Ron Harrell, P.E.

Chairman Emeritus Ryder Scott Company

Mr. Harrell is a Petroleum Engineering graduate of Louisiana Tech University and continues as Chairman Emeritus of Ryder Scott Company. Ron remains active in the industry as a licensed engineer in three states and serves on several Management and Advisory Boards including corporations, not-for-profit organizations and three universities. He is a Senior Advisor to RSK (UK) LTD, Board Member of eCORP International plus holds energy advisory positions for The Carlyle Group and Morgan Stanley private equity energy divisions. He is a founding member and past Chairman of the UH Petroleum Engineering Advisory Board and an active member of the UH Subsea Engineering Program since its formation.

Mr. Harrell is also a founding member and Vice Chairman of the College of Engineering Advisory Board for Houston Baptist University. He served as an SPE Distinguished Lecturer in 2007-2008. He remains a member of SPE's Distinguished Lecturers Selection Committee and is a peer reviewer for SPE M&I technical papers. Further, he serves as SPEE's Observer on the SPE Oil & Gas Reserves Committee (OGRC).

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Panel Discussion

Potential Effects of ESG Requirements on "SPE's Reserves Estimating and Auditing Standards"

Moderated by Ron Harrell

OUR PANELISTS

Money:

Calvin White
Executive Director
Morgan Stanley

Industry:

John Hessenbruch
Associate
David Hoffman & Associates

Research:

Christine Ehlig-Economides
Professor & Hugh Roy and Lilly Cullen Distinguished University Chair
University of Houston – Petroleum Engineering Program

Moderator:

Ron Harrell
Chairman Emeritus
Ryder Scott Company

Panel Discussion

The Costs to Capture Carbon

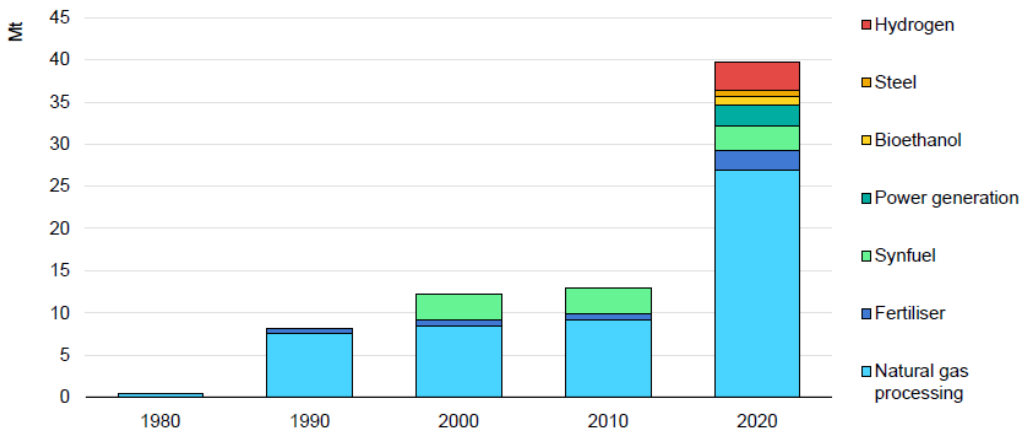
By Calvin White, Morgan Stanley Energy Partners

Introduction to CCUS

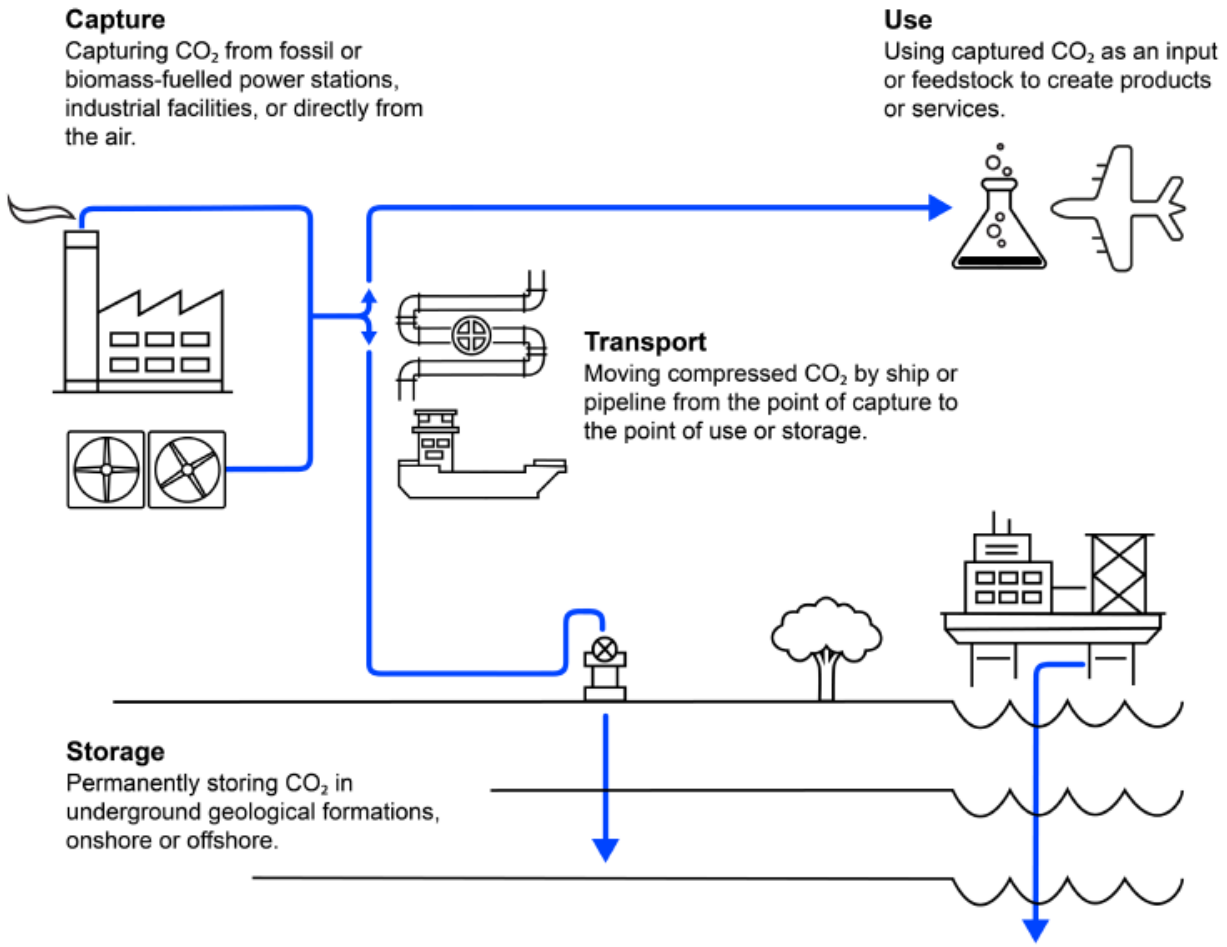
Summary Overview

- Carbon capture use and storage (CCUS) refers to a category of processes whereby CO2 is captured from industrial facilities or directly from the atmosphere, transported, and either used in industrial processes or permanently stored underground in geological formations
- Technology has been in commercial operation since early 1970s; 21 operational CCUS facilities globally as of 2020 have the capacity to capture up to 40 million tons of CO2 per year [1]
- CCUS is considered by both the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) to be critical to reach net-zero emissions targets
- Energy industry uniquely qualified to lead CCUS development due to relevant expertise, capability and resources

