Welcome!

The program will begin soon.

You will not hear audio until we begin.

Grand Challenges for the Oil and Gas Industry for the Next Decade and Beyond

Moderator:
Gaurav Agrawal, NewPark Resources

Speakers:
Jeffrey R. Bailey, ExxonMobil (retired)
Scyller J. Borglum, WSP
Thomas C. Halsey, Rice University
Kishore K. Mohanty, University of Texas at Austin

October 13. 2023

Webinars

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The Past is Prologue…

- At the beginning of the 2010's, the SPE Research and Development Technical Section conducted a series of workshops to determine key oil and gas technical / R&D challenges for next decade
  - Resulted in a series of challenges mostly within the conventional definition of the upstream industry
  - Exception: Carbon Capture and Sequestration
- Now, in the 2020's, our franchise in upstream oil and gas is under more pressure than we might have foreseen a decade ago
  - Sustainability, especially climate concerns
  - New energy sources (solar, wind) and end-use technologies (EVs)
  - Cost pressures, especially evident 2015-2020

Grand Challenges of the Last Decade
Increasing Recovery Factors
In-situ Molecular Manipulation
Carbon Capture and Sequestration
Produced Water Management
Higher Resolution Subsurface Imaging
Sustainability (underlies all of the other challenges)

A. Judzis, R. Felder, D. Curry, B. Seller, J. Petro. Tech. 2011

SPE Grand Challenges Workshop: Oil and Gas Technology for a Net-Zero World

Webinars

- SPE Workshop held 23-25 January 2023 at UT Austin, 120 participants
- Plenary sessions:
  - Pathways to Net Zero and Uncertainties Thereof
  - Improving the Sustainability of Energy Production
  - New Energy Market Opportunities
  - Decarbonizing Products
  - Carbon Capture, Utilization, and Storage
  - Geothermal Energy and Repurposing Existing Wells

- Panelists: IOCs, NOCs, service providers, NGOs, academia
- Breakout Sessions to define and rank new Grand Challenges

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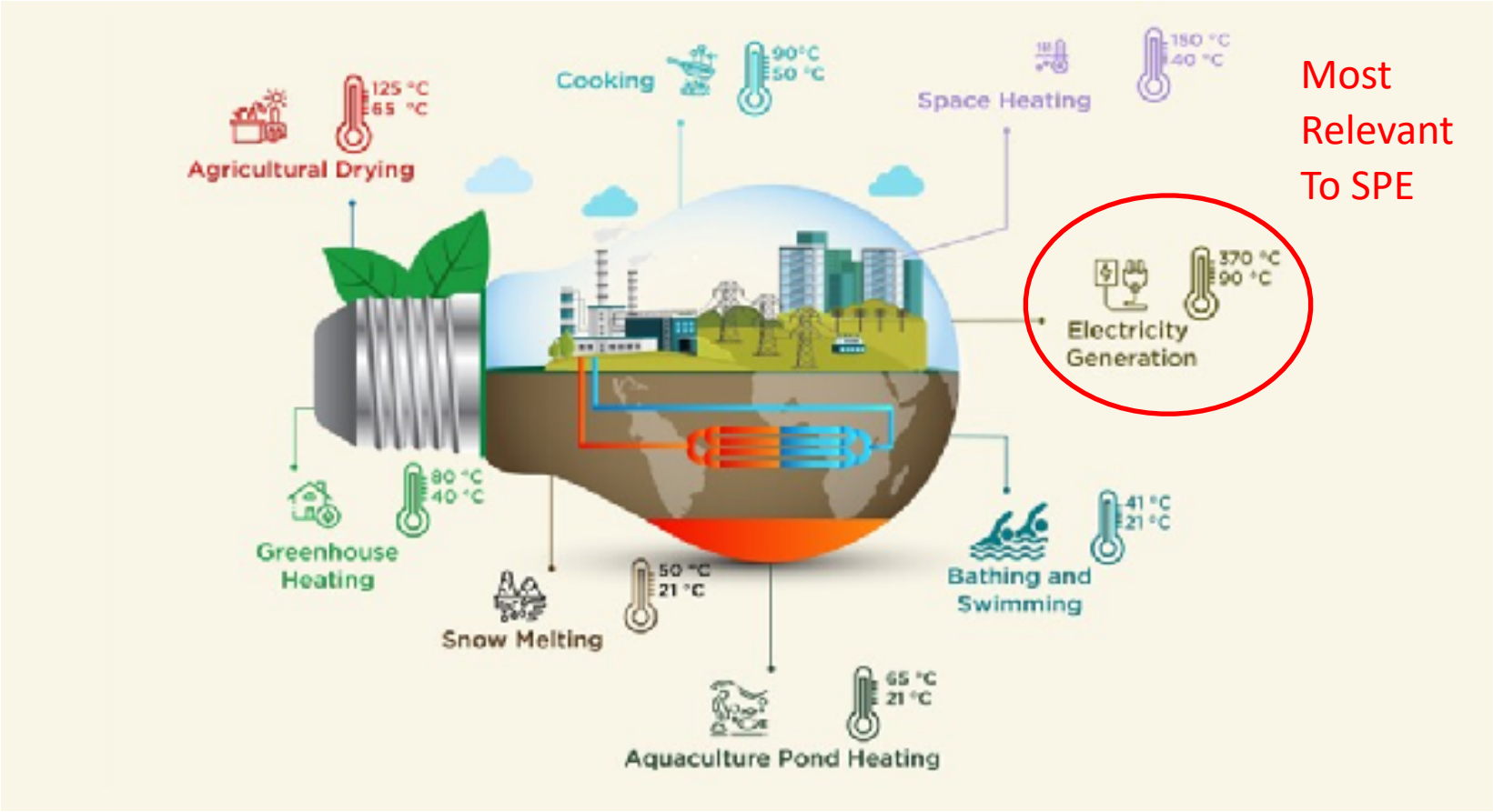
The New Grand Challenges

- Geothermal Energy
  - Baseload power—important as grid moves towards renewables
- Improved Recovery from Tight / Shale Resources
  - Perennial economic driver for any resource
- Carbon Capture, Utilization, and Storage
  - Modeling implies CCUS will be necessary for any economic net-zero pathway
- Net-zero Oil and Gas Operations
  - We must control our own emissions to be a trusted partner with society in addressing global emissions
- Digital Transformation
  - Opportunity to materially reduce costs across the industry
- Education and Advocacy
  - More effective engagement with thought leaders required to advance and deploy new technologies in all five of these areas

Geothermal Energy

The Geothermal Elephant

- Electricity Generation & “Direct Use” applications
- Heat Engines & The Second Law of Thermodynamics

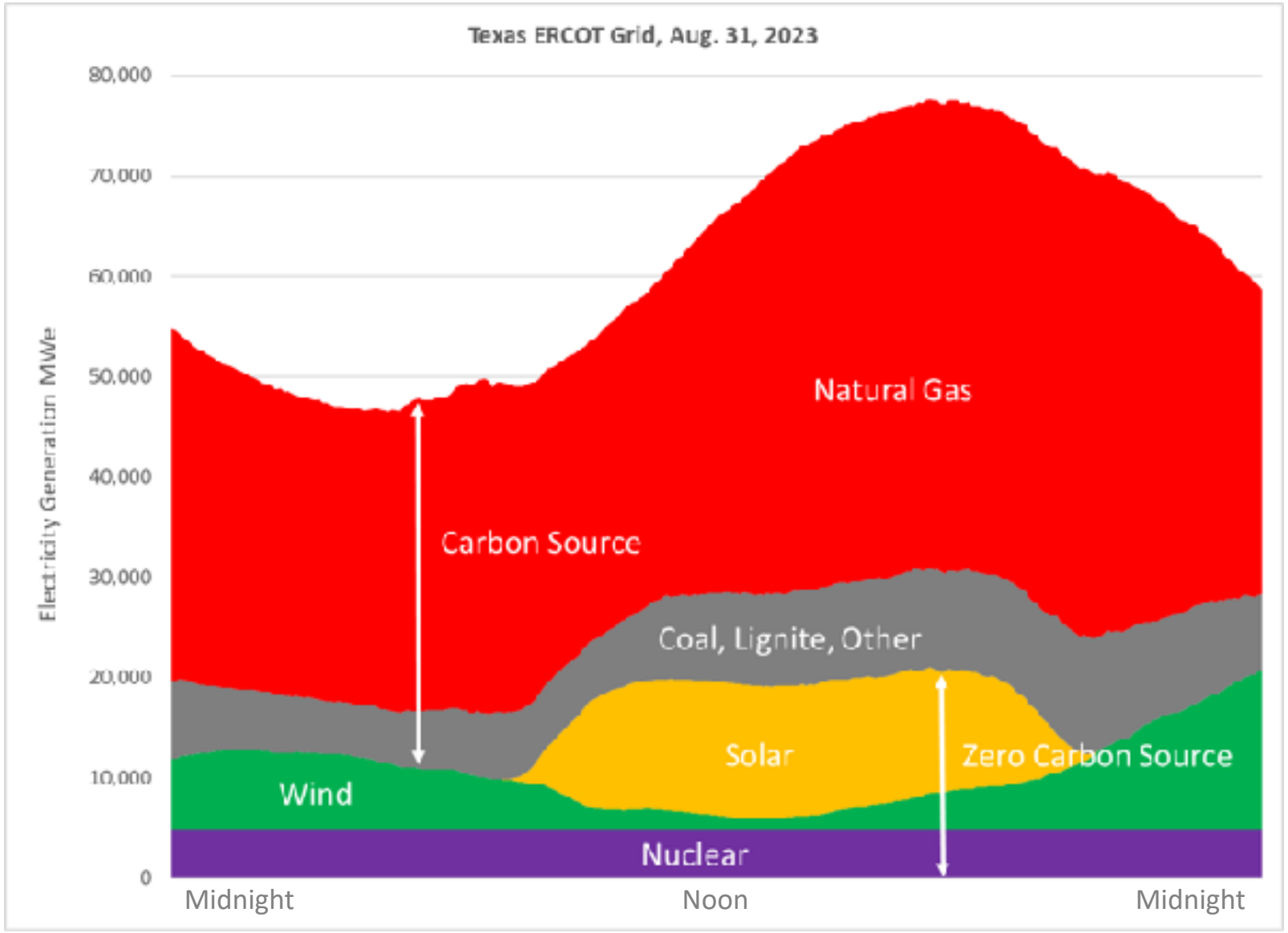


Most Relevant To SPE

Geology, Drilling, Subsurface, Facilities skillsets of SPE

Source: University of North Dakota, from JPT article: The Multiple Facets and Versatility of Geothermal Energy, July 20, 2023

