# Comparative Summary of Conventional O&G Injectors, $CO_2$ EOR and $CO_2$ Storage Injectors

## SPE Denver Webinar – June 17, 2020, 12:00 to 1:00 pm (MST)


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***Acknowledgements:*** *IEAGHG Technical Report "Well Engineering and Injection Regularity in CO2 Storage Wells", 2018/08, November 2018 – www.ieaghg.org*

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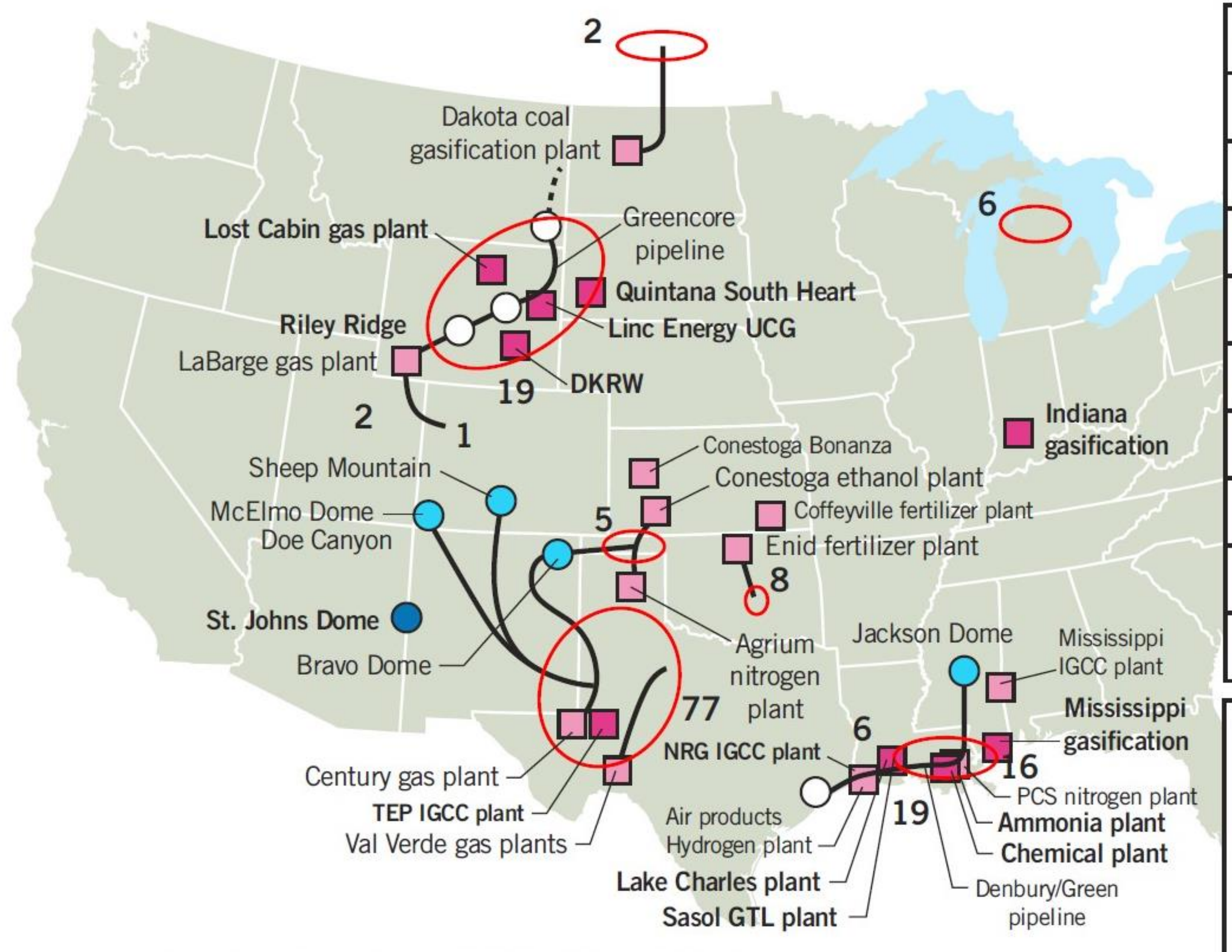
*IEAGHG Managers – James Craig and Lydia Rycroft*


TALIB SYED and ASSOCIATES, Inc.
CONSULTING PETROLEUM ENGINEERS

# Outline of Presentation

- Increasing Role of $CO_2$ for Enhanced Oil Recovery (EOR) and Geologic Storage (GS) applications
  - Climate change and reduction in greenhouse gas (GHG) emissions
- Key Comparative Factors – O&G Injectors, $CO_2$ EOR and $CO_2$ Storage Injectors
  - High Injection/Operating/Reservoir Pressure Management
  - $CO_2$ Corrosion
  - Well Design & Construction
  - Well Integrity (vs Wellbore Integrity Terminology)
  - Material Selection
  - Plugging & Abandonment
  - Regulatory – Class II versus Class VI Wells
- Summary