Global CO2 Capture Capacity by Source [1]



CCUS Schematic [1]

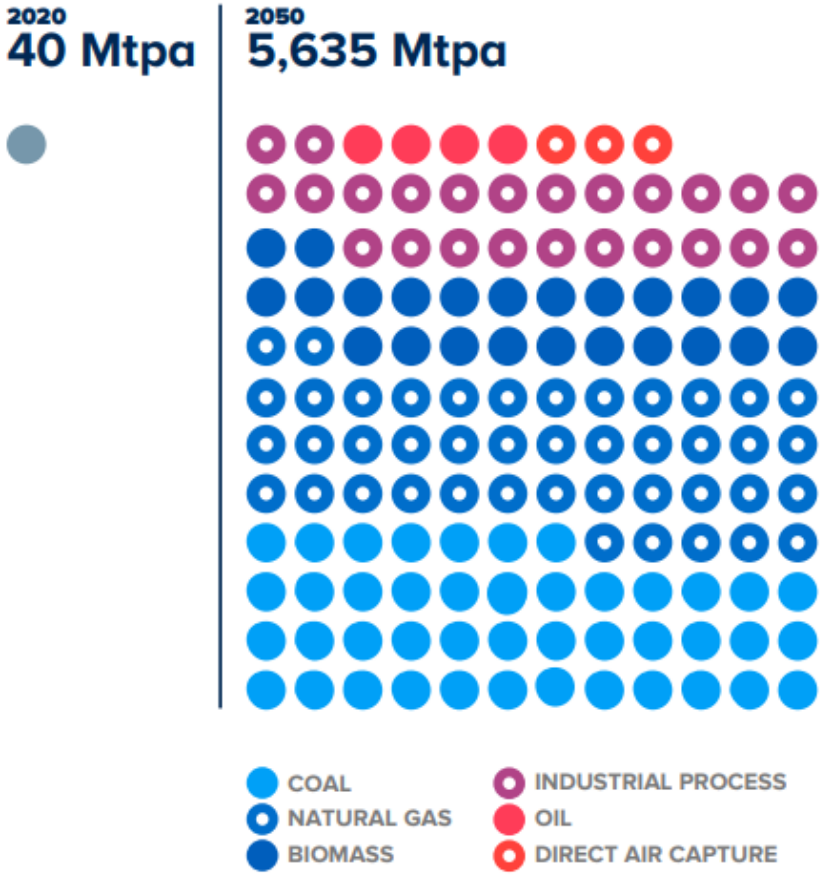


Notes:

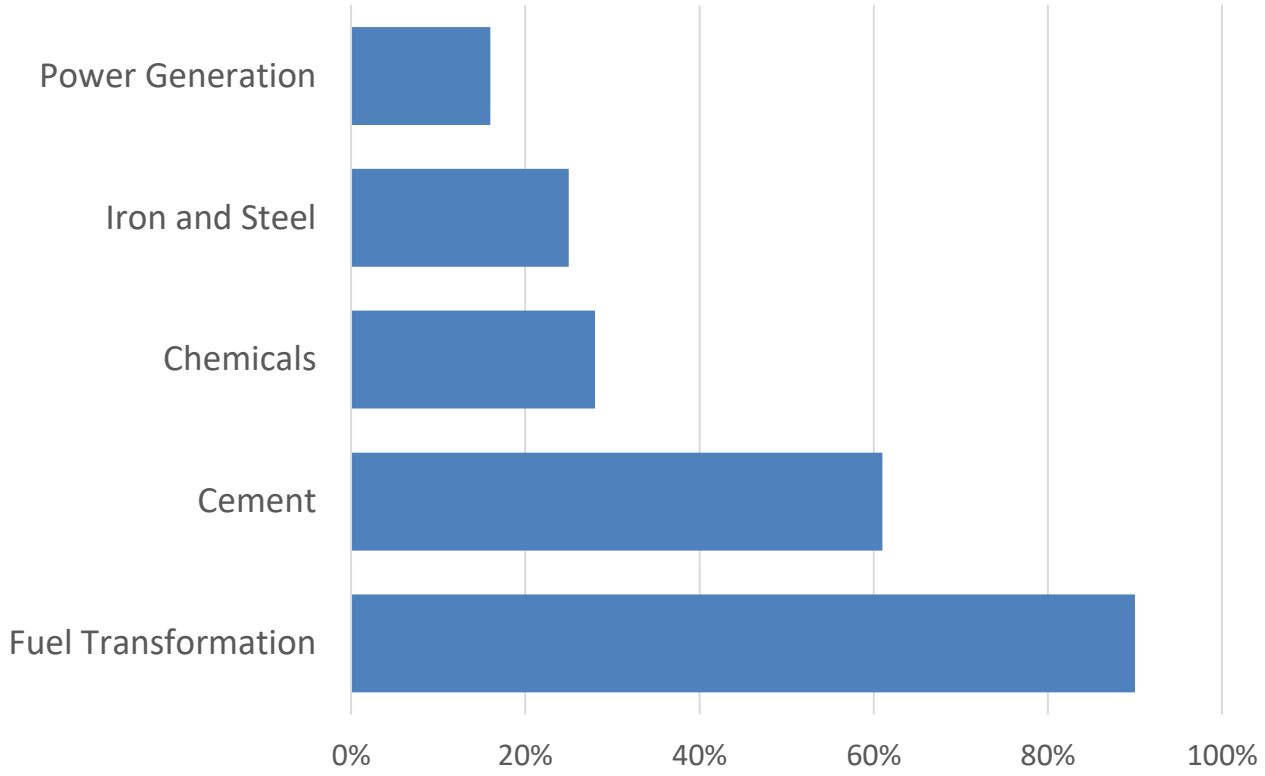
1. Source: IEA Energy Technology Perspectives 2020; Special Report on Carbon Capture Utilization and Storage

CCUS is Critical to Reaching Global Decarbonization Targets

CO2 Capture Capacity: 2020 vs 2050 by Fuel/Sector [1]



CCUS Contribution to Sector CO2 Emissions Reductions by 2070 [1]