The Need for Low-Carbon Baseload Power

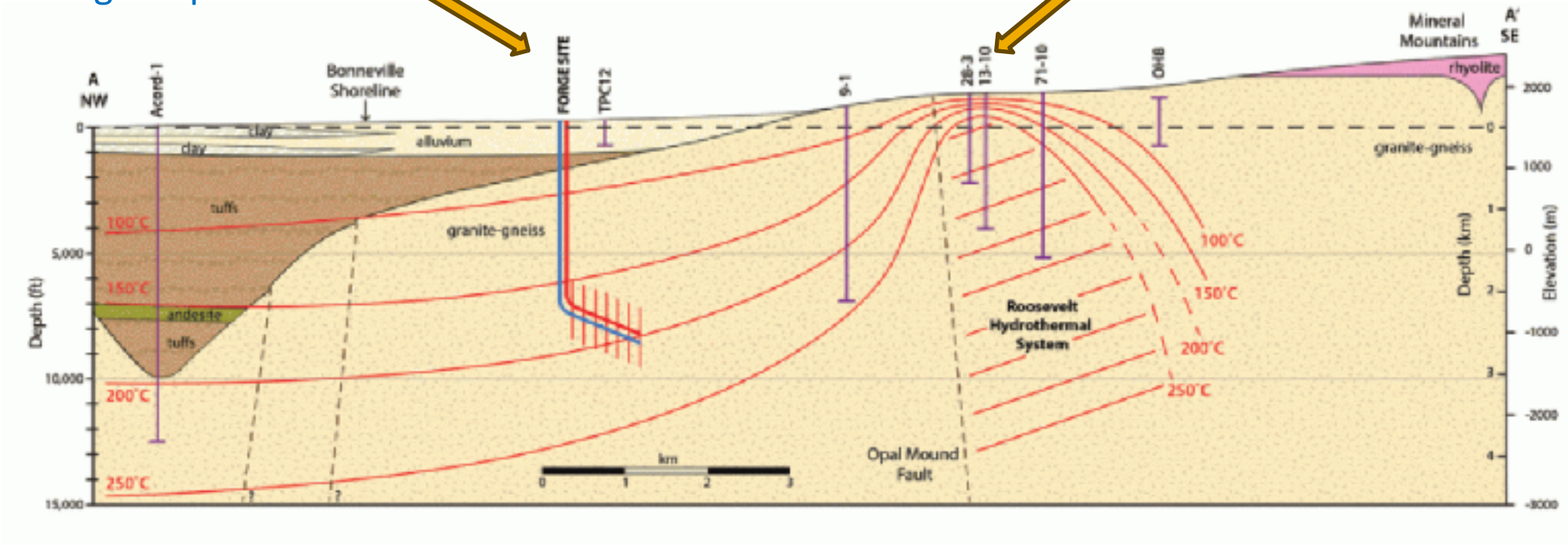


- Zero Carbon Source is still limited and varies with time
- Natural Gas fills the large gap between demand and supply

Engineered and Conventional Systems

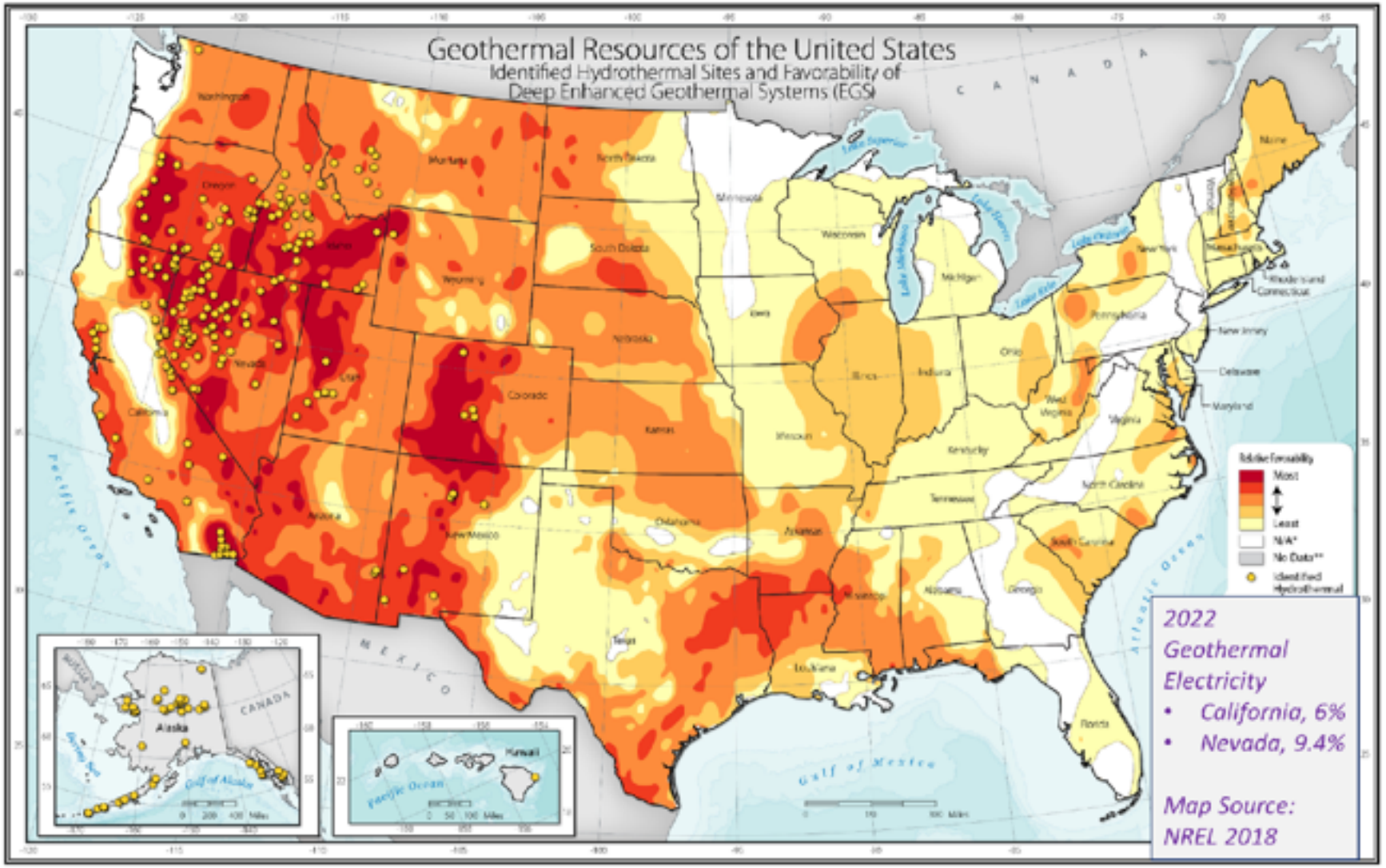
DOE FORGE Site to Evaluate EGS Development
Doublet wells drilled 2022-23, now evaluating circulating temperatures

Blundell 38 MWe Plant (Operational since 1984)



UGS is Major Partner in Large Geothermal Project near Milford, Utah - Utah Geological Survey
(by Rick Allis, Survey Notes, v. 48 no. 3, September 2016)

Geothermal Resources More Favorable in Western US

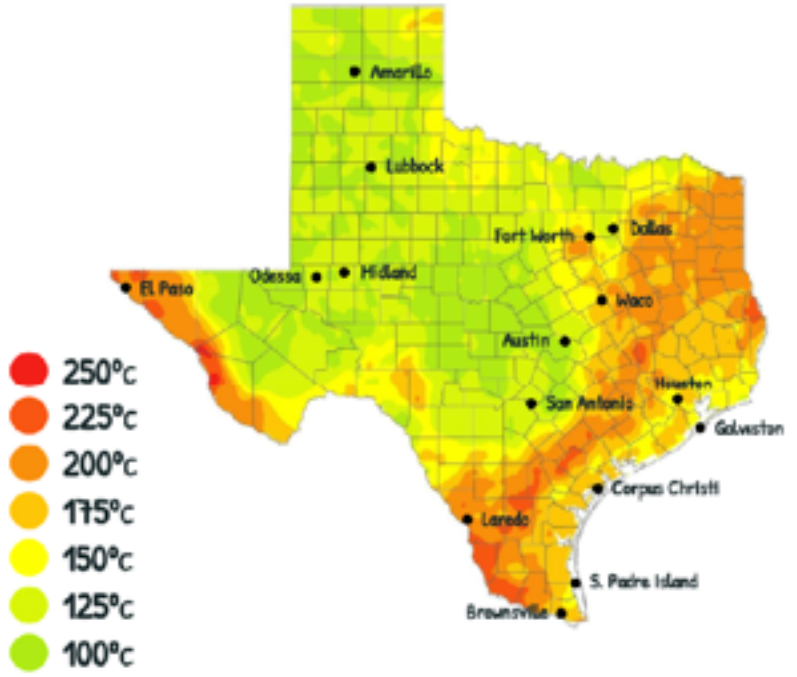


The Geothermal Challenge

Can Geothermal reach the required scale and economics?

