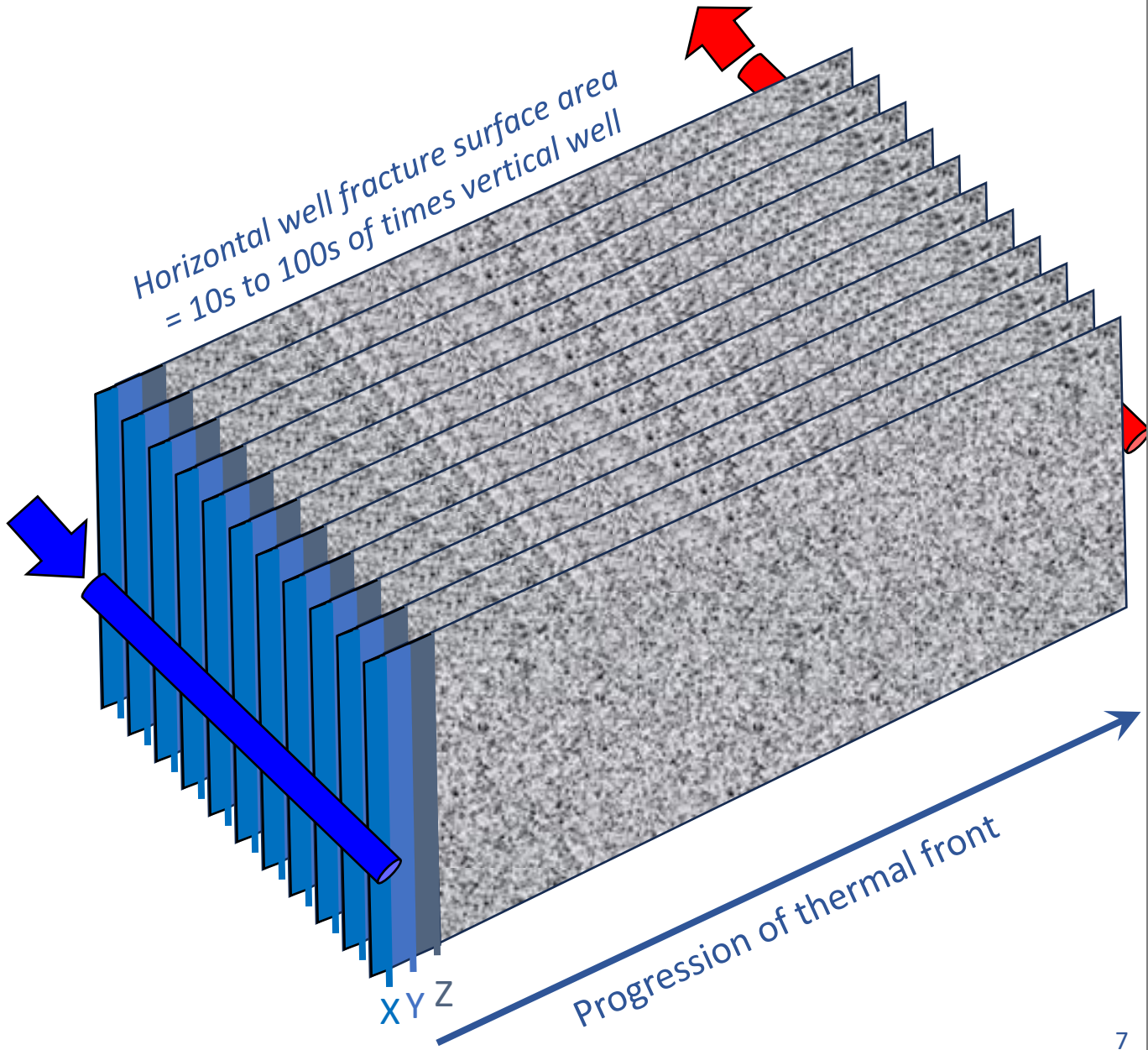
Horizontal Wells

Oblique views; not to scale

EGS with vertical wells



EGS with horizontal wells

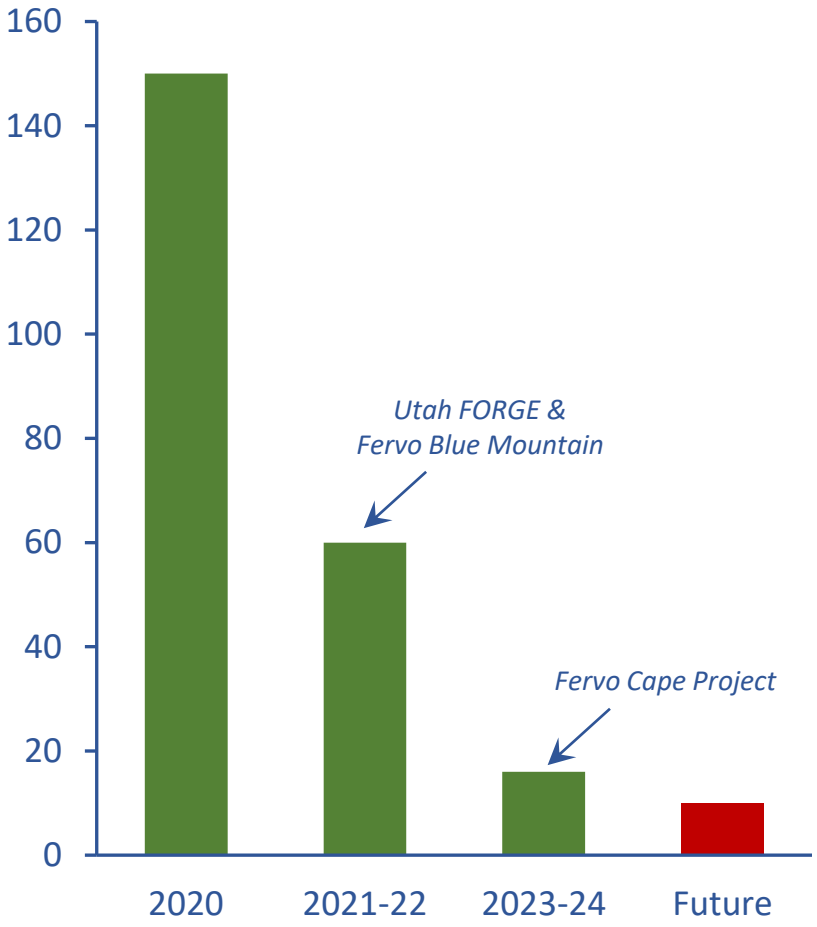


Cross section views; simplified depiction of hydraulic fractures; diagrams are not to scale

O&G technological innovations have delivered game changing results

Spectacular drilling performance improvements

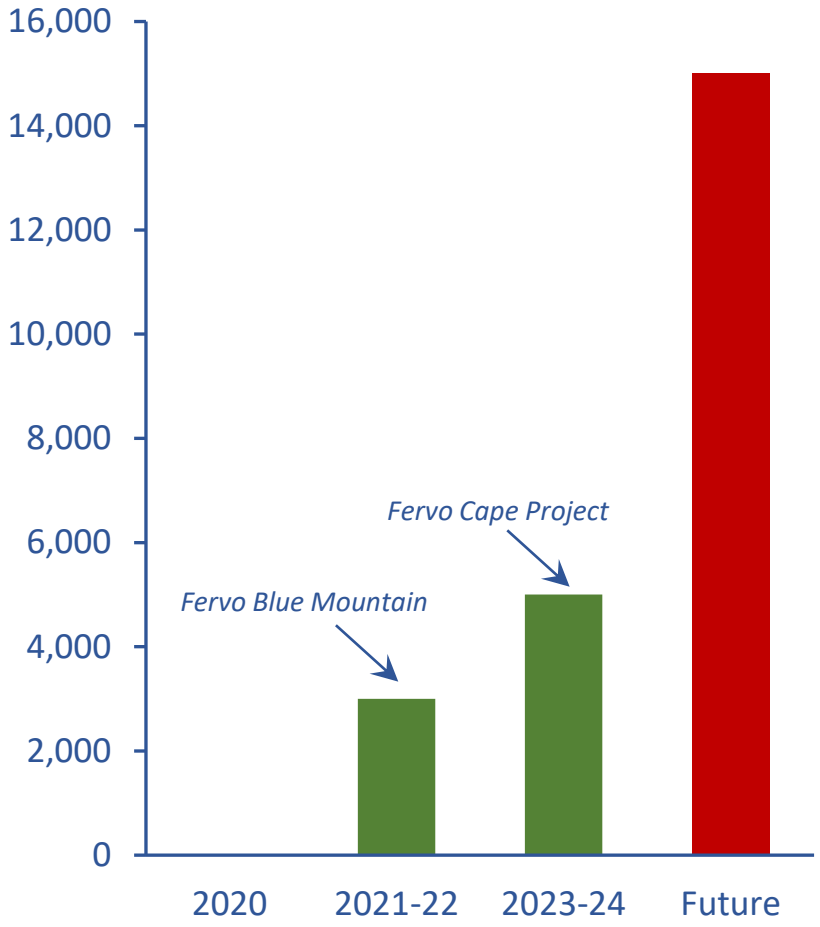
Drilling days to 12,000' MD



Sources: El-Sadi et al, 2024, Review Of Drilling Performance In A Horizontal EGS Development; Winkler and Swearingen, 2021, Summary of Drilling Activities, Well 16A(78)-32 (Utah FORGE)

Ability to D&C horizontal laterals in basement rocks

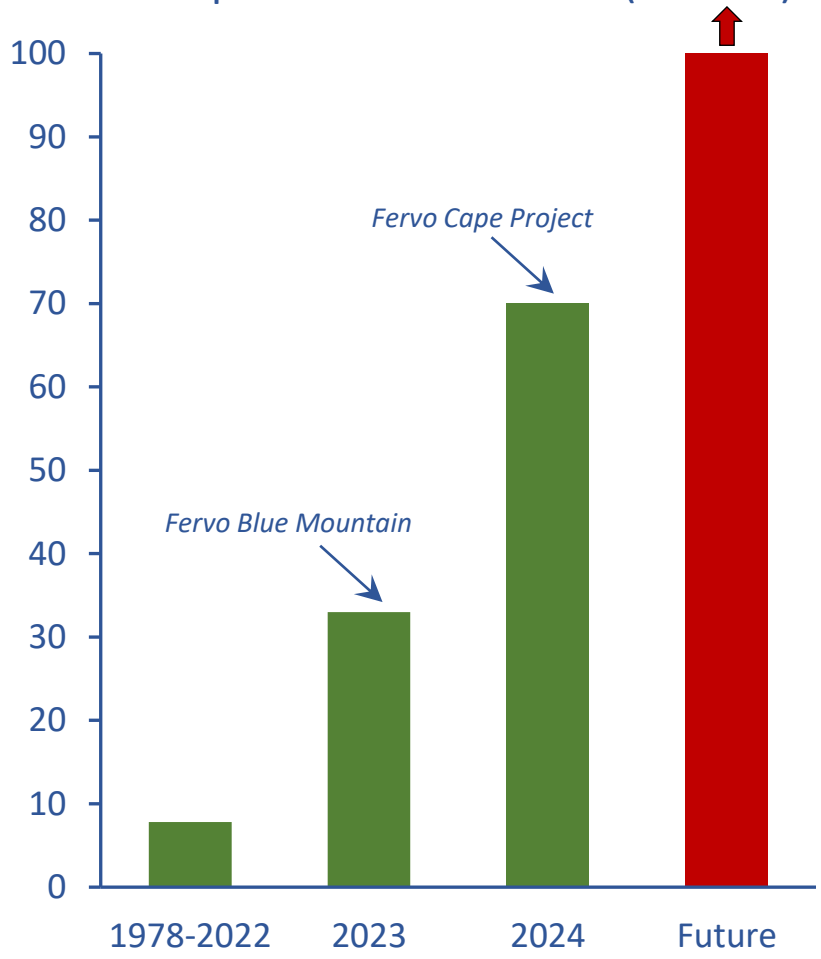
Lateral length (feet)