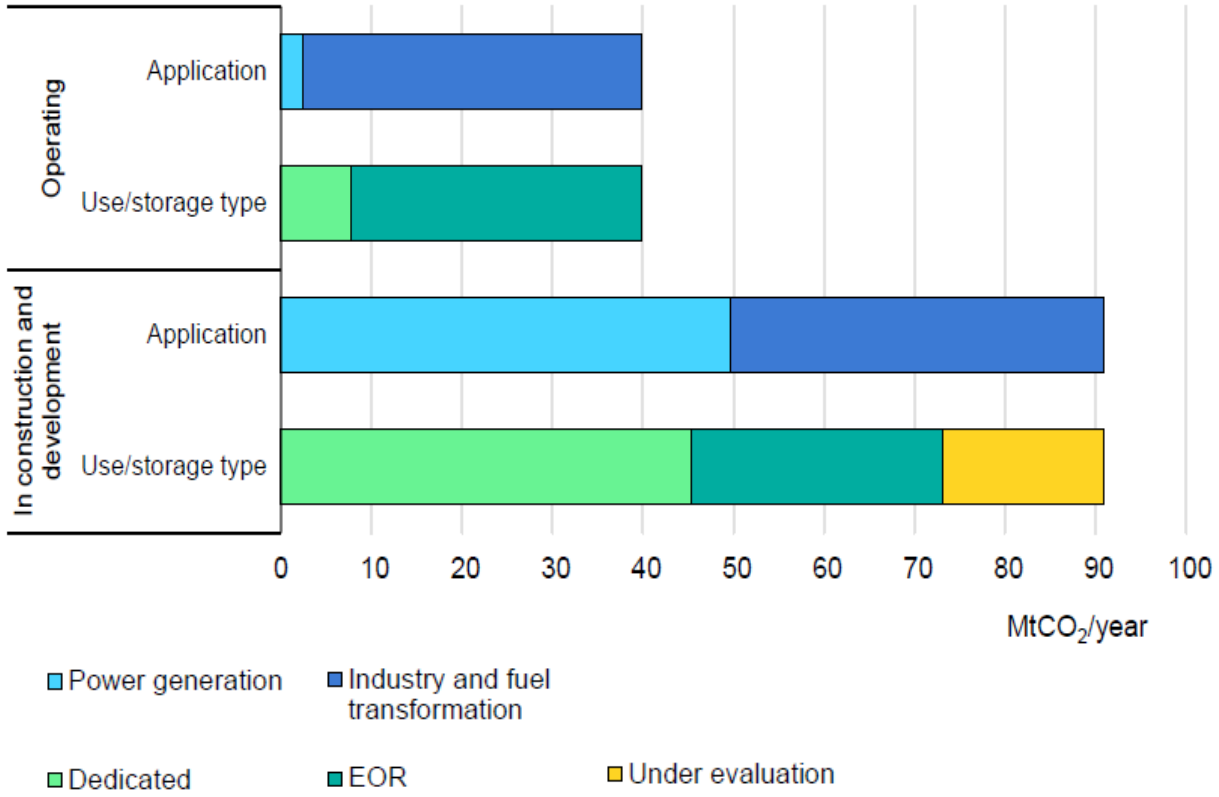
Notes:

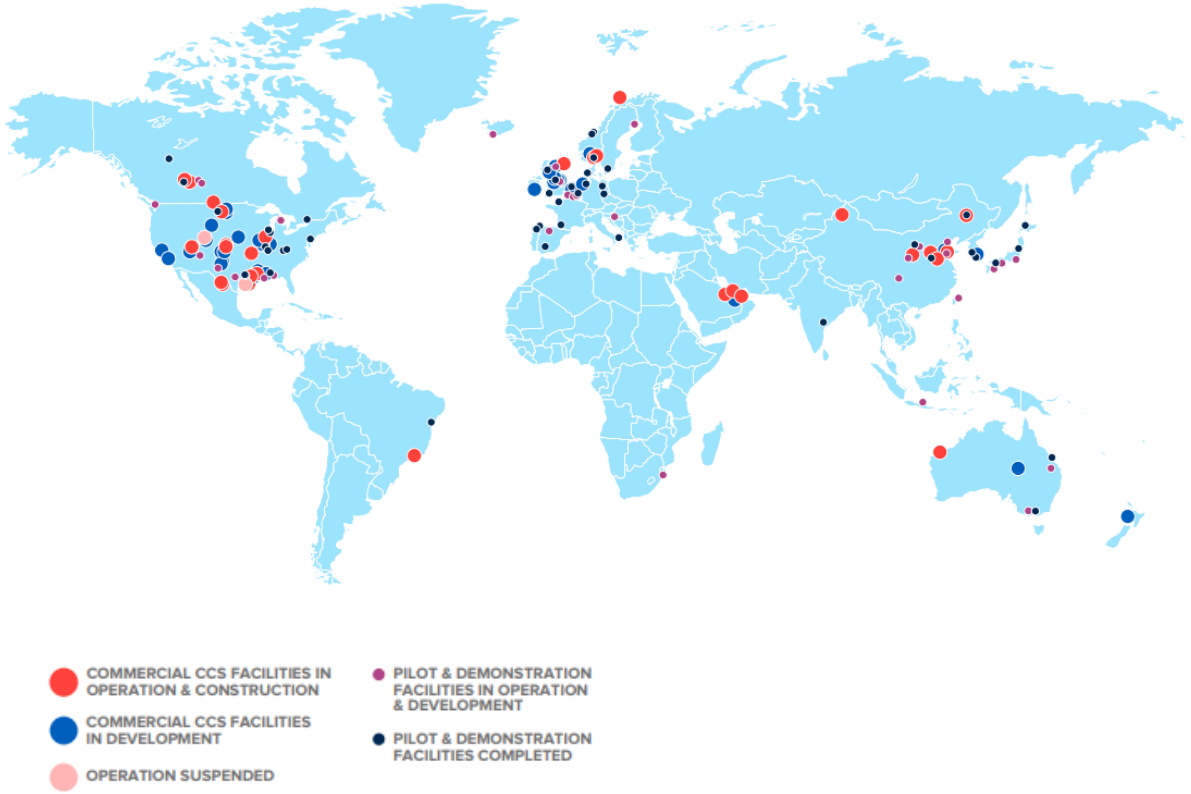
1. Source: Global CCS Institute: Global Status of CCS 2020 report (IEA Sustainable Development Scenario)

ALL FORECASTS ARE SUBJECT TO CHANGE AT ANY TIME AND MAY NOT COME TO PASS DUE TO CHANGES IN MARKET OR ECONOMIC CONDITIONS.

Global CCUS Development Pipeline

Projects Under Development Exceed Capture Capacity of 90 Mtpa[1]





Notes:

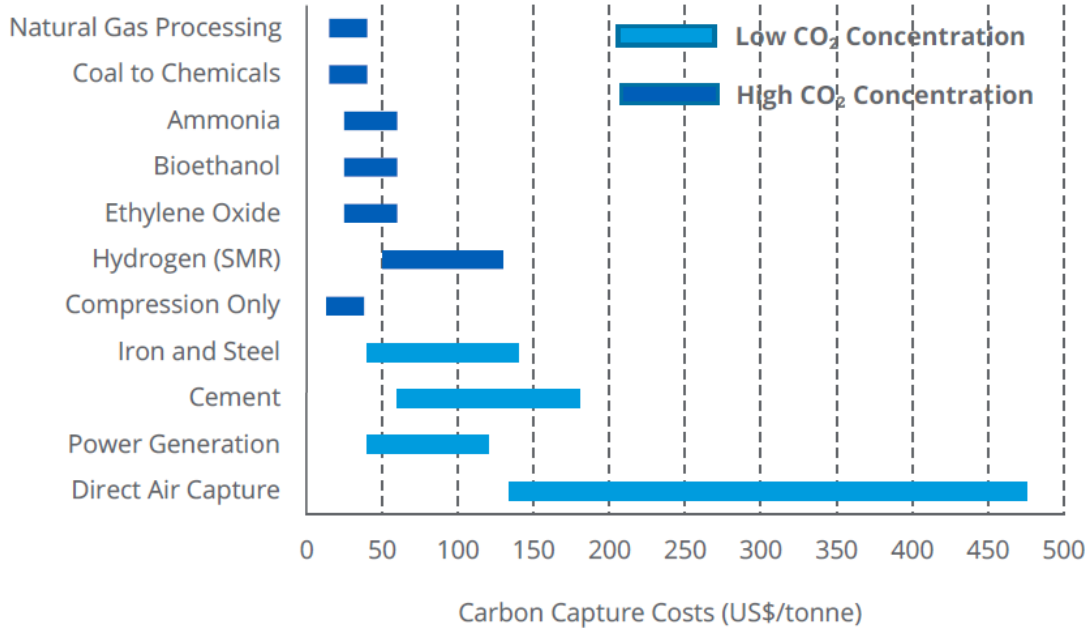
1. Source: IEA Energy Technology Perspectives 2020; Special Report on Carbon Capture Utilization and Storage and Global CCS Institute: Global Status of CCS 2020 report

ALL FORECASTS ARE SUBJECT TO CHANGE AT ANY TIME AND MAY NOT COME TO PASS DUE TO CHANGES IN MARKET OR ECONOMIC CONDITIONS.