- Evaluating “Geothermal Anywhere”
- DOE RD&D efforts
- PIVOT conferences held since 2020
- Start-ups & new ventures

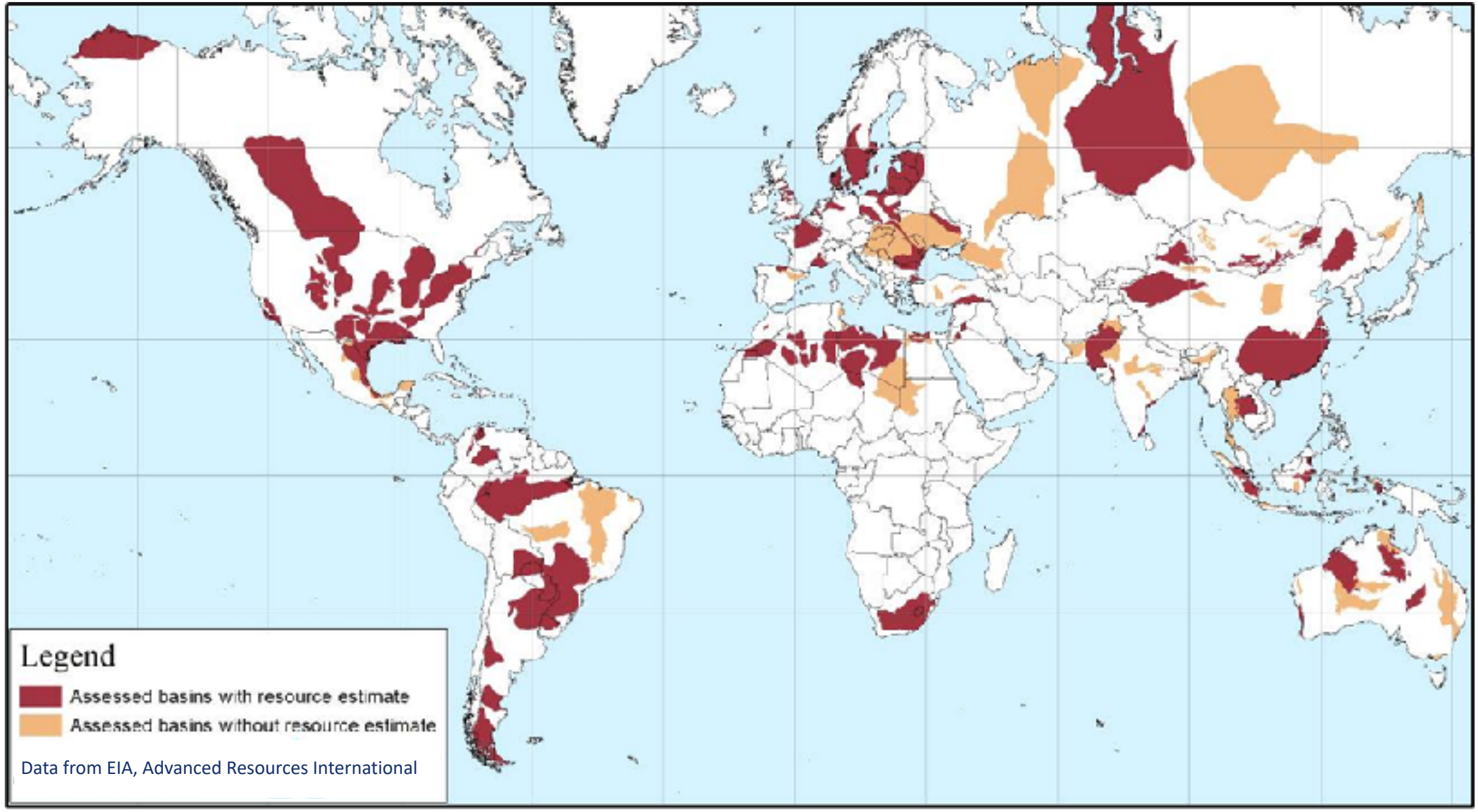
2023 UT Report:
“The Future of Geothermal in Texas: The Coming Century of Growth & Prosperity in the Lone Star State”



Temperature of Texas geothermal resources at 6.5 kilometers depth. As mapped, much of the State is at or near conventional minimum viable temperatures for geothermal power generation. Source: *Adapted from SMU Geothermal Laboratory.*

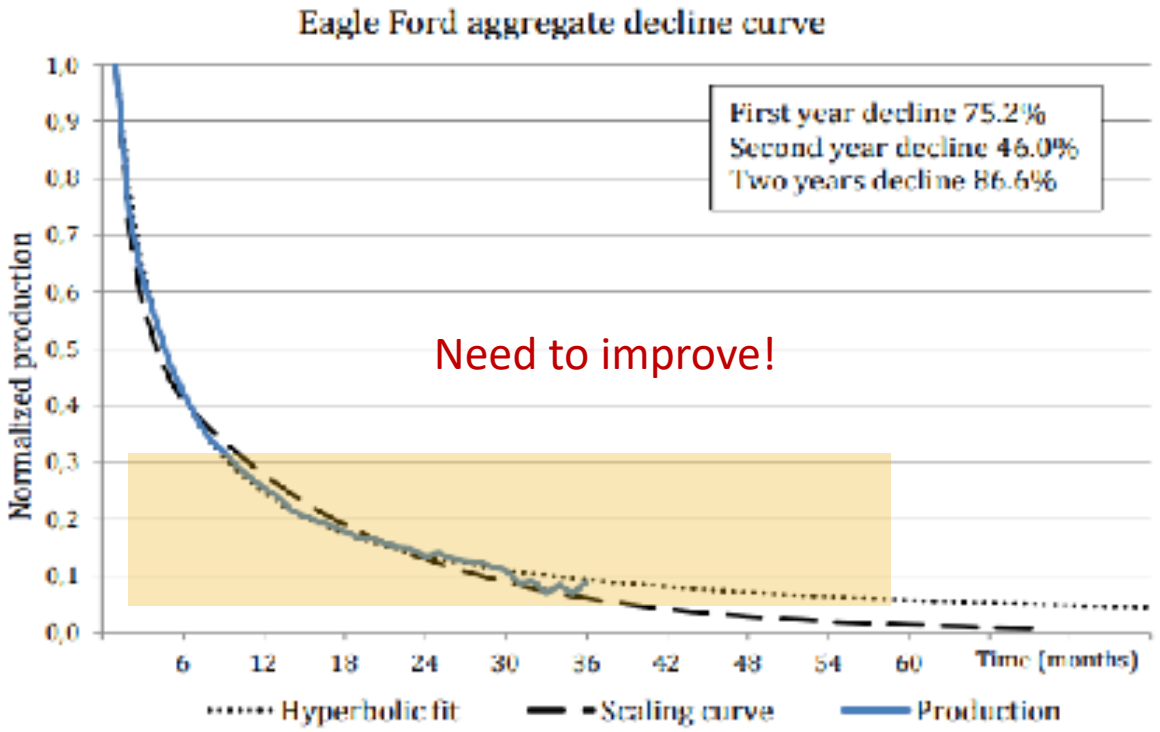
Improved Recovery from Tight / Shale Resources

Improved Recovery from Unconventionals



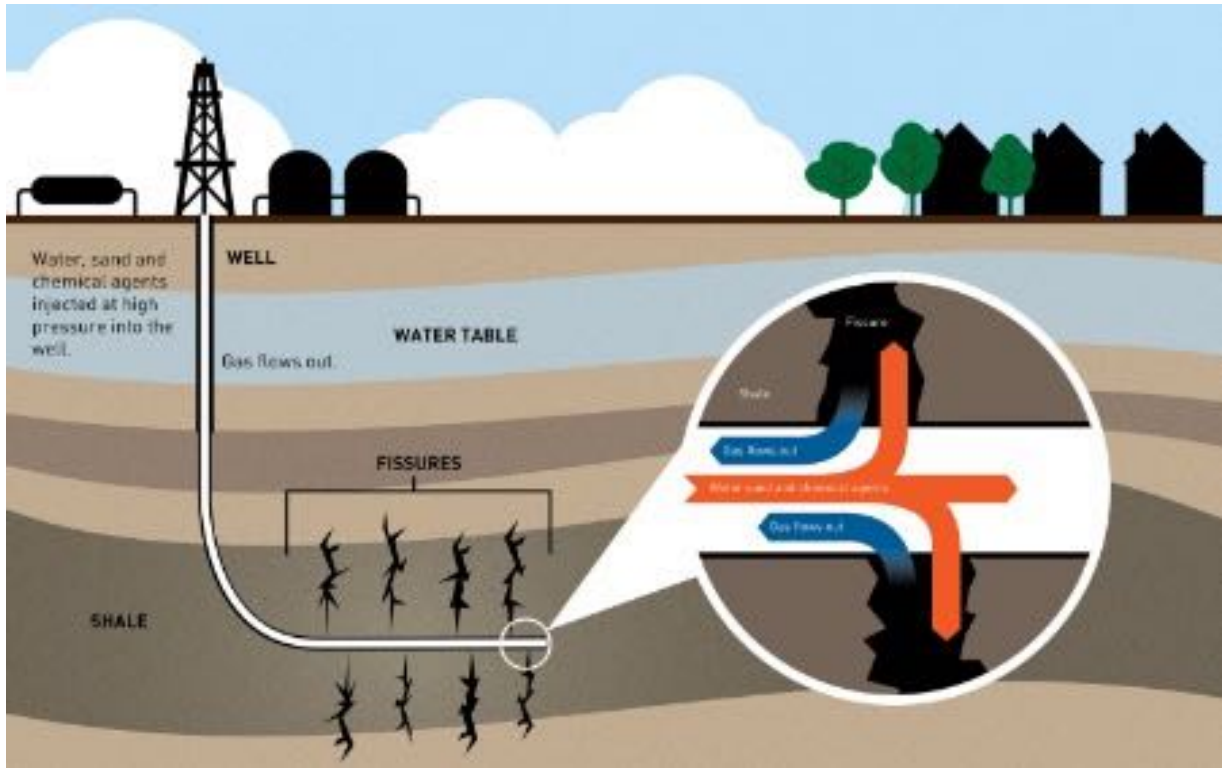
Rapid Production Decline

- More than 60% of US oil production comes from shales
- Production rate of shale wells declines very fast (75% in first year)
- Oil recovery is less than 10% OOIP in shale oil by depressurization



https://uu.diva-portal.org/smash/get/diva2:762320/FULLTEXT01.pdf

Why Low Primary Recovery?