Note: The first fully horizontal EGS wells drilled were those drilled by Fervo at their Blue Mountain project in 2022. D&C = drill and complete

Near order-of-magnitude increase in per well production

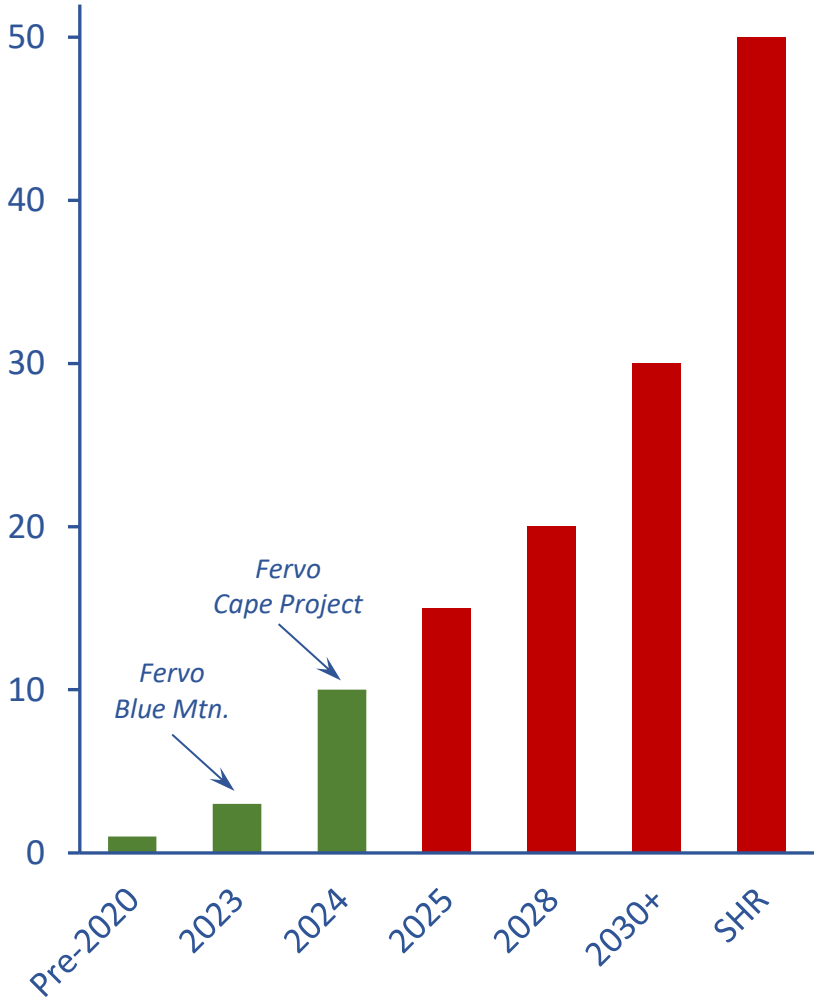
Peak production flow rate (MBFPD)



Note: 1978 – 2020 data from 11 projects; average peak flow rate shown (7,800 bfpd); range was from 2,700 to 16,300

Technological innovations have vastly improved EGS project outcomes

Per well power output (MW)



SHR = Super hot rocks

Science & engineering efforts underway to further improve results

Higher Flow Rates

- Larger casing = >rate
- > Fracture conductivity
- Blue Mtn. 25M bfpd
- Cape design 70M bfpd

> Thermal Output

> Fracture Surface Area

- Longer laterals
- Wider well spacing
- LL: 3M → 5M → 15M ft.
- WS: 300’ → 600’ → __

>Thermal Longevity

One Plant / Deeper Layers

- Synergy with Super Hot Rocks progress
- Reuse as much of plant as possible after initial wells die

Lower Plant Cost

Super Hot Rocks

- Blue Mtn. ≈ 375° F
- Cape 400° to 435° F
- SHR target 705° F[1]
- ≈ 1 MW per 25° F[2]

> Thermal Output

Improved Conformance

- Well placement
- Completion design
- Operating practices
- Remediation options

>Thermal Longevity

Scaling Management

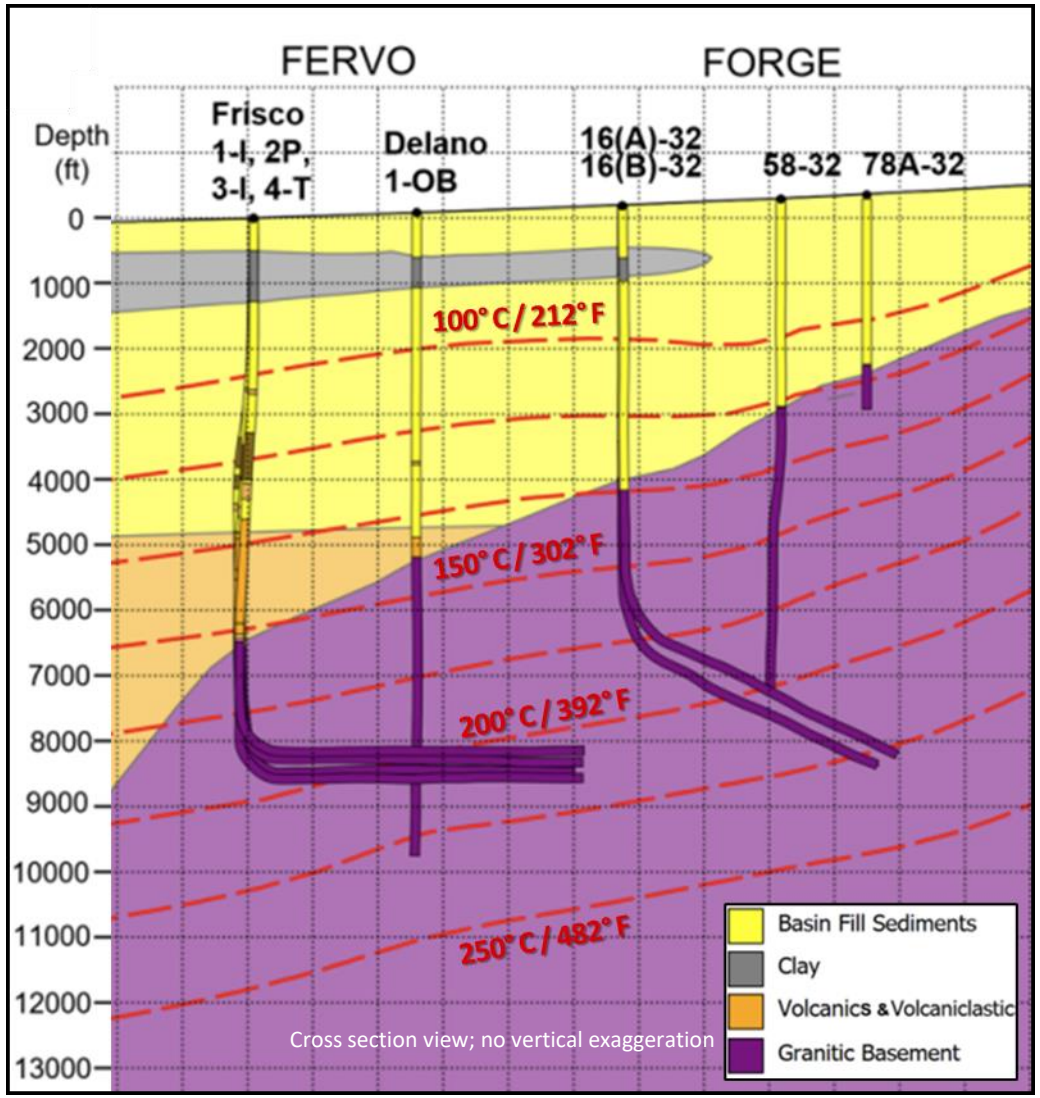
- Robust scaling characterization and treating programs
- Same for corrosion

Plant & OPEX Cost

Not an exhaustive list; [1] 374° C; [2] at 50,000 bfpd flow rate

30-Day flow tests performed during Q3 2024 at FORGE & Fervo's Cape Project have provided invaluable insights about four key EGS subsurface value drivers

1. Heat content of the rock
   - Bottom hole temperatures at both locations are > 400° F
   - Fervo's Blue Mountain demonstration project was ≈ 375° F
2. Fluid flow rate
   - Cape Project 30-day flow test set world record EGS flow rate (107 kg/sec; 70,000 bfpd)
   - FORGE achieved similar results if scaled up for length of perf section (≈ 1,000' with only 21 perf clusters → 14,400 bfpd)
3. Rock/fluid contact surface area
   - Hydraulic fracturing of Cape Project wells almost certainly enabled the largest ever EGS rock/fluid contact surface area[1] (wells 2,000' longer and ≈ twice as far apart as Blue Mtn.)
4. Conformance
   - Fiber optic measurements, production logs, and tracer surveys have been acquired; results not yet divulged