Carbon Capture Costs and Incentives Globally

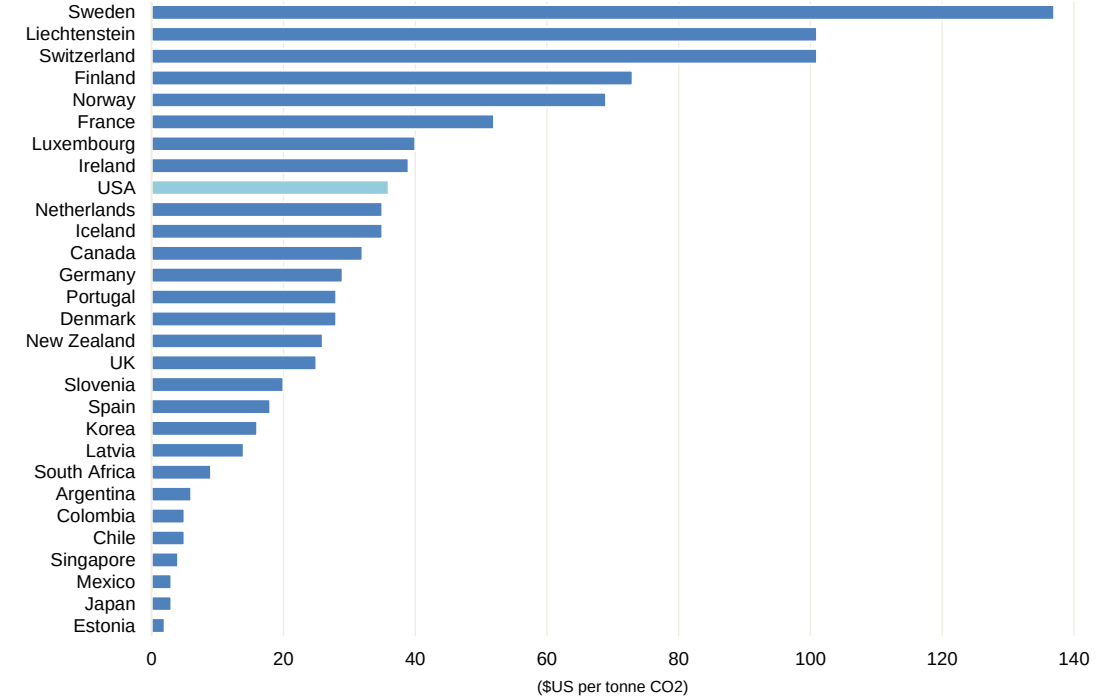
Global CCUS Incentives are Growing in Scope and Value

Levelized Cost of CO2 Capture by Sector and Initial CO2 Concentration (2019) [1]



Source: IEA, ATB Capital Markets

Carbon Price/Credits by Country (2021)



Source: The World Bank State and Trends of Carbon Pricing 2021

Notes:

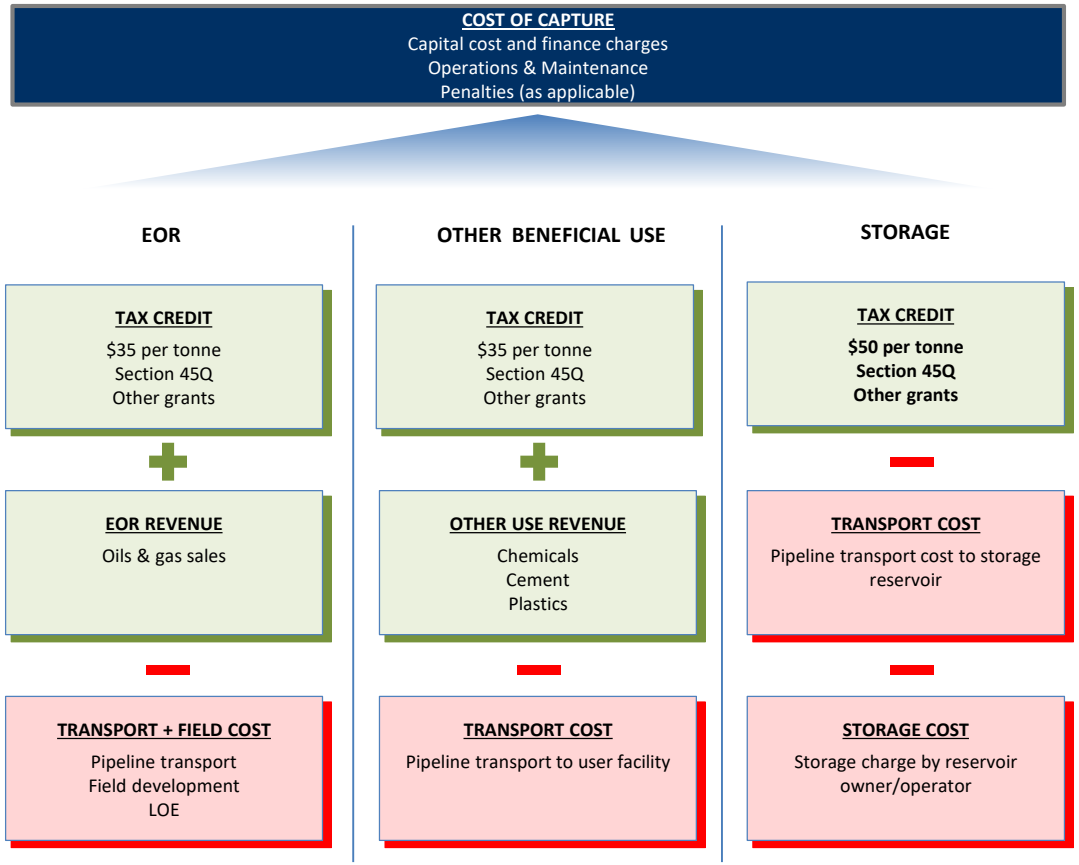
1. CO2 capture costs of hydrogen refers to the production via SMR of natural gas; the broad cost range reflects varying levels of CO2 concentration: the lower end of the cost range applies to CO2 capture from the concentrated "process" stream, while the higher end applies to CO2 capture from the more diluted stream coming out of the SMR furnace. All capture costs include the cost of compression. They do not include revenues from EOR or utilization.