- Extremely low permeability
- Limited reservoir energy
- Closing of microfractures
- Organic depositions
- Frac water blocking

https://www.oilandgasiq.com/oil-and-gas-production-and-operations/news/what-is-fracking

Strategy to Improve Oil Recovery

Mechanical

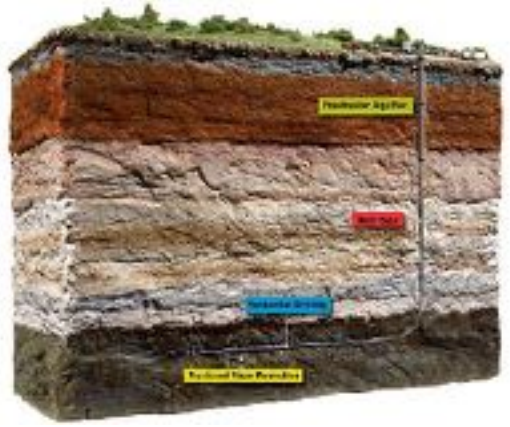
- Re-fracturing

Chemical

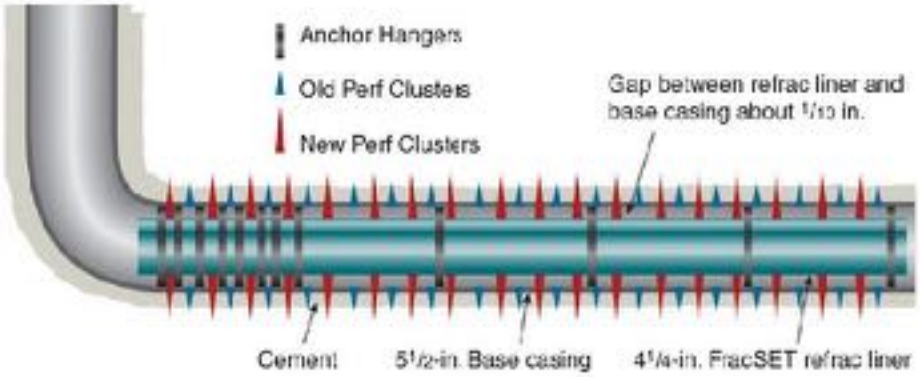
- Gas Huff-n-Puff
- Chemical blend Huff-n-Puff
- Propping of microfractures

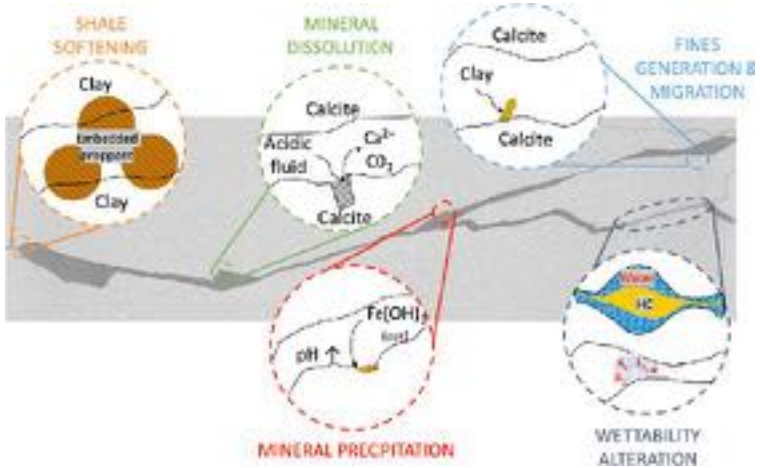
Thermal

- In situ heating



- Multi-scale understanding of shales
- Mechanics and fracturing
- Fluid-rock interaction at the nano-scale

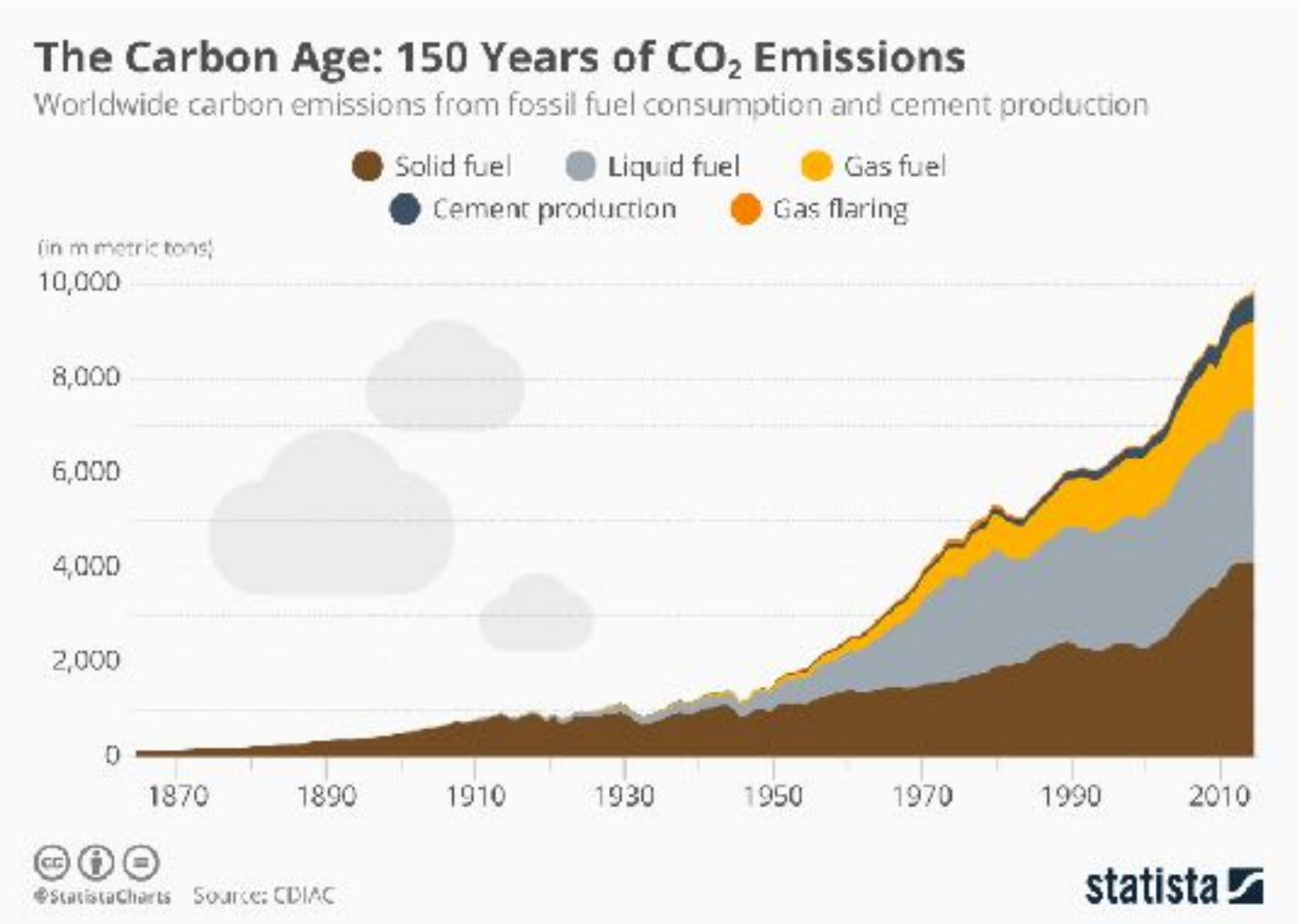




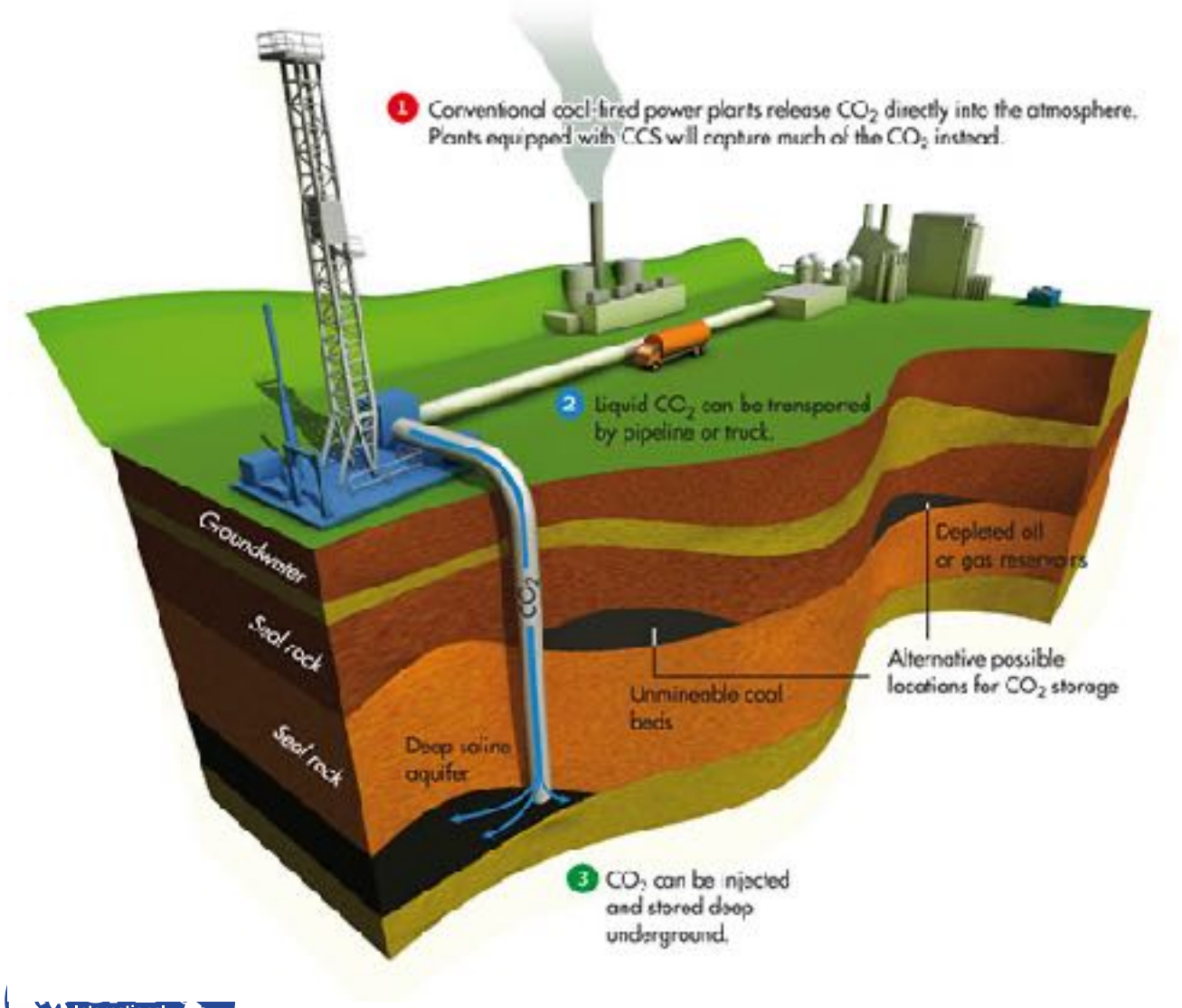
Carbon Capture, Utilization, and Storage

Global CO_2 Emissions

- 2010 Carbon emissions ~ 10 Gt/yr, doubled in last 30 years
- Equiv. CO_2 emissions ~37 Gt/yr
- US emissions are ~1/4th
- Most is from fossil fuels
- Some from cement, steel, aluminum industries