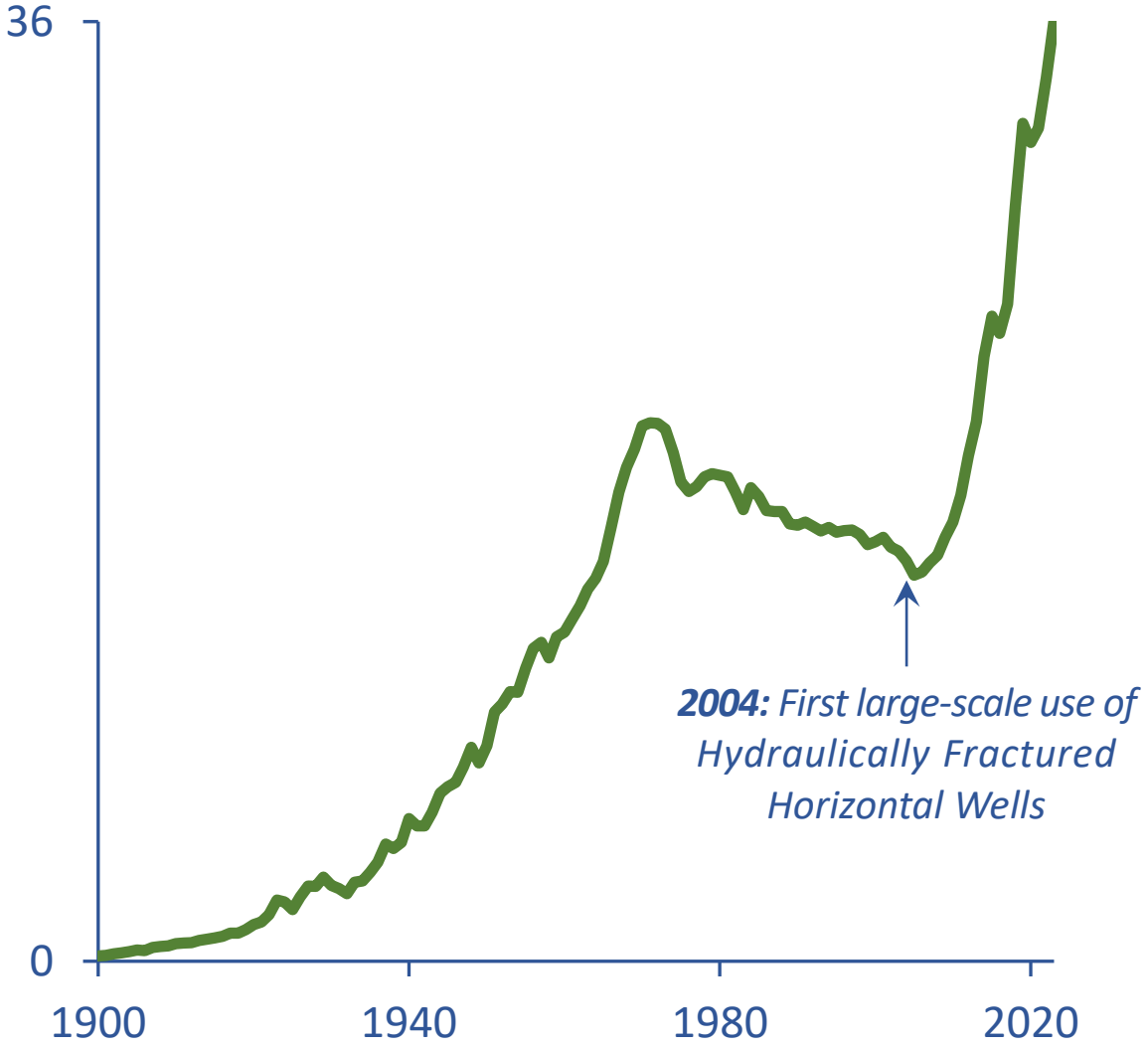
[1] Fervo's economic model is based on 20 MM sq/feet of surface area; actual result could easily be larger (600' offset * 400' FH * 250 PC * .75 ≈ 50 MM sq/Feet)

Diagram taken from 2024 paper presented at the Stanford Geothermal Workshop by Fercho et al.

It is possible that EGS could replicate unconventional O&G learning curve

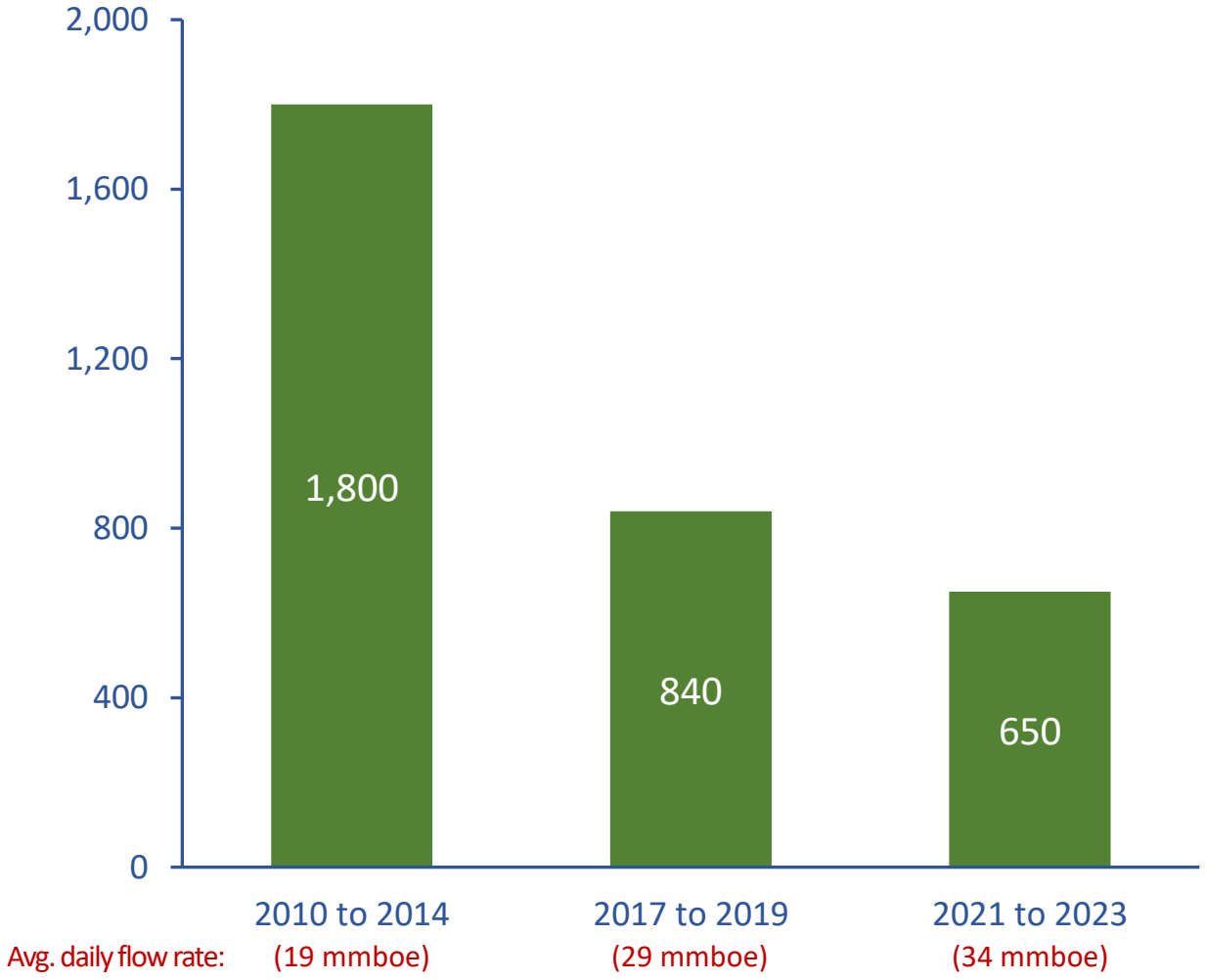
U.S. Oil & Gas Production

(Million BOE per day)



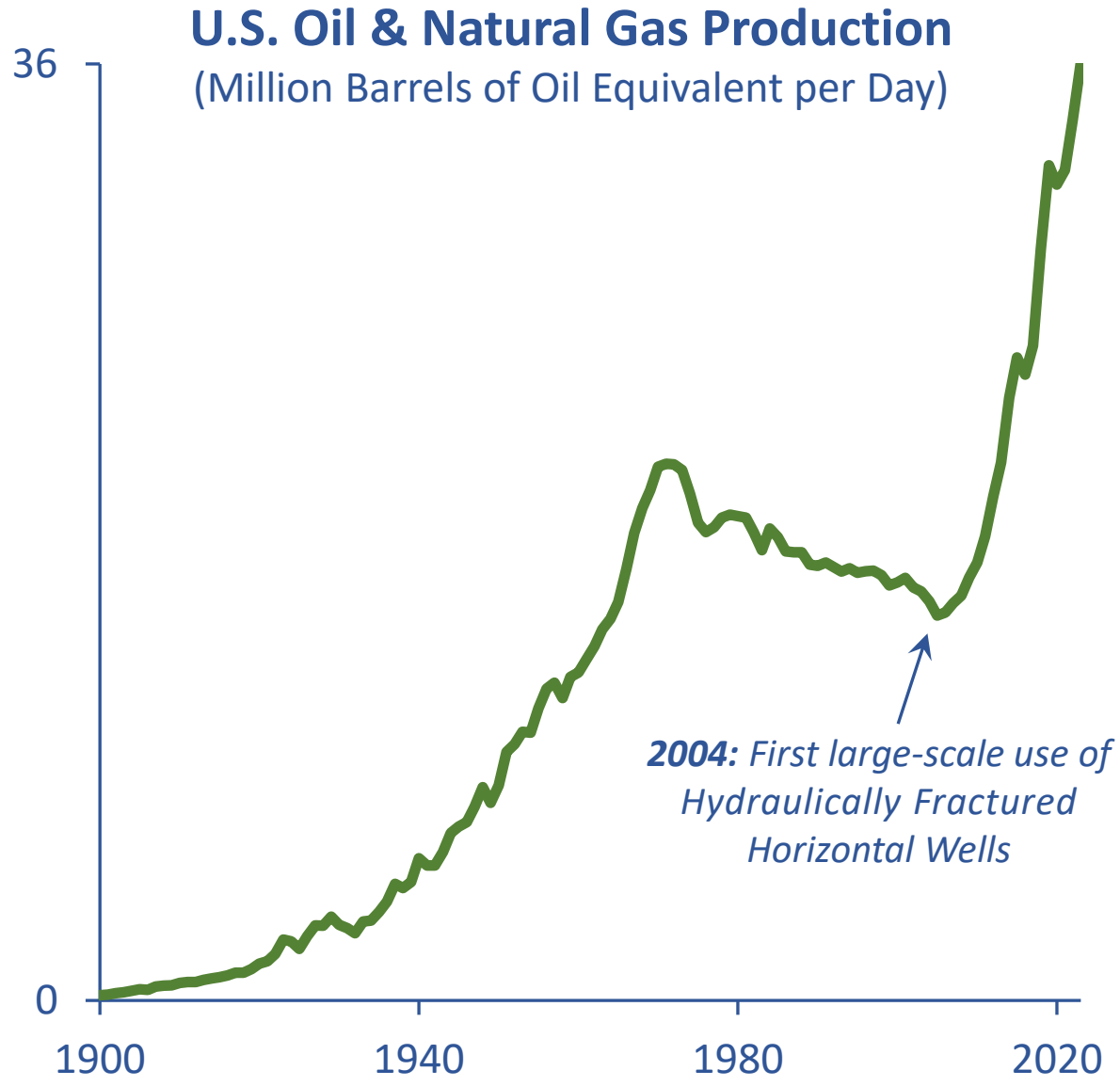
Source: Post 1965 from World Energy 2024 report; Pre-1965 oil production from EIA; Pre-1965 gas volumes estimated from multiple sources