Carbon Capture Opportunities

Project Economic Considerations

- **Large Scale**
  - Large volume emission stream, ideally with multiple emitter source options (hub and spoke)
- **Stable Emission Streams**
  - Long-life assets with predictable and consistent supply sources
- **Desirable Emission Quality**
  - High purity CO2 with low level of sulfur/particulates
- **Beneficial Use Case**
  - CO2 EOR or other beneficial use such as fuel feedstock, chemicals, concrete, plastics
  - Brownfield development required for most EOR
  - Opportunities for continued area use expansion
  - Vertical integration
- **Proximate to Use/Storage Location**
  - Close proximity between emitter(s) and use/storage site minimizes midstream costs
  - Tie-in to existing infrastructure networks
  - Areas with large "natural sinks" for storage (e.g. Gulf Coast)
- **Favorable Regulatory / Tax Environment**
  - Geographies with favorable, long-term carbon incentives (i.e. credits/grants) and/or penalties (i.e. tax)

High Level Framework[1]



Notes:

1. Adapted from NPC Study Meeting the Dual Challenge: A Roadmap to At-Scale Development of Carbon Capture, Use and Storage (Topic Paper #1). December 12, 2019.

John Hessenbruch

Geological Consultant

Retired-Occidental Petroleum

John has over 35 years of domestic and international experience in managing E&P programs for Fortune 500 energy firms (Oxy, BP and Shell) and private, high-growth companies. He has directed successful geoscience programs in the Permian Basin, Rockies, Mid-Continent, Appalachians, Gulf Coast (Onshore/Offshore), California (Onshore/Offshore) and Alaska.

John is currently associated with David Hoffman & Associates (DHA), a consulting firm which assists independent operators with cost effective strategies to comply with current and future CCUS guidelines. John has considerable experience working with industry leaders such as Oxy, British Petroleum, and Shell Oil.

Mr. Hessenbruch is an active member of the AAPG, HGS and RMAG.

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Panel Discussion

Carbon Capture, Utilization and Storage (CCUS) Applications for the Energy Industry

By John Hessenbruch, David Hoffman & Associates

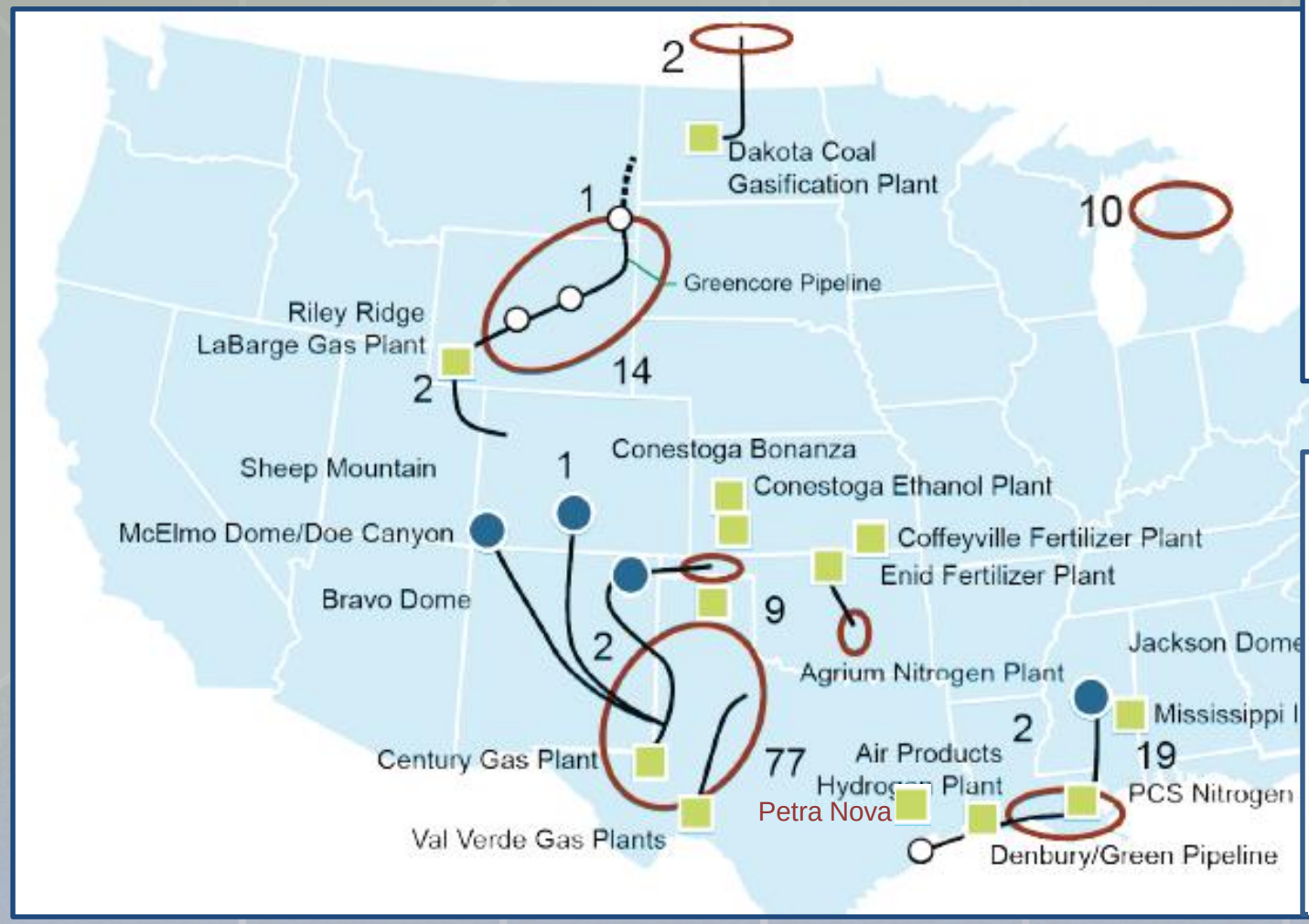
CARBON SEQUESTRATION IS A KEY COMPONENT FOR CLEAN ENERGY TRANSITION

“Reaching net zero will be virtually impossible without CCUS” *

- Major driver for current CCUS implementation is EOR development using CO2.
- Future investment will include EOR applications and permanent saline storage.

* The International Energy Agency (IEA) *Energy Technology Perspectives 2020*
(Special Report on Carbon Capture, Utilization and Storage in Clean Energy Transitions)

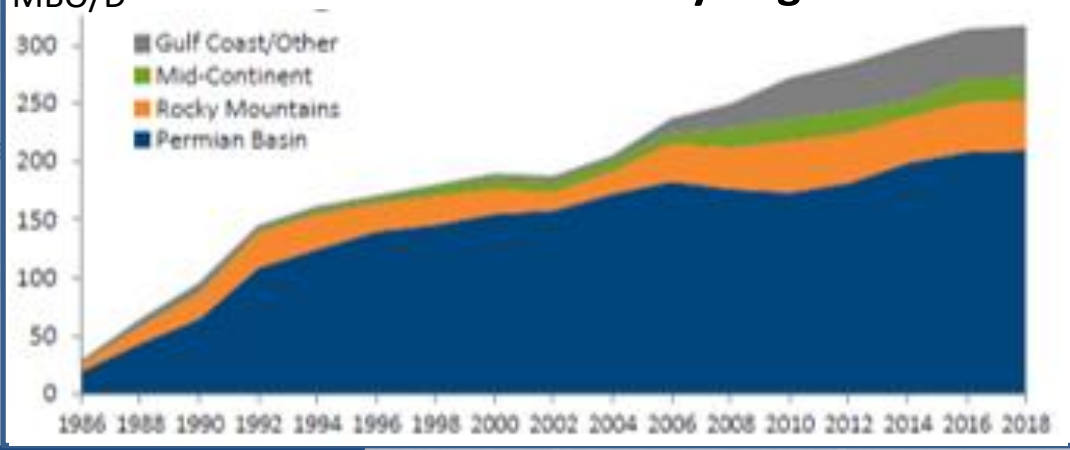
DOMESTIC CO2 INFRASTRUCTURE FOR EOR DEVELOPMENT