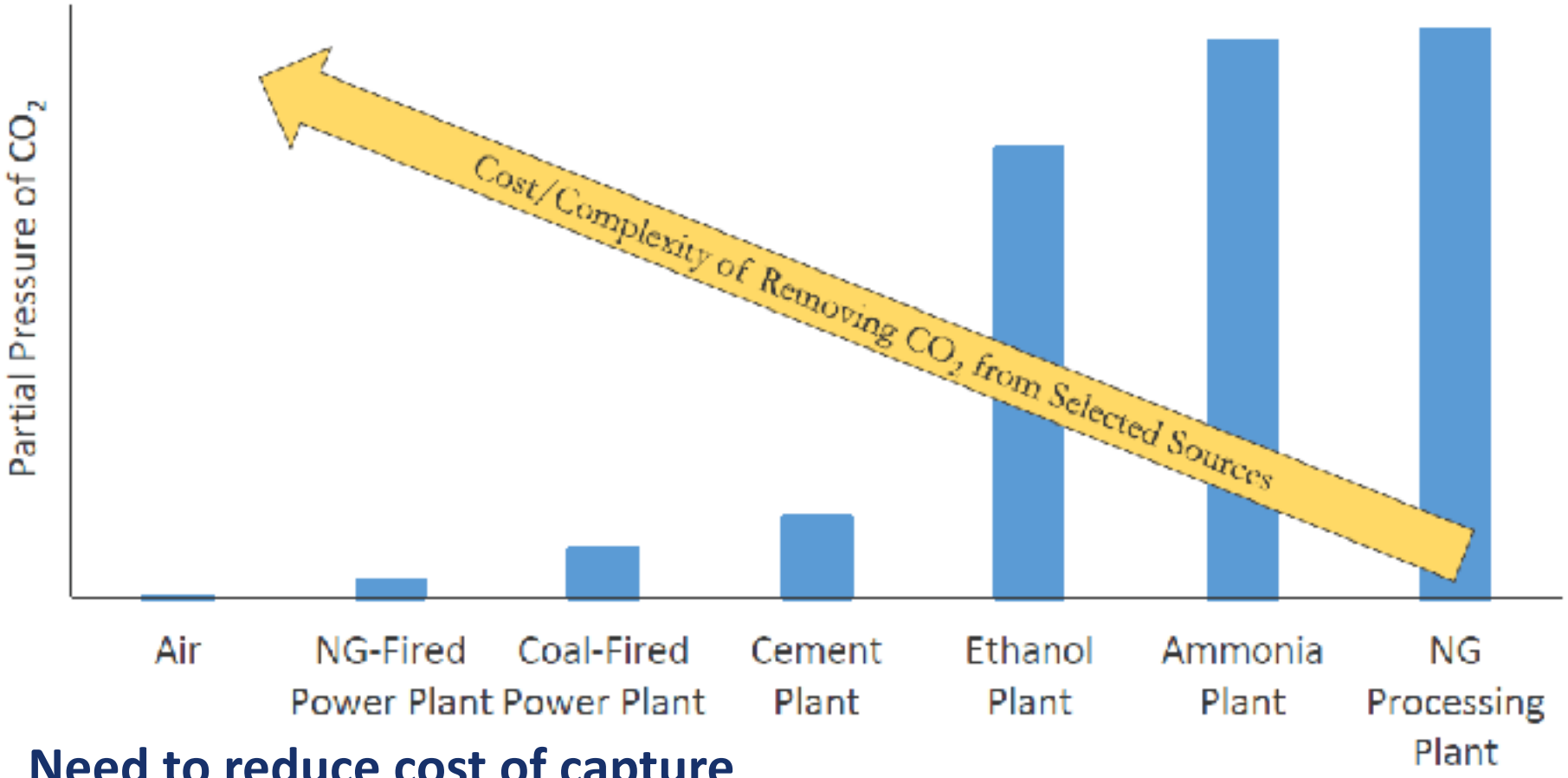
Carbon Capture & Storage (CCS)



- CO_2 Emission:
  - Point sources
  - Direct Air Capture
- CO_2 Capture & Separation
- CO_2 Compression
- CO_2 Transportation
- CO_2 Injection
- Monitoring

Need to develop the supply chain

CO_2 Partial Pressure & Capture Cost



Need to reduce cost of capture

(Cost of capturing CO2 from industrial sources, Jan. 10, 2014, DOE-NETL, 2013/1602)

Post-Combustion Carbon Capture

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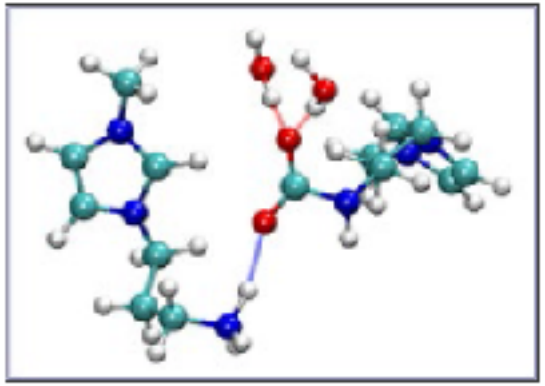
Solvents



- Regeneration energy
- Solvent loss

Sorbents

- Regeneration energy
- Effect of humidity

Membranes

- Flux
- Selectivity

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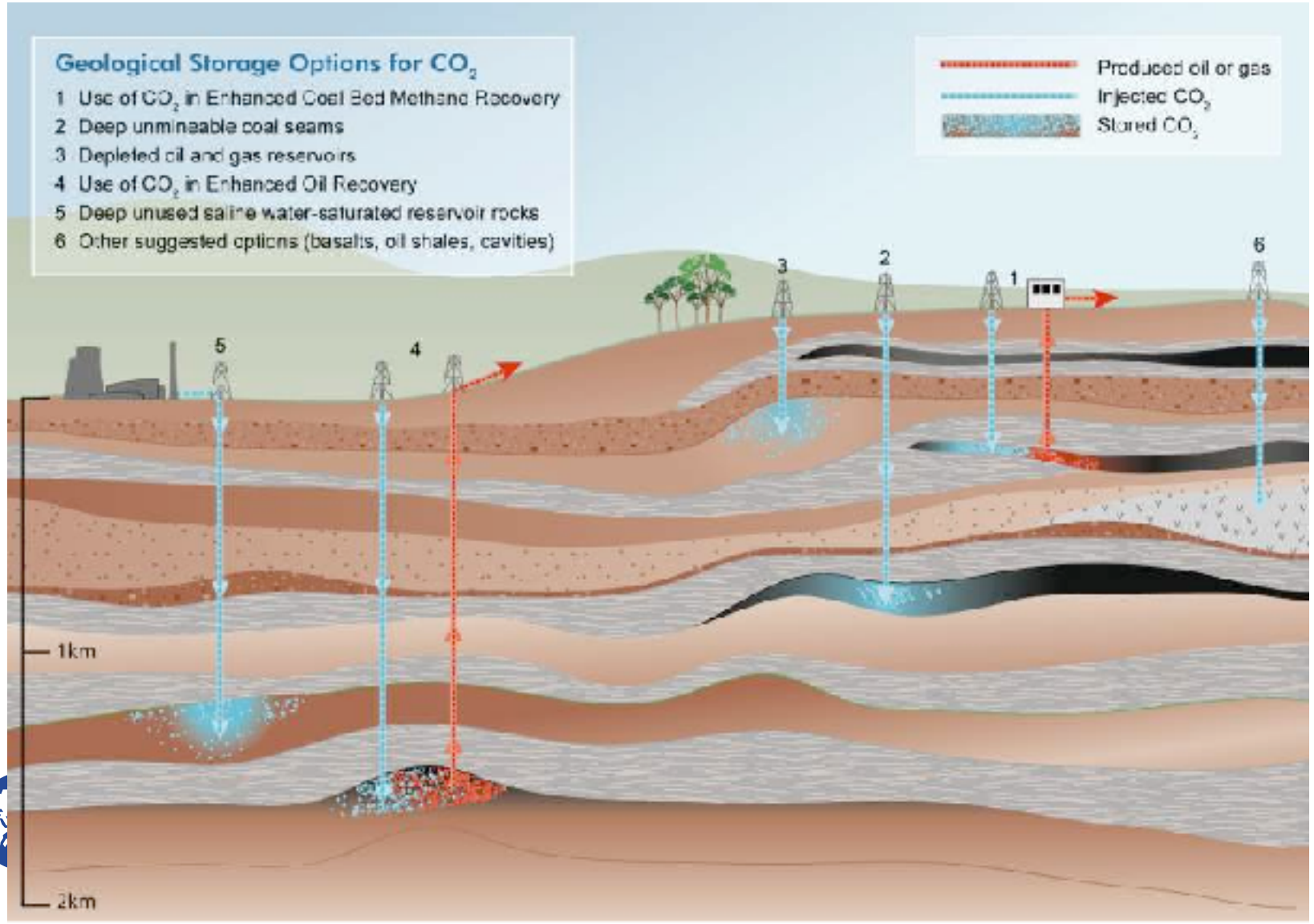
Geologic Formations



Need to define:
-Regional supply chain
-Business model
-Long-term liability

Digital Transformation

Digital Transformation

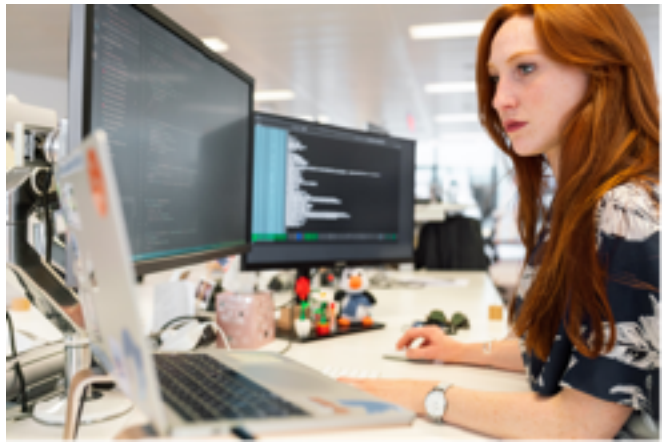
- Combination of
  - Cloud computing (access to broad range of data)
  - Data science and engineering to manage data
  - Analytics, machine learning, artificial intelligence
  - New data-centric business models
- Move from digitalization of existing business processes to digital transformation of enterprises through creation of new data-enabled business processes and business models