U.S rig count needed to grow annual production by > 1,000,000 BOE per day

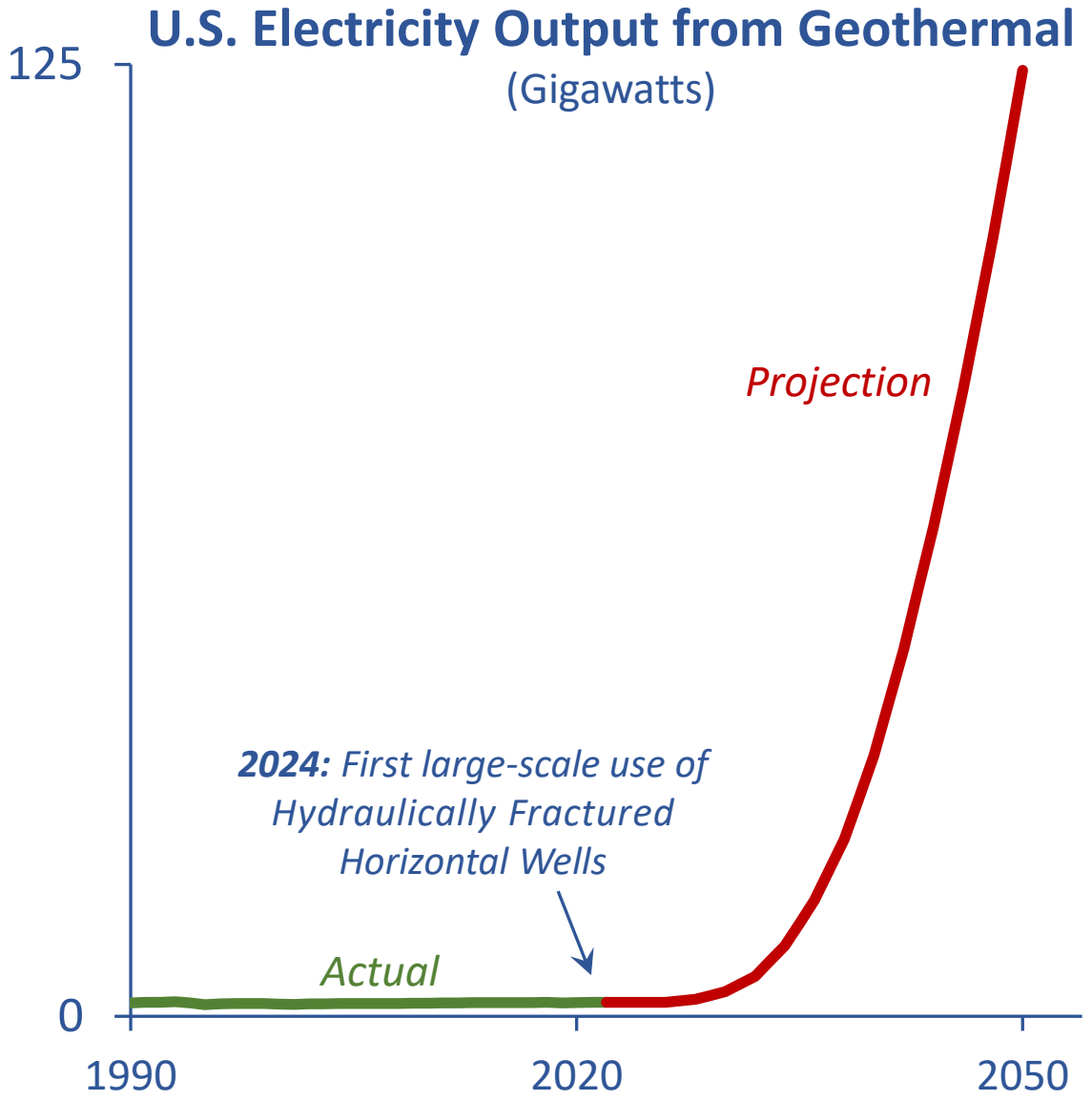


Sources: U.S. production = U.S. EIA, Energy Insights, and BP websites; Rig count = Baker Hughes; BOE = Barrels of oil equivalent; natural gas converted at 6 mcf per barrel of oil. mmboe = million barrels of oil equivalent

In the U.S., O&G technologies are poised to enable a geothermal power breakthrough like that achieved in U.S. unconventional O&G reservoirs

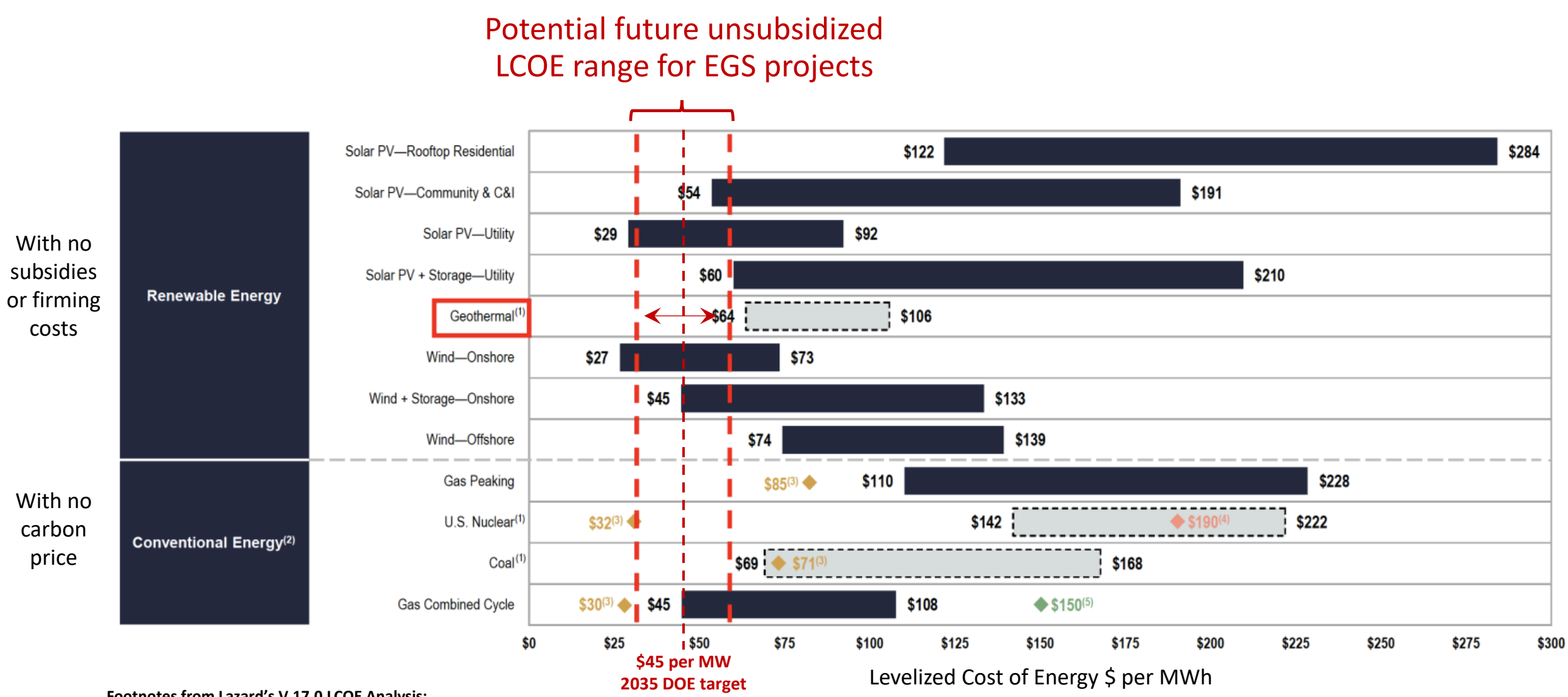


Sources: U.S. EIA, Energy Insights, and BP websites



Sources: U.S. EIA for 1990 to 2022; 2022 average output = 1.8 GW (0.4% of U.S. total); Author projection from 2023 to 2050

Levelized Cost of Energy (LCOE) comparison if EGS breakthrough fully realized



Footnotes from Lazard's V.17.0 LCOE Analysis:

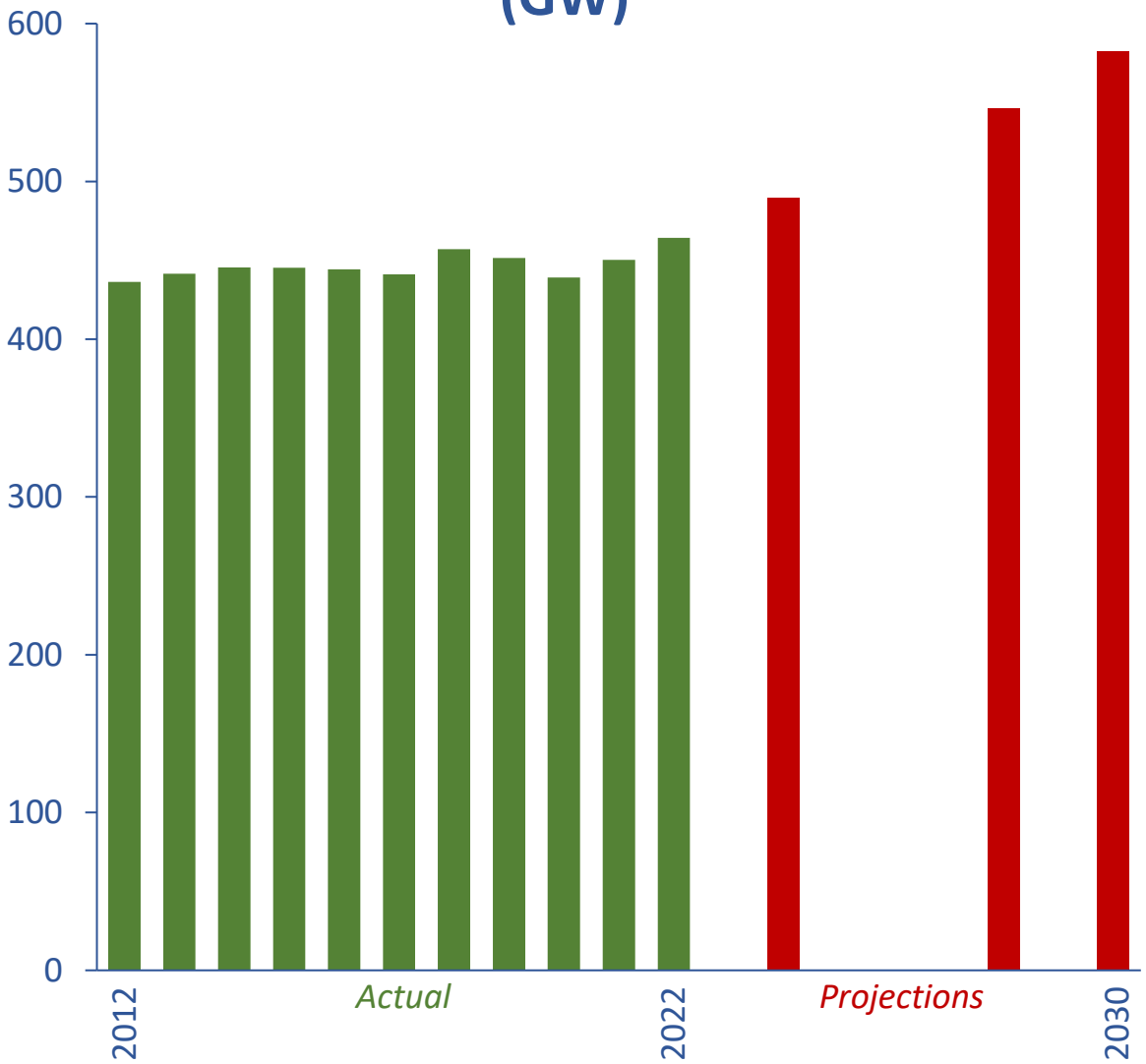
All LCOE assessments assume 60% debt at an 8% interest rate and 40% equity at a 12% cost of capital.