142 Domestic CO2 EOR Projects: 300 MBOD

- Industrial CO2 Sources: 13 (1 BCFD)
- Natural CO2 Sources: 4 (2 BCFD)
- CO2 Pipeline: ~5000 Miles
- CO2 Pipeline (Proposed)
- EOR Development: 4 Major Regions

EOR Oil Production by Region



Advanced Resources Int, 2021 Denbury, 2020; WY EOR Deployment, 2017

GEOSCIENTIST ROLE IN EOR EVALUATIONS FOR CCUS APPLICATIONS

1. **In each basin where company is conducting operations, evaluate key analog EOR fields with respect to reservoir characterization and proximity to CO2 pipelines.**

2. **In legacy fields undergoing secondary floods, determine which of these fields could be considered for future CO2 floods and analyze the following reservoir parameters:**
   - Lithology, thickness, overlying seal, fracture network, areal extent, induced seismicity
   - Characterization - Por, perm, Soi, Swi, Sgi
   - Pressure/temp history of reservoir under primary/secondary production
     - Evaluate potential WAG (Water/Gas) process to maintain pressure
     - Determine miscibility (super critical state: 88F, 1070 psi)
   - Compute OOIP & remaining recoverable reserve potential via tertiary prod

3. **Evaluate wellbore integrity issues for converting old producers into CO2 injectors.**

4. **Generate an economic analysis to determine the additional cost of installing a gas processing plant, amine unit, dehydration system, and compressor stations.**

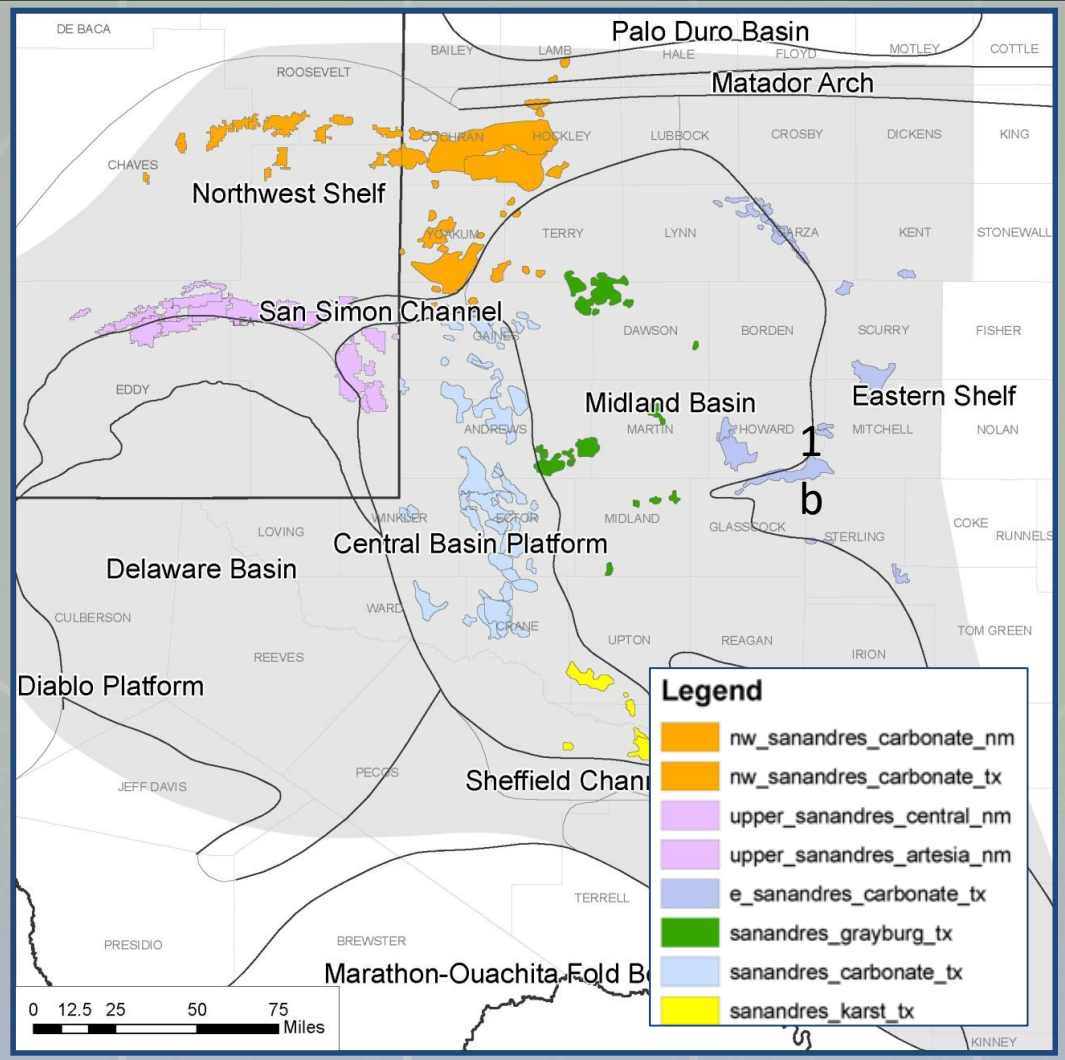
5. **File a CCUS application and MRV (Monitor, Recording & Verification) Plan.**

SAN ANDRES: STRATEGIC RESERVOIR IN PERMIAN BASIN FOR CO2 EOR DEVELOPMENT

Stratigraphic Column

Permian	Queen
	Grayburg
	San Andres
	Glorieta
	U. Clearfork
	Tubb
	L. Clearfork
	Wichita
	Wolfcamp
Penn	Cisco
	Canyon
	Strawn
	Atoka
Miss	Barnett
Devonian	Woodford
	Devonian (31)
Silurian	Wristen
Ordovician	Ellenburger

C. Kerans, Bureau of Economic Geology, 2006



- **Number of Fields/Units: >20**
- **Field History**
  - Discovery: 1930-40s
  - Waterflood: 1960's
  - CO2 flood: 1980-2000's
- **Trap: Combination (Structural & Strat)**
- **Strategic Reservoir Parameters**
  - Lithology: limestone, dol (Carb ramp)
  - Average Depth: 4,500-7,500'
  - Average Porosity: 7-12%
  - Average Permeability: 2-8 mD
  - Average Temperature: 98-120F
  - Average Gravity: 28-34 API
  - Previous Production: Waterflood

Oil and Gas Journal, 2014

2021 CONFERENCES & SYMPOSIUMS ON CCUS AND ESG

1. **SPE Annual Technical Conference and Exhibition (Sept 21-23) -** Technical sessions on Environment & Sustainability
   - Virtual/On-Site Event (Dubai, UAE) - https://www.atce.org