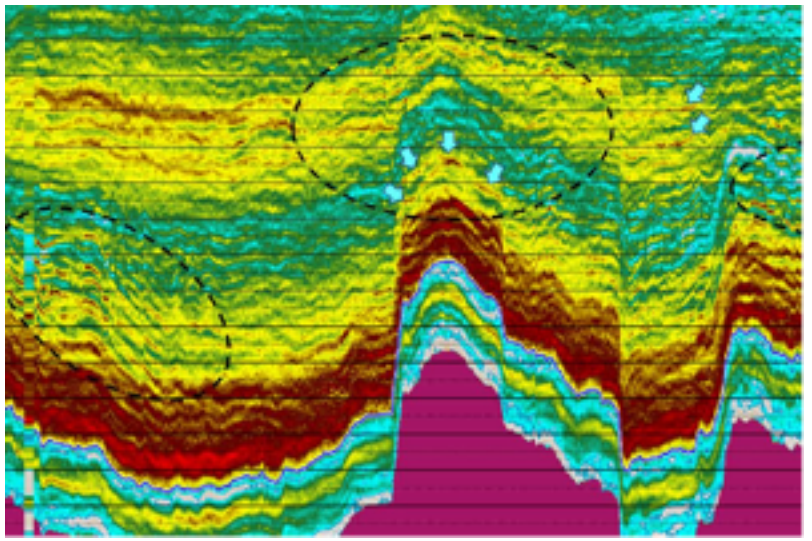
Digital Transformation in Oil and Gas

- Oil and Gas Industry has often been at the forefront of applying digital technologies
  - Since c. 2000, the “Digital Oil Field”
- Focus of Digital Oil Field was on using digital technologies to improve efficiency of operations
  - In many upstream settings, e.g. offshore brownfield, data is scarce and expensive
- Logistics and back office processes are analogous to other industries managing global supply chains
- Manufacturing: refining, petrochemicals, large upstream processing operations, e.g. for bitumen mining

Potential for Disruption?

- Many high-value upstream processes rely on large quantities of geoscience data, combined with extensive domain knowledge, often in the minds of specialists
- Workflows are complex, time-consuming, and go back and forth between IT and human-centric processes
  - Exploration
  - Development planning
  - Reservoir management and simulation
- Opportunities for radical, digital transformation driven changes in
  - Knowledge management
  - Seismic to simulation workflows





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Net-zero Operations in Oil and Gas

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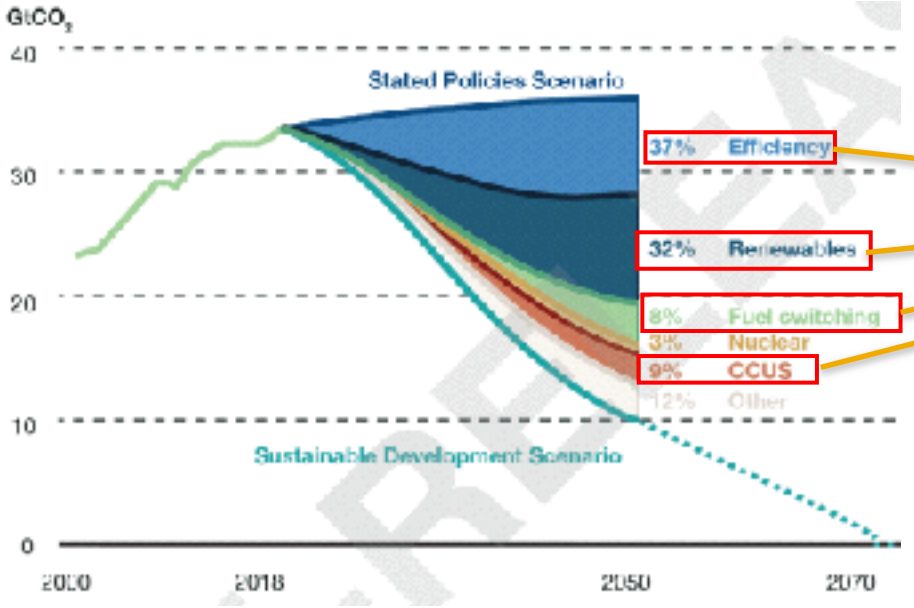
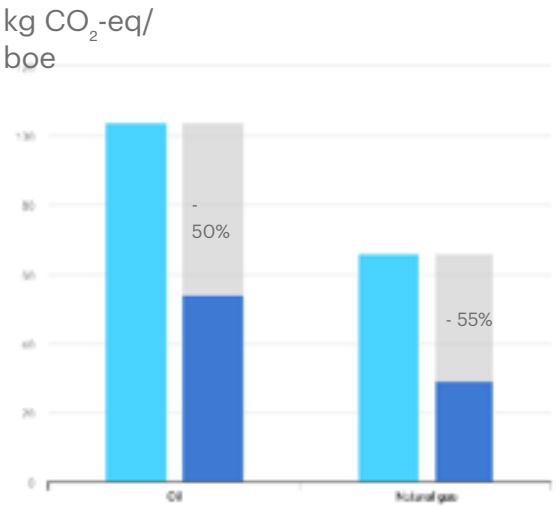
Bending of the Emissions Curve has Begun, but a Large Ambition Gap Remains



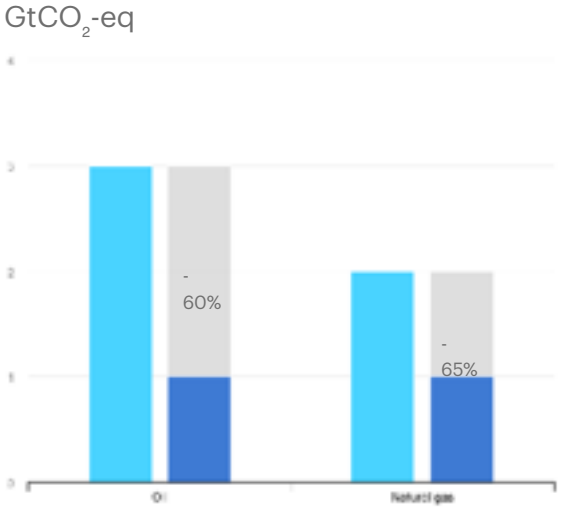
1. **Reduce Scope 1 & 2 emissions**
2. **Scale up large renewable energy projects**
3. **Low carbon H_2 / biofuels / synfuels / EVs**
4. **CCUS hubs**

IEA NZE Scenario through 2030 calls for:

- **Drop in emissions intensity >50%**
- **Reduction in oil and gas consumption**
- **>60% total reduction in O&G operational emissions**



Emissions intensities of oil and gas operations in the Net Zero Scenario, 2022-2030



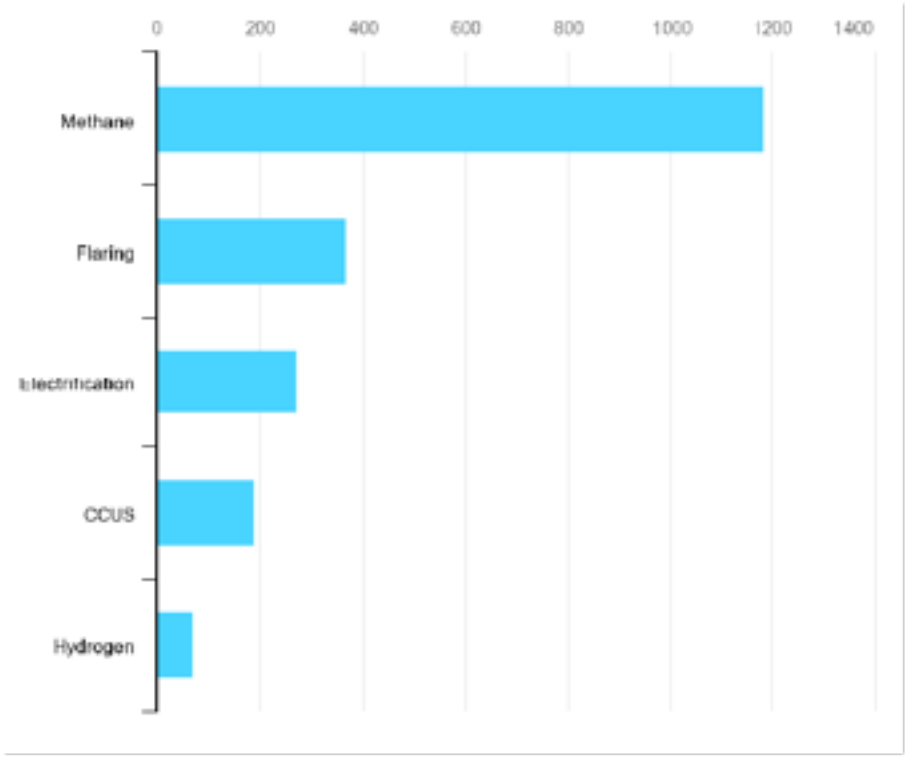
Total emissions of oil and gas operations in the Net Zero Scenario, 2022-2030

Levers for Scope 1 & 2 Emission Reductions

O&G industry operations are **~15%** of energy-related emissions or **5.1 billion tonnes of CO_2e** in 2021

Five key levers to meet the challenge:

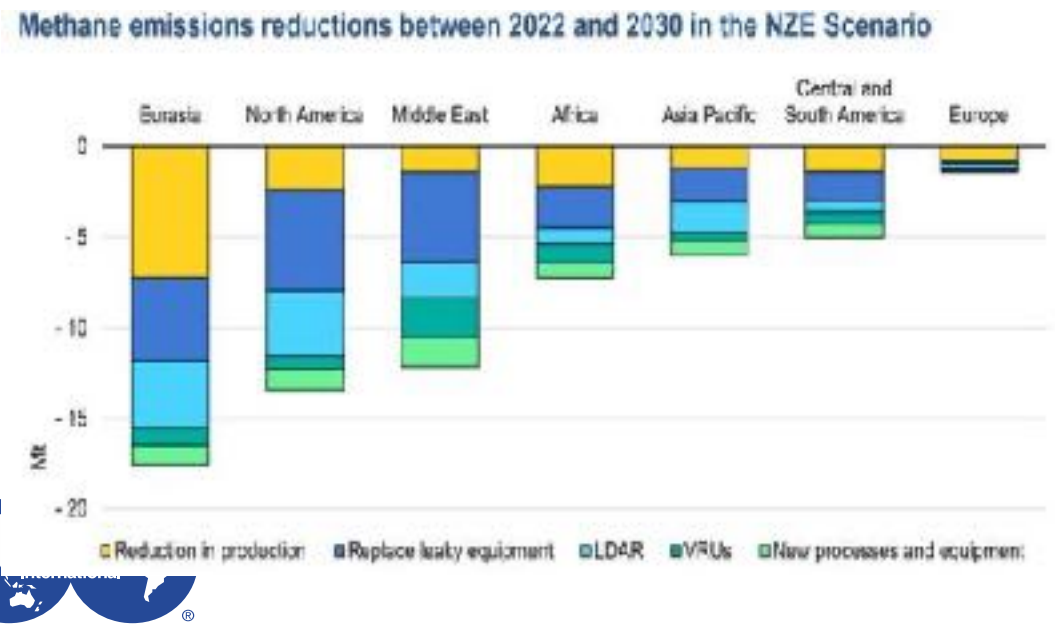
1. tackle methane emissions (~1.2 GT)
2. eliminate all non-emergency flaring (~0.4 GT)
3. electrify upstream facilities w/ renewable energy (~0.3GT)
4. equip oil and gas processes with carbon capture utilisation and storage (CCUS) (~0.2 GT)
5. expand the use of low-emissions electrolysis hydrogen in refineries (~0.1GT)