[1] Given the limited public or observable data available for new build geothermal, coal, and nuclear projects, the LCOE presented herein reflects Lazard's LCOE V.14.0 results adjusted for inflation. Coal LCOE does not include the cost for transportation & storage.

[2] The fuel cost assumptions for Lazard's LCOE analysis for natural gas generation, coal generation, and nuclear generation are $3.45 per MMBTU, $1.87 per MMBTU, and $0.85 per MMBTU, respectively

Demand for power is growing, with clean, firm power attracting a pricing premium

U.S. power consumption is growing rapidly (GW)



Sources: 2012 to 2022 U.S. EIA; 2024, 2028, and 2030 NERC projections modified by BCG; Annual output in TWh converted to GWs to allow easy comparison to available capacity

State government and big tech net-zero goals are creating a clean, firm power pricing premium

CALIFORNIA ENERGY COMMISSION

Mid-Term Reliability Mandate

Meta

Net-Zero by 2030

Google

Using carbon-free energy 24/7/365 by 2030

Microsoft

Carbon negative by 2030; by 2050, remove all carbon emitted since 1975

Fervo PPAs with Google and SCE rumored to be > $90 per MWh

Google

115 MW PPA with Fervo

SOUTHERN CALIFORNIA EDISON®

15-year, 320 MW PPA with Fervo

California's mid-term reliability mandate, which the state issued in 2021, ordered load serving entities to purchase 1 GW of non-weather-dependent, non-battery, zero-emission energy by 2028

EGS breakthrough – Today in the U.S., soon in many places across the globe

Key take-away messages

- Enormous prize, but efforts to economically unlock resource have been disappointing
- The use of hydraulically fractured horizontal wells is poised to change this outcome
- "Unsubsidized" LCOEs < $45 per MWh appear achievable (< $30 with IRA PTC)
- < $45 per MWh LCOE is competitive with all current renewables and natural gas[1]
- Some U.S. power purchasers are paying > $90 per MWh for clean, firm power
- EGS can scale quickly given the technologies are proven and supply chains mature
- 2050 U.S. output > 125 GW is a reasonable expectation (> 250 GW is possible)
- This is a prize that American Upstream O&G companies are best positioned to secure

[1] Even without "firming costs" for intermittent renewables and "carbon costs" for natural gas

Additional materials

- *Slide 18: EGS Upsides (that could be proven via experimentation)*
- *Slide 19-20: EGS key challenges and downsides*
- *Slides 21-24: FORGE and Fervo results and latest information*
- *Slide 25: EGS key activities timeline (next 8 quarters)*
- *Slide 26: Characteristics of an ideal geothermal prospect*
- *Slides 27-28: Resource pyramid visualizations – O&G and EGS*

Testable, engineerable, potentially significant, near-term EGS "upsides"

Super Hot Rocks	*Higher Flow Rates*	*Greater Surface Area*	*Improved Conformance*	*"Open Hole" Producers*[2]	*One Plant / Deeper Layers*
• Blue Mtn. ≈ 375° F • Cape 400° to 435° F • SHR target 750° F • ≈ 1 MW per 25° F[1]	• Larger casing = >rate • Blue Mtn. 25M bfpd • Cape design 70M bfpd • Higher rates possible	• Longer laterals • Wider well spacing • LL: 3M → 5M → 15M ft. • WS: 300' → 600' → __	• Completion design • Operation practices • Remediation options	• $5 MM or more per well cost reduction • Uncertain flow rate impact, but could yield higher rates	• Synergy with Super Hot Rocks progress • Reuse as much of plant as possible after initial wells die
> Thermal output	***> Thermal output***	***>Thermal longevity***	***>Thermal longevity***	***Less D&C cost***	***Less plant cost***

	2024	2024	2025	2025	2025	2025	2026	2026	2026	2026	2027	2028	2029
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	FY	FY	FY
SHR		Mazama slant well D&C Progressively hotter targets at Cape (400 → 435 → 450 → 500° F)					Mazama Newberry Volcano 650 - 750° F SHR project						
HFR	Cape/FORGE 30-day tests	Flow tests w/larger casing					Flow tests w/larger casing		Cape Phase 1 Production			Cape Phase 1 and 2 Production	
GSA	Cape 30-day tests	Progressively longer and wider spaced laterals at Cape; Longer and wider spaced laterals at yet to be announced projects											
IC	Cape/FORGE	Blue Mountain Production							DOE funded data wells	Cape Phase 1 & 2 Production			
OHP	Cape 30-day test[3]				Additional Cape tests?				Cape Phase 1 & 2 Production				
OP/DL											Blue Mtn. or Cape deeper Layer?		

[1] at 50,000 bfpd flow rate; [2] Wells could be completed open hole or with a slotted liner, either way, the cost of casing and hydraulically fracturing the well would be eliminated; [3] Fervo left one of the initial Cape Project wells as an open hole completion

EGS key remaining uncertainties and challenges

(Work in progress; Incomplete list)

- Subsurface and facilities:
  - Exploration; Leasing; Water Rights
  - Conformance – which impacts thermal longevity, induced seismicity, water leakoff
  - Induced seismicity (real & perceptions)
  - Water management (EGS uses a lot of H_2O)
  - Scaling and corrosion mitigation
  - Tools for big holes, high temp., high Δ T
- Commercial / supply chain / infrastructure
  - Maturity of EGS legal framework, leasing ecosystem, regulatory (state by state & fed.)
  - Maturity and optionality of PPAs (e.g., NV Energy – Google partnership LINK)
  - High voltage transmission; BTM customers
  - Proximity to supply chain, work force
  - "Pull" with O&G and EPC service industry
- Financial and market maturity
  - EGS has a poor historical track record of delivering adequate returns on investment
  - Only a small number of knowledgeable participants (need more O&G operators; Geothermal operators; VC and PE investors)
  - Ability for VC/PE companies to monetize investments (other than by operating them)
  - Agreed and auditable reserves/resources classification scheme; Legal & regulatory
- Public and thought leaders' perceptions
  - Operating in areas without O&G heritage
  - "Fracing" has been maligned by many factions
  - NIMBY (concerns about everything from truck traffic to induced seismicity)
  - Geothermal hasn't been talked about nearly as much as wind, solar, CCUS, hydrogen

Testable, engineerable, mitigation of potentially significant “downsides"

Conformance Related Issues ⟷

Thermal Breakthrough	Fluid Leakoff	Induced Seismicity	Conductivity Loss	Corrosion	Scaling
• Well length, spacing & stacking, flow rates • Completion design • Operating practices • Remediation options	• Avoiding tectonically stressed localities • Completion design • Operating practices • Remediation options	• Avoiding tectonically stressed localities • Completion design • Operating practices • Remediation options	• Proppant placement best practices • Proppant type • Operating practices	• Robust corrosion characterization and treating programs • Materials selection	• Robust scaling characterization and treating programs
Thermal longevity	***Plant & OPEX cost***	***License to operate***	***Thermal longevity***	***Plant & OPEX Cost***	***Plant & OPEX Cost***

	2024 Q3	2024 Q4	2025 Q1	2025 Q2	2025 Q3	2025 Q4	2026 Q1	2026 Q2	2026 Q3	2026 Q4	2027 FY	2028 FY	2029 FY
TB	Blue Mountain Production								Cape and Blue Mountain Production				
FL	Blue Mountain Production & Cape 30-day tests								Cape & Blue Mountain Production				
IS	Blue Mountain Production; Cape Fracture Stimulation Activities; Utah FORGE testing program								Blue Mountain& Cape Production; Cape Fracture Stimulation Activities				
CL	Blue Mountain Production								Cape and Blue Mountain Production				
C	Blue Mountain Production and Utah FORGE testing program								Cape and Blue Mountain Production				
S	Blue Mountain Production and Utah FORGE testing program								Cape and Blue Mountain Production				