2. **AAPG/SEG Annual Meeting (Sept 26-Oct 1)** – Multiple sessions & workshops on CCUS and EOR Development
   - Virtual/On-Site Event (Denver, CO) - https://imageevent.org/2021
   - Workshops and Short Courses - https://imageevent.org/2021/program/short-courses-workshops
     - From Exploration to Reservoir Characterization in Saline Aquifers or Depleted Oil and Gas Fields
     - How to Design and Implement a "Smart" Monitoring Plan
     - Principles of Energy Storage and Carbon Capture Storage and Utilization

3. **SPE Virtual Symposium (Sept 28-30):** CCUS Management – Achieving Net Zero Carbon and Sustainability Goals
   - Virtual Event - https//www.spe.org/events/en/2021/symposium/22sm03/ccus-achieving-net-zero-carbon.html

4. **2021 CO2 Conference (Dec 6-9**) – Multiple sessions on EOR Development from Residual Oil Zone (ROZ) Reservoirs
   - Virtual/On-Site Event (Midland, TX) - https://CO2conference.net

Numbers to *Count On*. Experts to *Trust*.

CARBON NEUTRAL FUELS FOR THE ENERGY TRANSITION

CHRISTINE EHLIG-ECONOMIDES

SEPTEMBER 16, 2021

CARBON NEUTRAL CRUDE OIL – CNCO

Solution Gas-Oil-Ratios for Large Fields and Plays

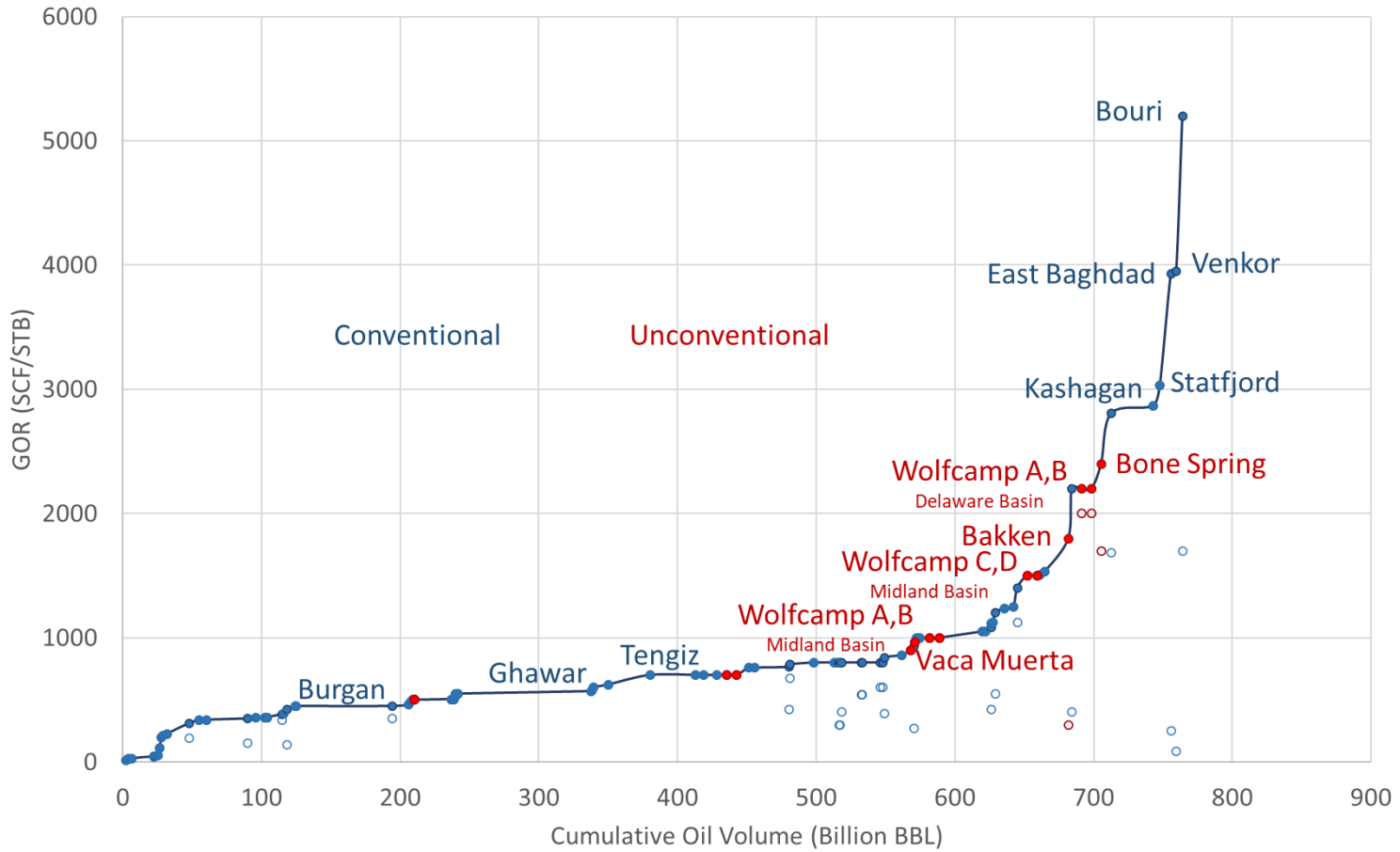
- Uses otherwise flared stranded associated gas
- Costs between \$100/tCO_2 and \$140/tCO_2
- Costs less than many of the point source captures reported by the NPC
- More expensive than nature-based negative emissions, but
  - Much smaller land footprint
  - More verifiable

Direct Air Capture (DAC) Unit

Keith et al. 2018

CARBON NEUTRAL CRUDE OIL – CNCO

Using Natural Gas-Powered Direct Air Capture (NG-DAC)



Tight oil has the advantage over big oil!