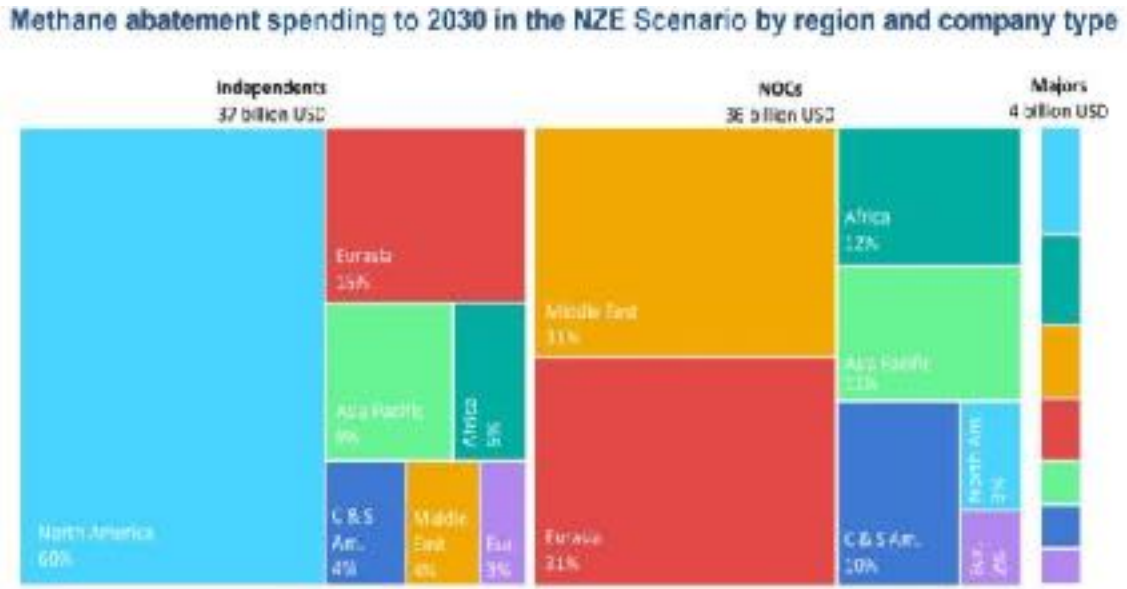


Source: *IEA*

Methane Offers the Greatest Near-term Potential

- Methane has a **global warming potential 84x greater than CO_2 for the first 20 years of release**
- Natural gas expected to meet growing demand for energy and reach 25% of power by 2050
- **Oil & Gas systems contribute 25% of global methane emissions**
- **Recovering income from lost methane means a 75% reduction by 2030 adds just $0.05/boe to production cost**



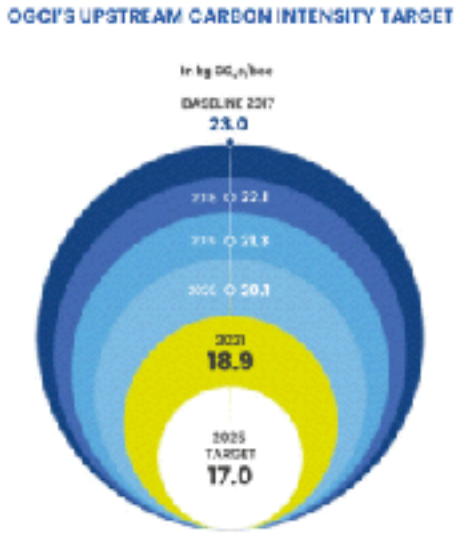


Source: *IEA methane tracker and IEA methane abatement*

Industry in Action

Industry-led efforts to tackle scope 1 & 2 emissions

Upstream Carbon Intensity



OGCI member companies aim to reduce average carbon intensity from 23 kg CO_2e/boe in 2017 to 17 kg by 2025.

Carbon intensity reached 18.9 kg in 2021, an improvement of 17% over the 2017 baseline.

Source: *OGCI*

Methane Emissions

AIMING FOR ZERO
Methane Emissions Initiative

The Aiming for Zero initiative treats methane emissions as seriously as safety.

IEA's 2022 Methane tracker: **357 MtCH4** was emitted in 2021, of which **80 MtCH4** came from the O&G sector. ➔ If the entire industry were to join the Initiative and reach near zero, it could eliminate around **23% of global human-caused methane emissions** (IEA, 2022).

Open to all players in the value chain: No cost, voluntary and self-engaging

Routine Flaring

GGFR
Global Gas Flaring Reduction Partnership

Launched in 2015, the World Bank's **Zero Routine Flaring** Initiative seeks to **end routine flaring no later than 2030**.

The Initiative aims for a system level approach through appropriate regulation, application of technologies, and financial arrangements

Education and Advocacy

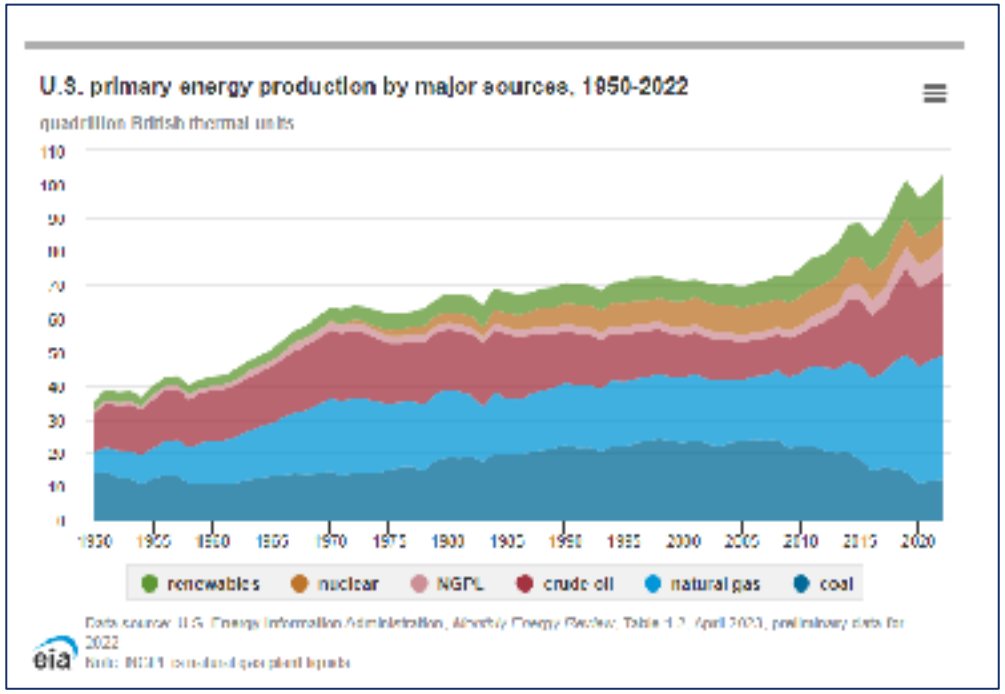
Education and Advocacy

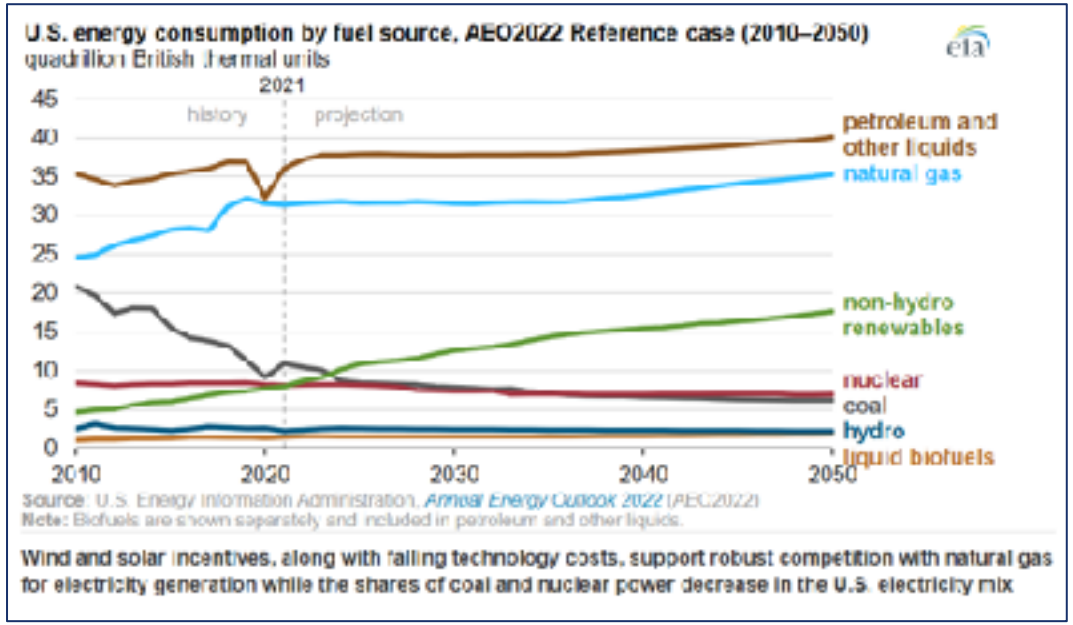
OIL MARKETS

Big Oil's Talent Crisis: High Salaries Are No Longer Enough

Energy companies scramble to attract engineers as young workers fret over climate and job security