EGS hydraulically fractured horizontal well milestones achieved to date

Fervo Blue Mountain Nevada demonstration project

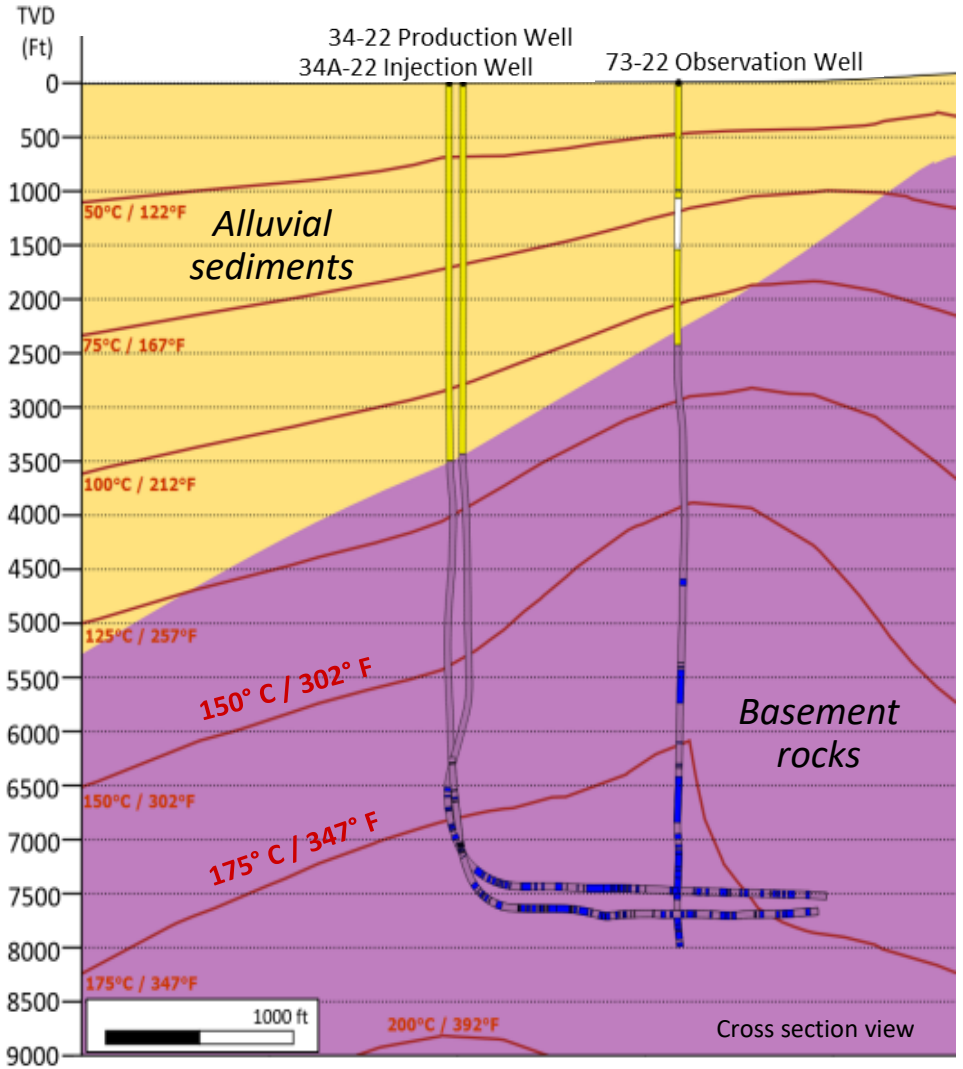


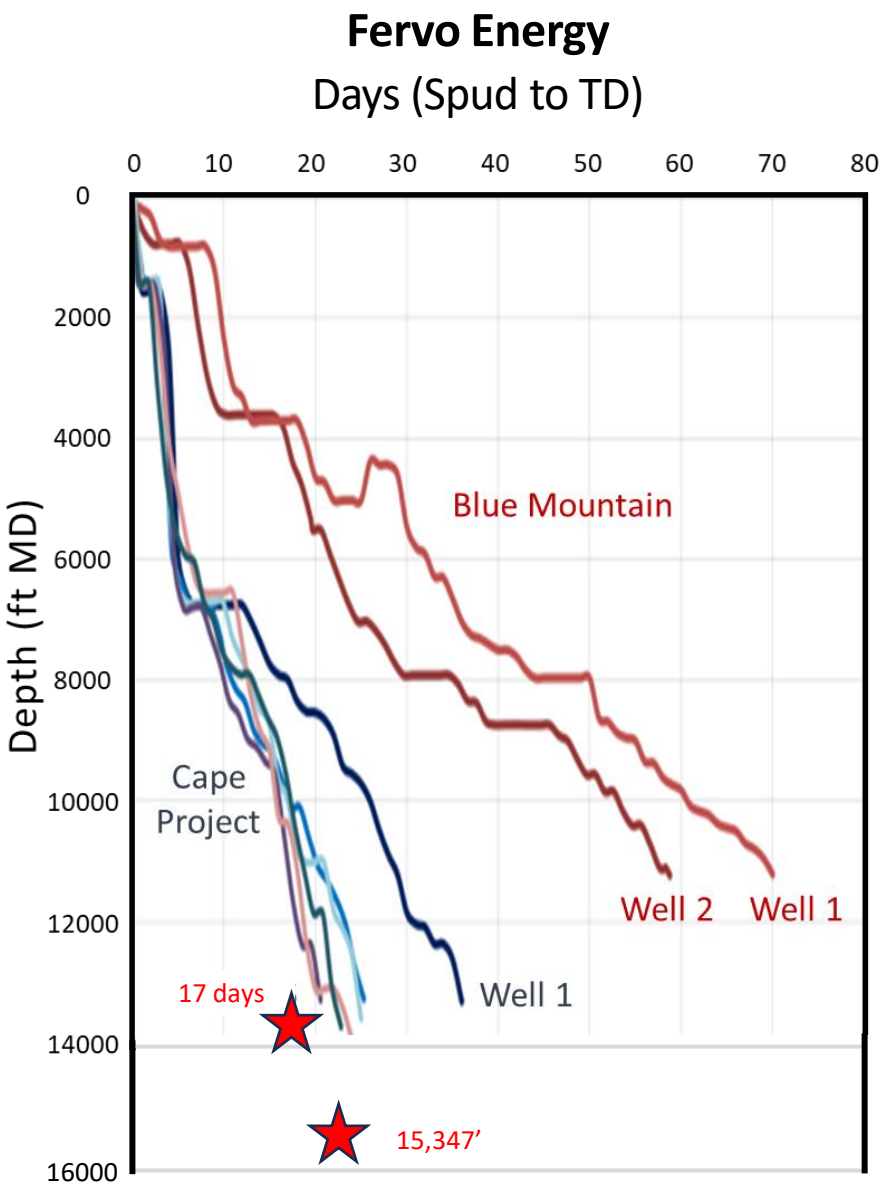
Diagram taken from 2023 paper by Jack Norbeck and Tim Latimer

- Ability to drill horizontally in hot, hard rocks
- Drilling time: from ≈ 150 days to < 20 days[2]
- Viability of plug & perf completions at 435° F[3]
- Establishment of robust connectivity between horizontal injectors and producers
- Record setting EGS production rates
- Consistent placement of injected fluid across > 3,000’ of horizontal section
- Data suggest thermal longevity greater than a decade in duration is achievable

[1] Includes results from both Fervo’s Blue Mountain Nevada demonstration project and their Cape Project commercial development in SW Utah
[2] From the “industry average” for a 12,000’ MD well drilled predominantly through hot, hard, abrasive basement rocks to Fervo’s actual results
[3] Reservoir conditions; not necessarily the temperature the equipment is exposed to due to cooling associated with circulating fluids in a well

Fervo Energy and Utah FORGE updates (as of 11/1/2024)

- Fervo revealed that the temperature of produced fluids at their Blue Mountain Nevada demonstration project have yet to decline[1]
- Fervo have recently achieved the following D&C results at their Cape Project in SW Utah:
  - TD'd a well with ≈ 5,000' long lateral section in 17 days
  - Drilled a well to 15,347' MD in 21.3 days spud to TD
  - Successfully D&C'd a well with a BHT of 435° F
- Challenges Fervo are working to overcome include:
  - Casing deformation issues in at least two wells
  - Higher levels of leakoff than modeled at Blue Mtn. (?)
  - Scaling during the Cape project 30-day flow test
- To learn about Utah FORGE's recent activities:
  - LINK to announcement of results from 30-day flow test
  - View video podcast by Joe Moore (LINK)
  - View video podcast by John McLennan (LINK)



[1] See next two slides for discussion about the importance of this result

Slide modified from one presented at the Stanford Geothermal Workshop by Fervo (LINK)

Fervo Energy Blue Mountain Nevada demonstration project

- A 37-day flow test was performed on Fervo's Blue Mtn. injector-producer well pair in April/May 2023 (see diagram below)
- First commercial production was achieved in late October 2023
- Fervo expected produced fluid temperatures to begin to decline after seven months based upon ResFrac modeling results
- As of September 2024, produced fluid temperature remains on plateau at approximately 347° F (per Fervo 9/10/24 Technology Day)

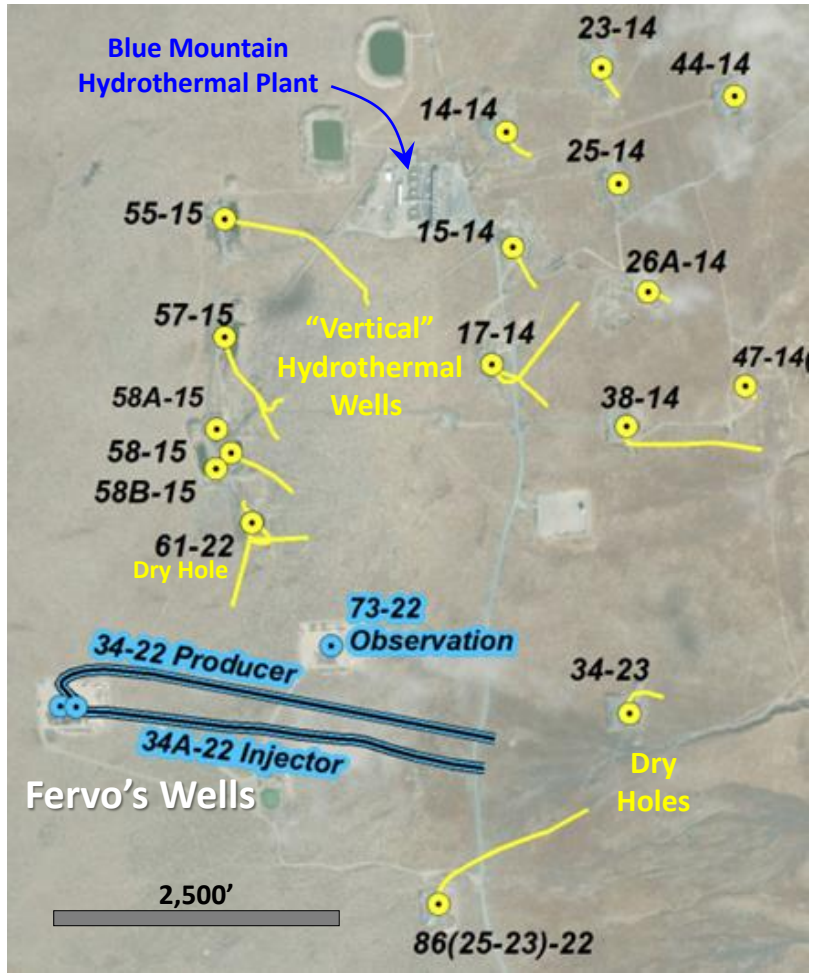


Diagram modified after one included in 2023 paper by Jack Norbeck and Tim Latimer (LINK)

2023 37-day flow test

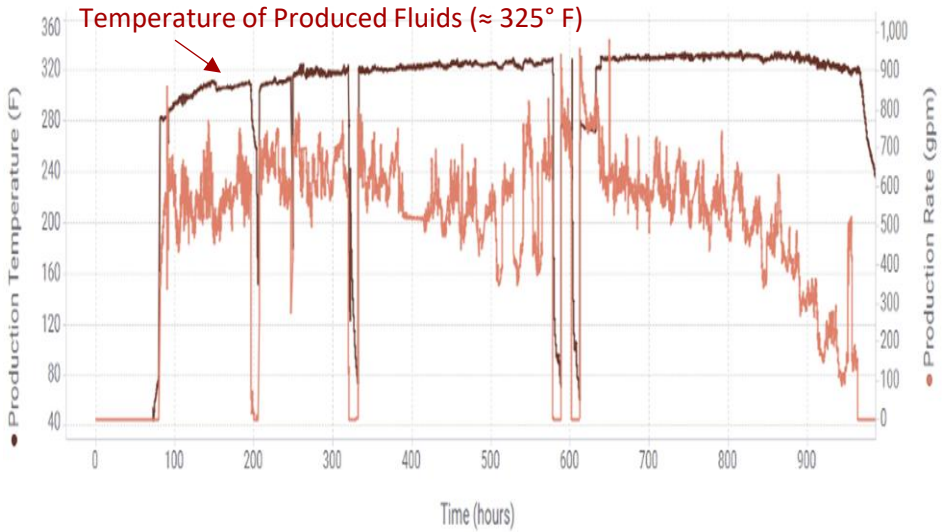


Diagram from 2023 paper by Jack Norbeck and Tim Latimer (LINK)