URTeC 5437

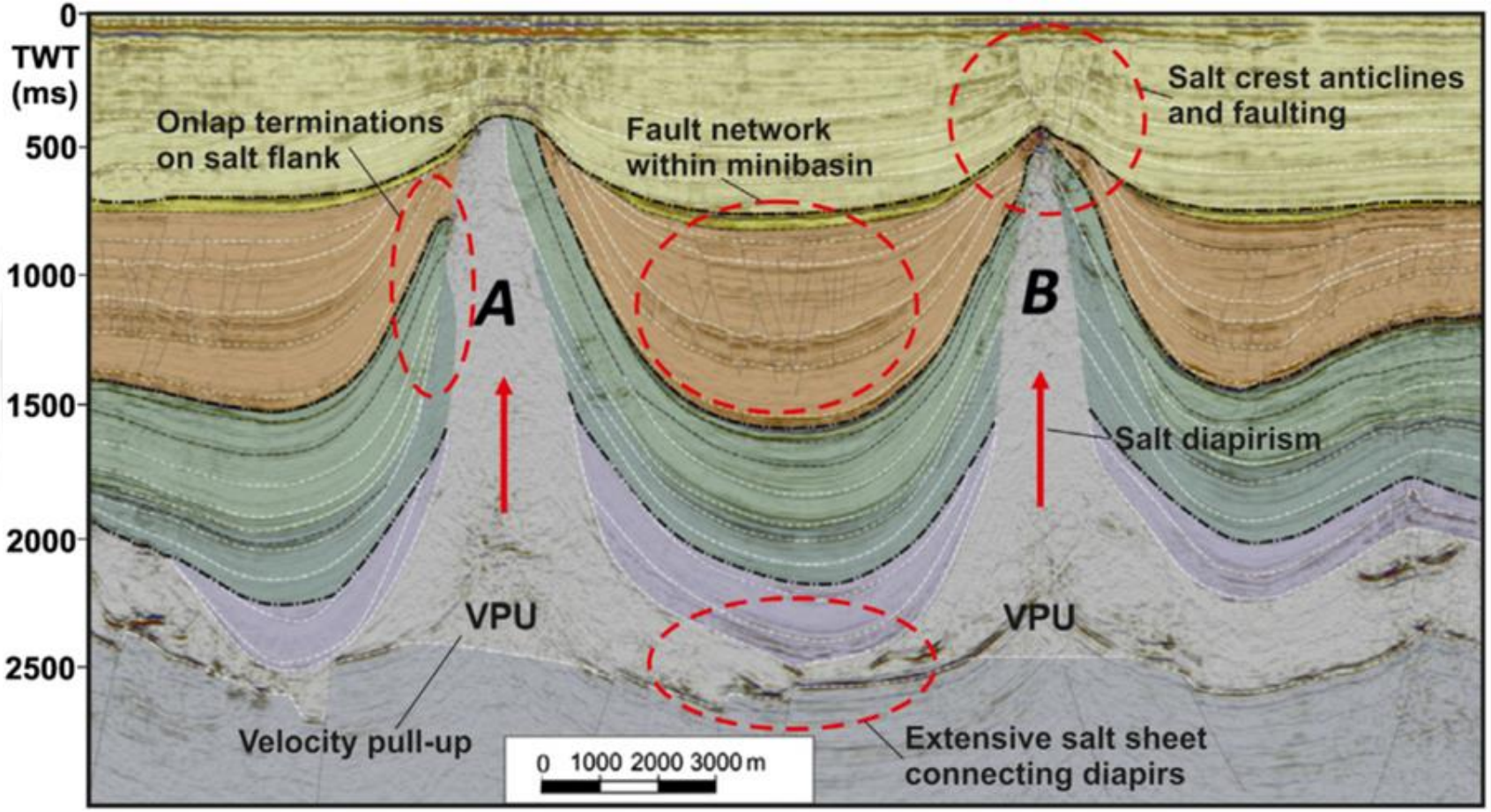
CARBON NEUTRAL CRUDE OIL – CNCO

Carbon Neutral Crude Oil is

NOW

CARBON NEUTRAL BLUE HYDROGEN

Methane Production and CO_2 and H_2 Storage



SPE 206282

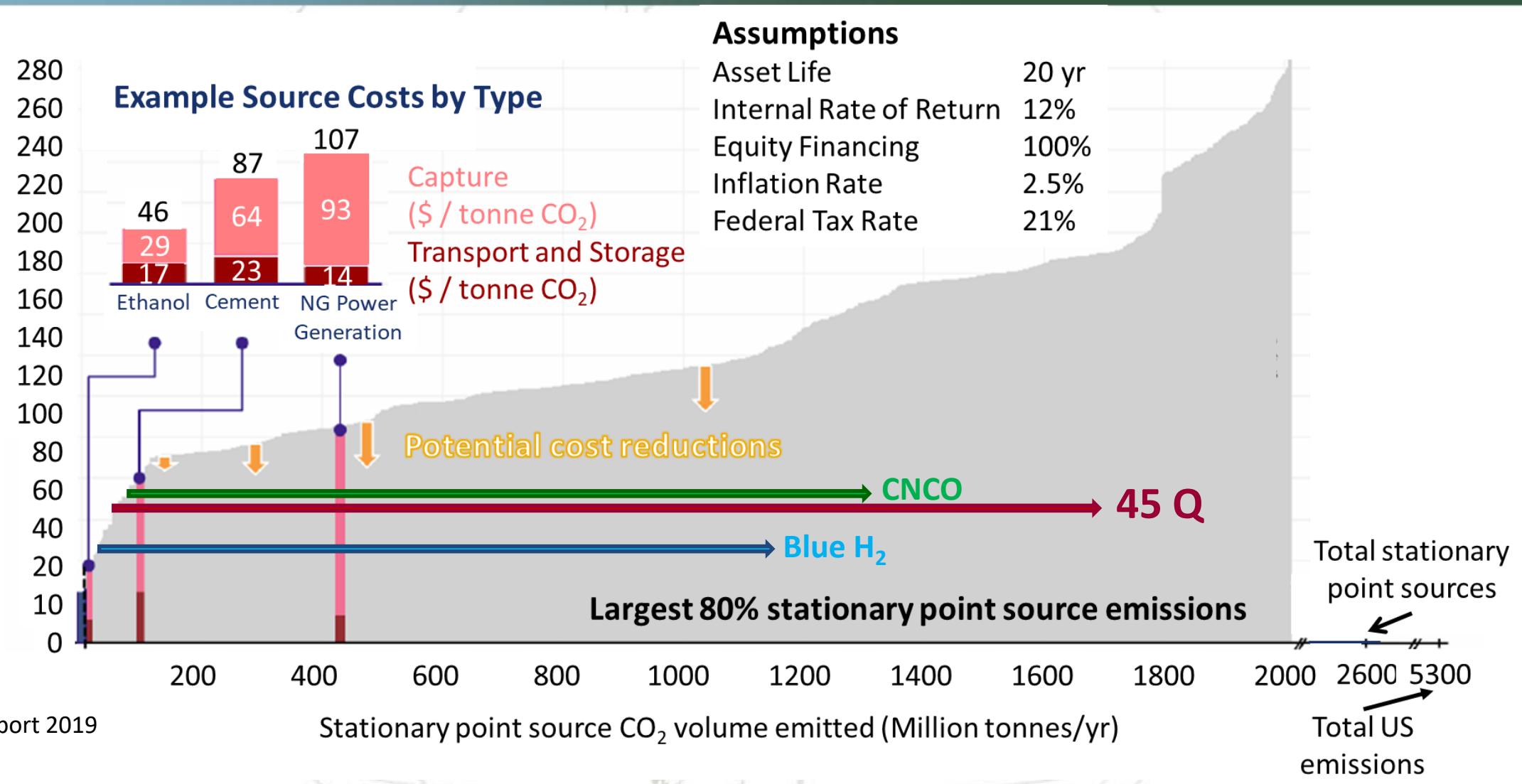
Cox et al. 2020

CARBON NEUTRAL BLUE HYDROGEN

Carbon Neutral Fuel – Blue H_2 is NOW

SPE 206282

U.S. CCUS COSTS BY POINT SOURCE IN $/TONNE CO_2



NPC Report 2019

Numbers to *Count On*. Experts to *Trust*.

UH AND THE ENERGY TRANSITION

PETROLEUM ENGINEERING RESEARCH

- CCUS (Thakur, Hatzignatiou, Ehlig-Economides)
- Injection Engineering (Wong, Myers, Hathon)
- Carbon Neutral Fuels (Ehlig-Economides, Hatzignatiou)
- Enhanced Geothermal Systems (Ehlig-Economides, Nikolaou, Sakhaee Pour)

NEW COURSES

- CCUS
- Geothermal Energy