Starved of new talent: Young people are steering clear of oil jobs

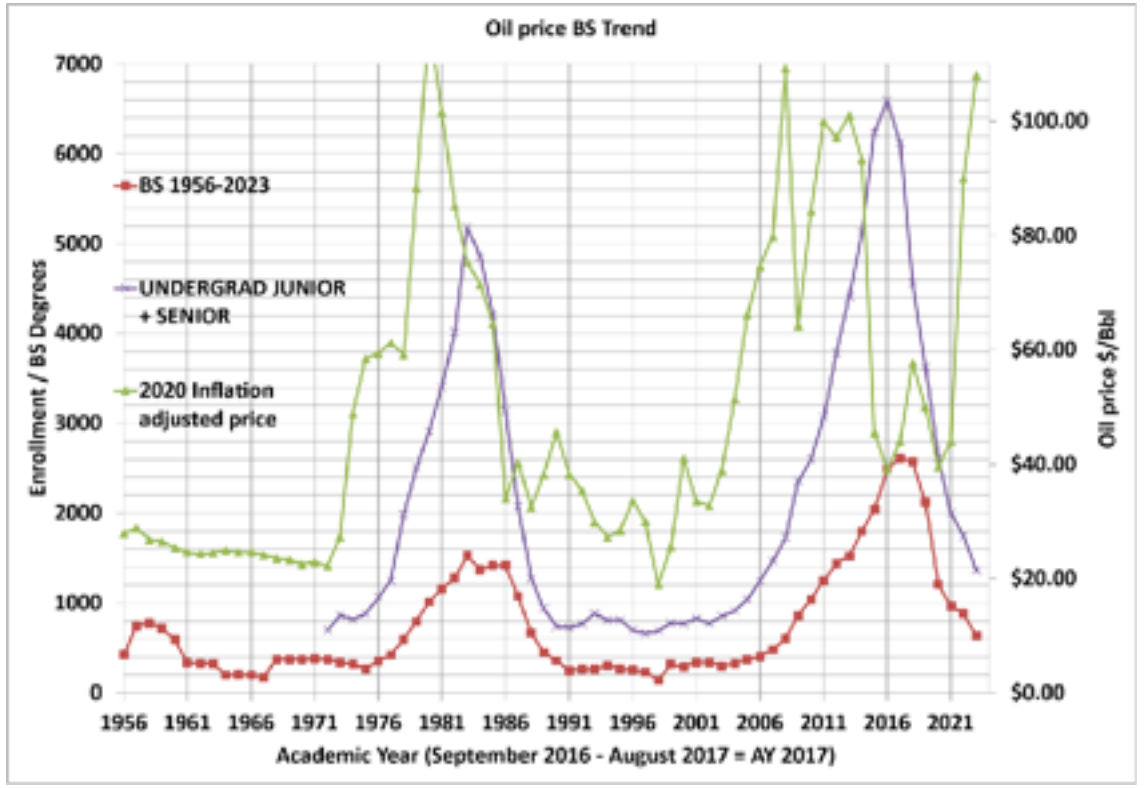




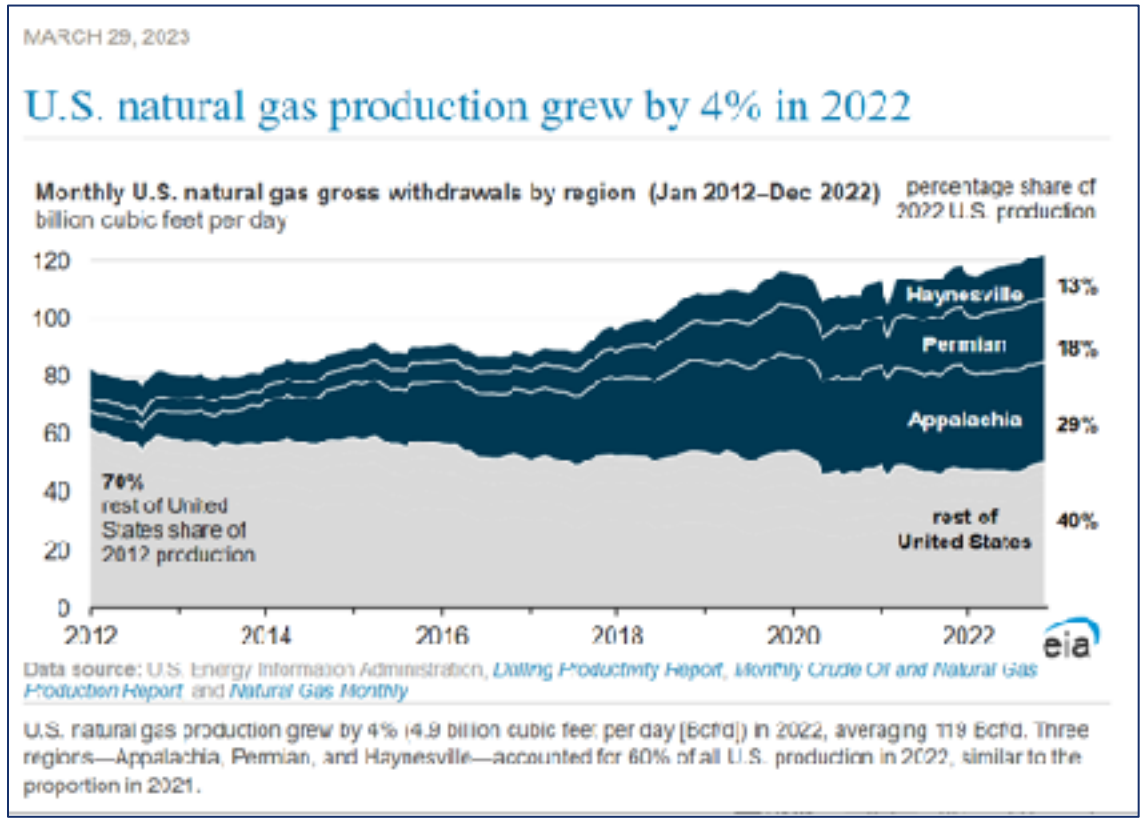
Wind and solar incentives, along with falling technology costs, support robust competition with natural gas for electricity generation while the shares of coal and nuclear power decrease in the U.S. electricity mix

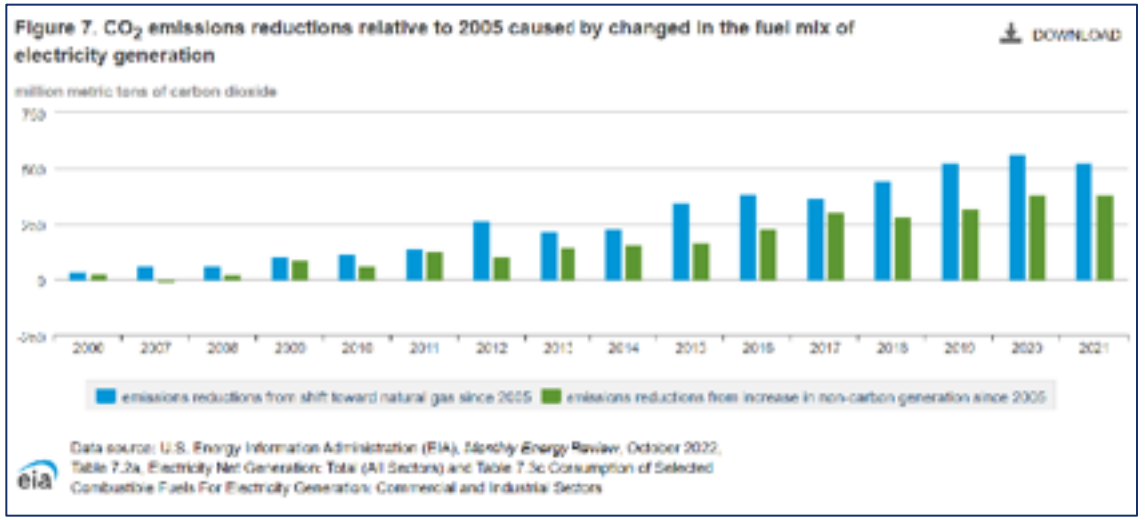
We Need Graduates

- Student enrollment typically follows increase in oil price
- Recent data suggest enrollment will trend upward but at a reduced rate
- Petroleum Engineering degrees critical for more than oil field
- Energy Industry needs to communicate value of degree



We Need to Tell Our Story





Summary and Conclusions

Summary

- Situation is very different from even a decade ago— sustainability and climate concerns have moved from periphery to center of our industry
- Only two out of the five challenges directly address traditional cost and recovery challenges of our industry
  - Improved recovery from tight / shale resources
  - Digital transformation
- One challenge requires rethinking and addressing our emissions throughout the life cycle of our operations
  - Net-zero emissions from oil and gas operations
- Two challenges propel the upstream oil and gas industry towards fundamentally new businesses
  - Geothermal Energy
  - Carbon Capture, Utilization, and Storage
- A great debate is underway over the future of industrial society. Our voices are needed to help global society to make the right choices to preserve prosperity (still unequally shared among nations) and our natural environmental endowment. This will require us to develop fundamentally new skills, without which much of our work in addressing the first five challenges will be frustrated
  - Education and advocacy

New “5+1” Grand Challenges

	Application	Challenges	Impact on Energy Transition	Technology Maturity	Scalability	Synergy With Existing Oil and Gas Skill Sets
Improved Recovery from Tight/Shale Resources	Tight and shale oil reservoirs	Cost-effective strategies with minimal environmental footprint	Low	Low	Medium	High
Net-Zero Operations	Operated assets in production, transportation, and processing	Scale and scope to achieve the goal; GHG detection and mitigation	High	Medium	High	High
Carbon Capture, Utilization, and Storage	Emissions that cannot be mitigated by other means	Cost of capture; assuring integrity of storage	High	Medium	High	High
Geothermal Energy	Baseload electricity	High capital costs; technology for drilling at high temperatures	High	Low (Enhanced Geothermal Systems)	Medium	Medium
Digital Transformation	All upstream and downstream processes	Combination of business and technology to maximize value	Medium	Medium	High	Medium

Table 2—Challenges, social and industry impact, and skills synergy of the five new technical grand challenges.

“+1” Challenge - Education and Advocacy

T. Halsey, G. Agrawal, J. Bailey, M. Balhoff, S. Borglum, K. Mohanty, M. Traver, J. Petro. Tech. 2023

Thanks to Matthew Balhoff and Michael Traver for assistance preparing this talk

Questions?