Commercial production 10/23 - 5/24

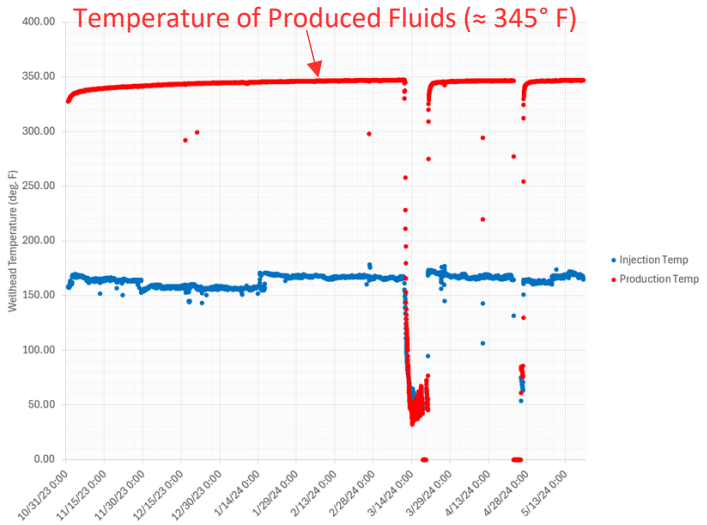
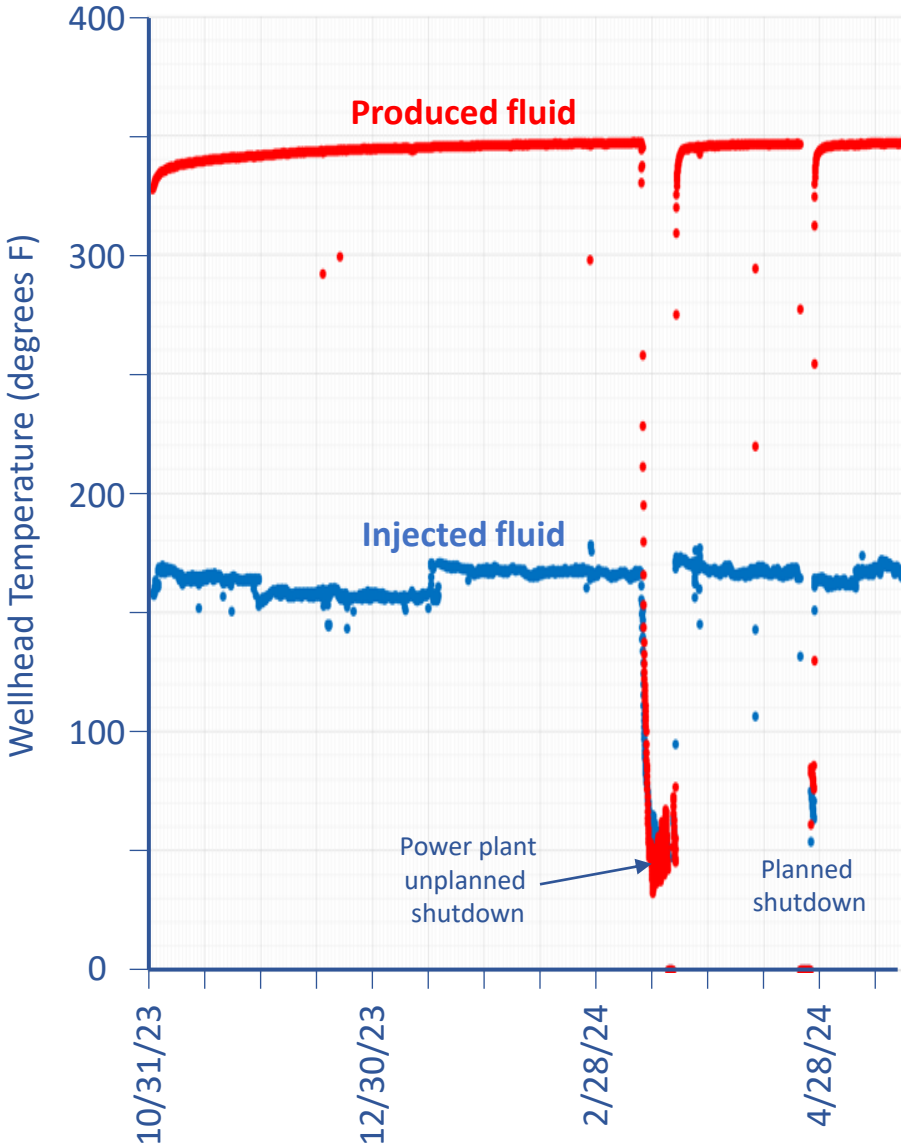


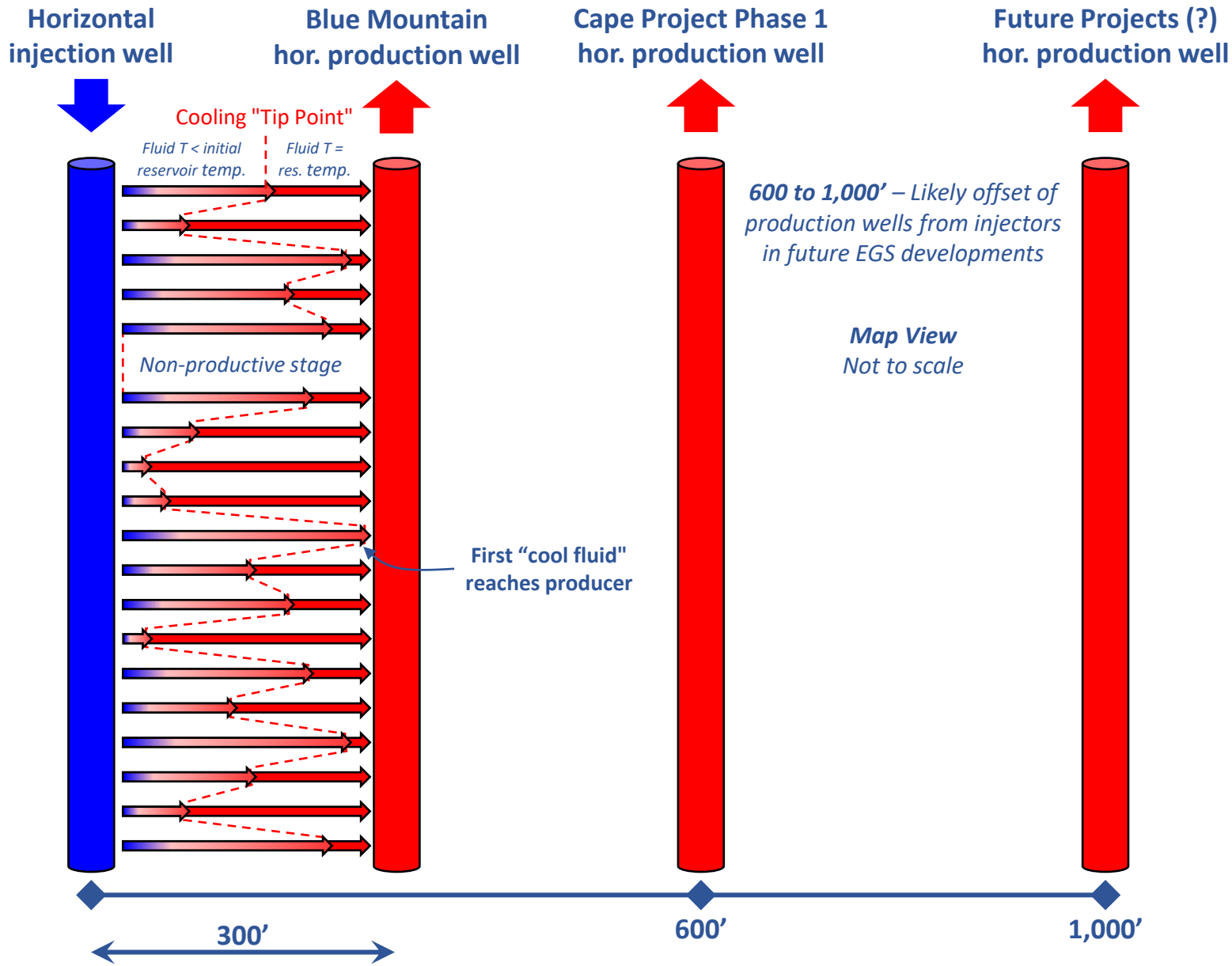
Diagram presented by Fervo at 2024 ResFrac Annual Technical Symposium

Conformance - Importance of Blue Mtn. produced fluid temperature data

Blue Mountain produced and injected fluid temperature



Graph taken from slide presented by Jack Norbeck, Fervo's CTO, at ResFrac's Annual Technical Symposium



Simplified Depiction of a Complex Physical Phenomenon; Depiction of cooling characteristics are for demonstration purposes only; they are not based on actual data

EGS key activities timeline
(Next 8 quarters; this is a work in progress!)

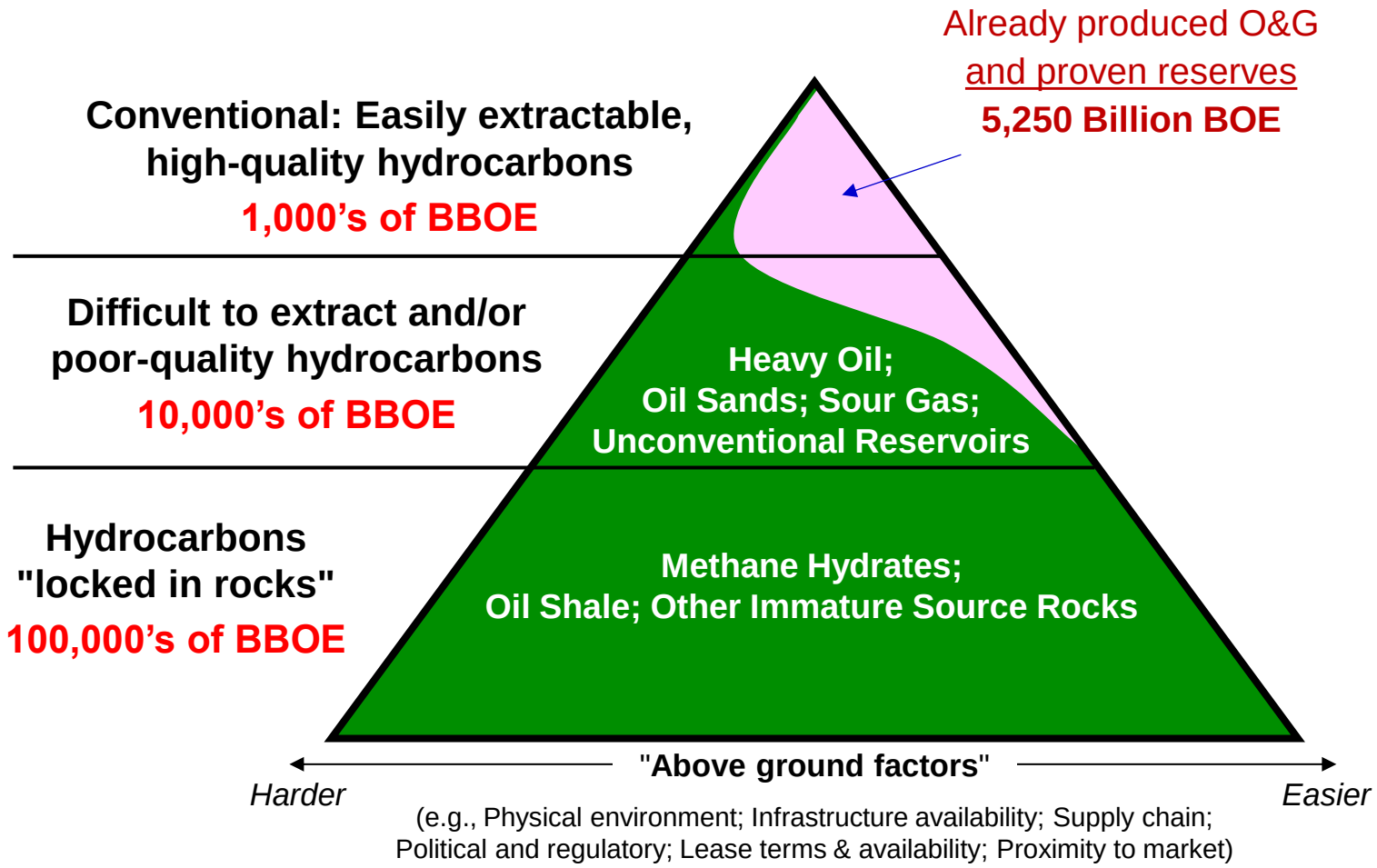
◆ = Results "published"

	Q3 2024	Q4 2024	Q1 2025	Q2 2025	Q3 2025	Q4 2025	Q1 2026	Q2 2026
Fervo Blue Mtn.		GRC ◆	◆ SGW			GRC ◆	◆ SGW	
Fervo Cape	30 Day Flow Tests	GRC ◆ Next Fund Raising "Round"?	◆ SGW	Complete D&C Phase 1 Wells (or sooner)		GRC ◆	◆ SGW	Phase 1 Start Up
Utah FORGE	30 Day Flow Test	GRC ◆	◆ SGW		Next Phase of Drilling Activity?? →	GRC ◆	◆ SGW	
U.S. DOE			Additional Funding for Geothermal Technologies and Development Projects					
Leasing		BLM Nevada Lease Sale				BLM Utah Lease Sale		
ORMAT	SLB Geothermal Partnership LINK		"Extensive ORMAT Exploration and Exploration Drilling Campaign"					
OXY	Geothermal Li Extraction w/BHE LINK				Drilling in DJ Basin LINK; LINK; LINK	◆ ?	DJ Basin Extended Flow Test LINK; LINK; LINK	
Chevron-Mitsui					Pilot Drilling?; Closed Loop or EGS? LINK			
Geo-Energie Suisse	Drilling Underway Haute-Sorne Project Switzerland (LINK)	◆ ?	Stimulation Testing?	◆ ?				
Conferences	Subsurface Geo. Symposium (7/31) LINK	Geothermal Rising (10/27) LINK	Stanford Geothermal Workshop (2/10) LINK	URTeC (6/9)	Subsurface Geothermal Symposium	Geothermal Rising	Stanford Geothermal Workshop	URTeC (6/9)

What makes for an "Ideal Geothermal Prospect" is different when using hydraulically fractured horizontal wells

Hydrothermal systems	Enhanced Geothermal Systems (EGS)	
Vertical wells	Vertical wells	Horizontal wells
• High subsurface temperature	• High subsurface temperature	• High subsurface temperature
• Pervasively fractured rocks	• Pervasively fractured rocks	
• Overpressured, fluid-filled fractures		***"Minimally fractured rocks" preferable to reduce the likelihood of thermal breakthrough, excessive leakoff, and induced seismicity***
• Pressure recharge mechanism		
EXCEEDINGLY RARE	***EXCEEDINGLY DISAPPOINTING***	***RIGHT TOOL FOR THE JOB***
Example: The Geysers, California	Example: Most EGS projects 1970-2023	Examples: Cape Project & Utah FORGE

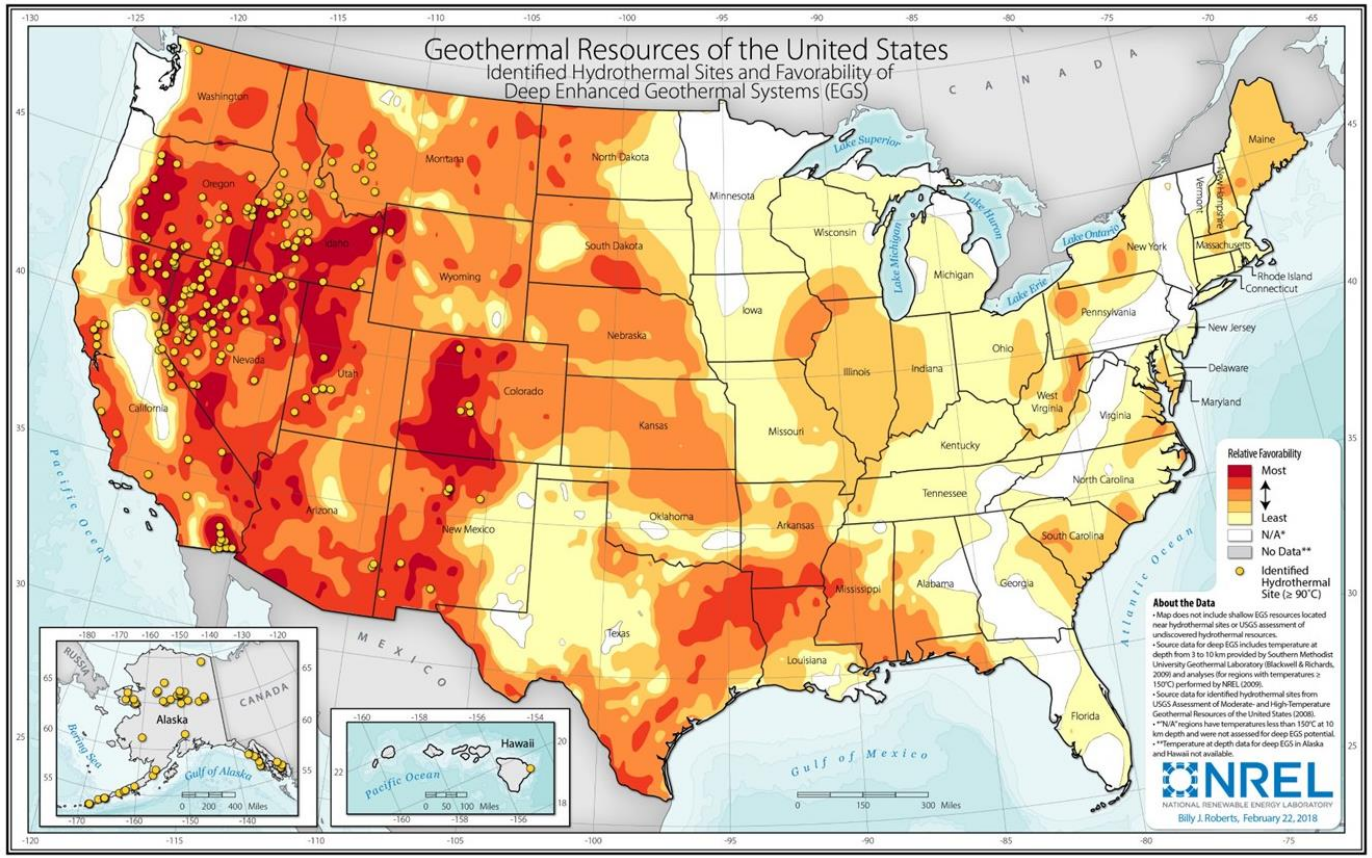
Global O&G resource pyramid that incorporates above ground challenges



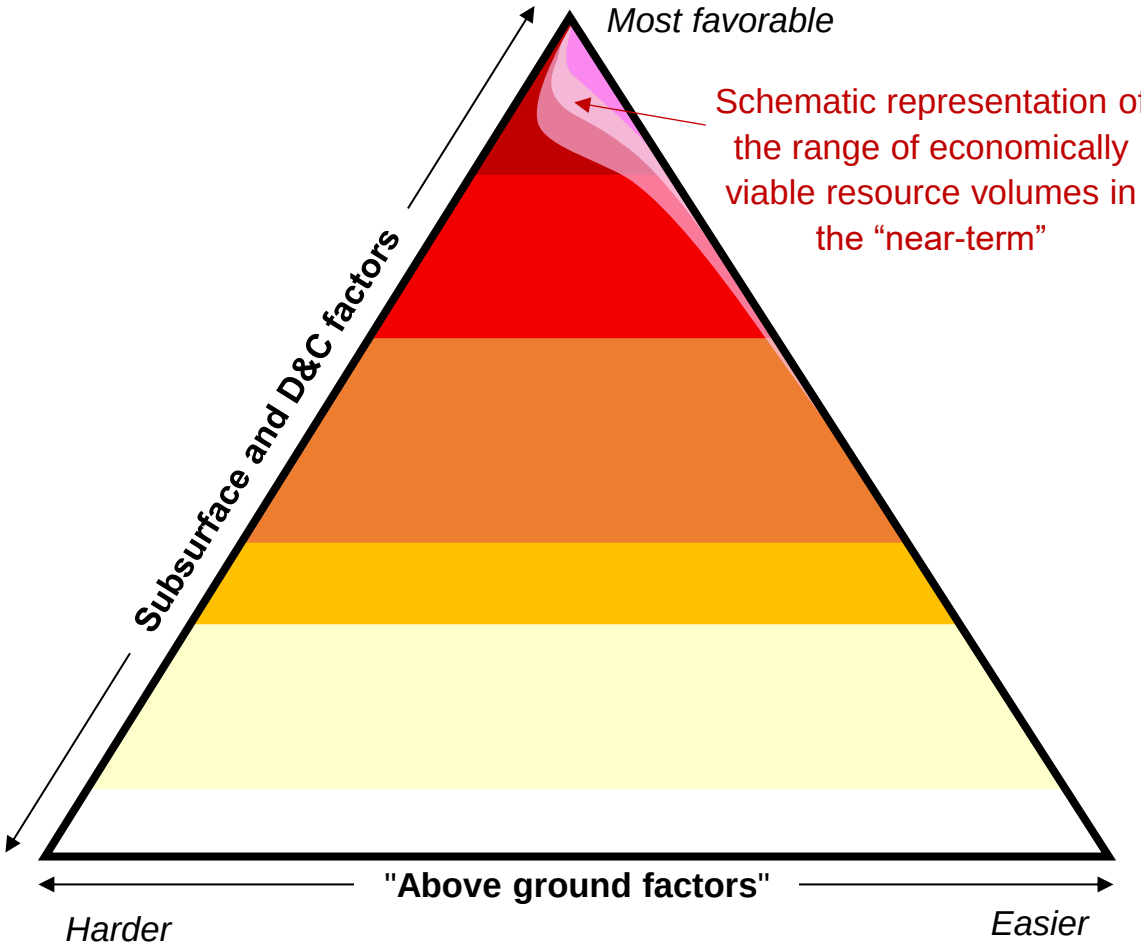
BBOE = Billions of Barrels of Oil Equivalent; Produced and proven resource estimates were taken from IEA and BP numbers; Produced = 2,450 BBOE and Proven = 2,800 BBOE as of YE 2023

Lower 48 EGS resource pyramid that incorporates above ground challenges

Favorability of EGS resources in 3 – 10 km depth range



Map taken from U.S. NREL website



(e.g., Proximity to power markets and/or high-voltage transmission lines; Infrastructure cost; Supply chain; Political & regulatory; Lease terms)