# PROJECTED $CO_2$, EOR OPERATIONS, AND $CO_2$ SOURCES: 2020

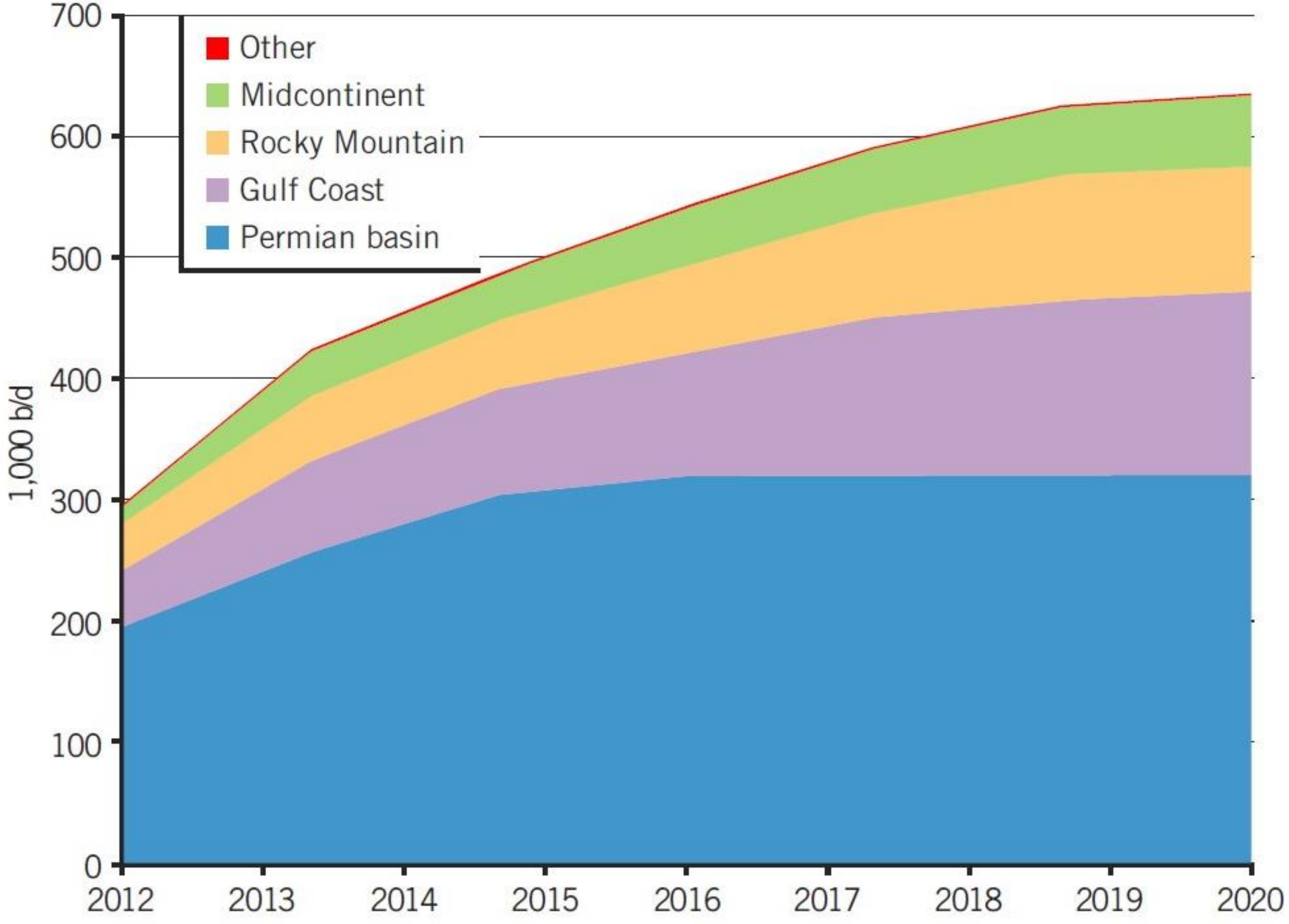



Source: Advanced Resources International Inc. based on OGJ EOR/Heavy Oil Survey 2014 and other sources

| Oil production, 2020 | |
|---|---|
| $CO_2$ –EOR projects | 147 |
| Oil production, 1,000 b/d | 638 |
| **$CO_2$ supplies, 2020** | |
| Number of sources | 30 |
| • Natural | 6 |
| • Industrial | 24 |
| $CO_2$ supply, MMcfd | 6.5 |
| • Natural | 3.4 |
| • Industrial | 3.1 |

**147** Number of $CO_2$-EOR projects
Natural $CO_2$ source
Industrial $CO_2$ source
$CO_2$ pipeline
$CO_2$ proposed pipeline

# PROJECTED $CO_2$-EOR PRODUCTION BY REGION




Source: Advanced Resources International Inc. adjustment to OGJ EOR/Heavy Oil Survey 2014

Figure 1 – The CCS Process
USDOE "Carbon Utilization and Storage Atlas", 2012

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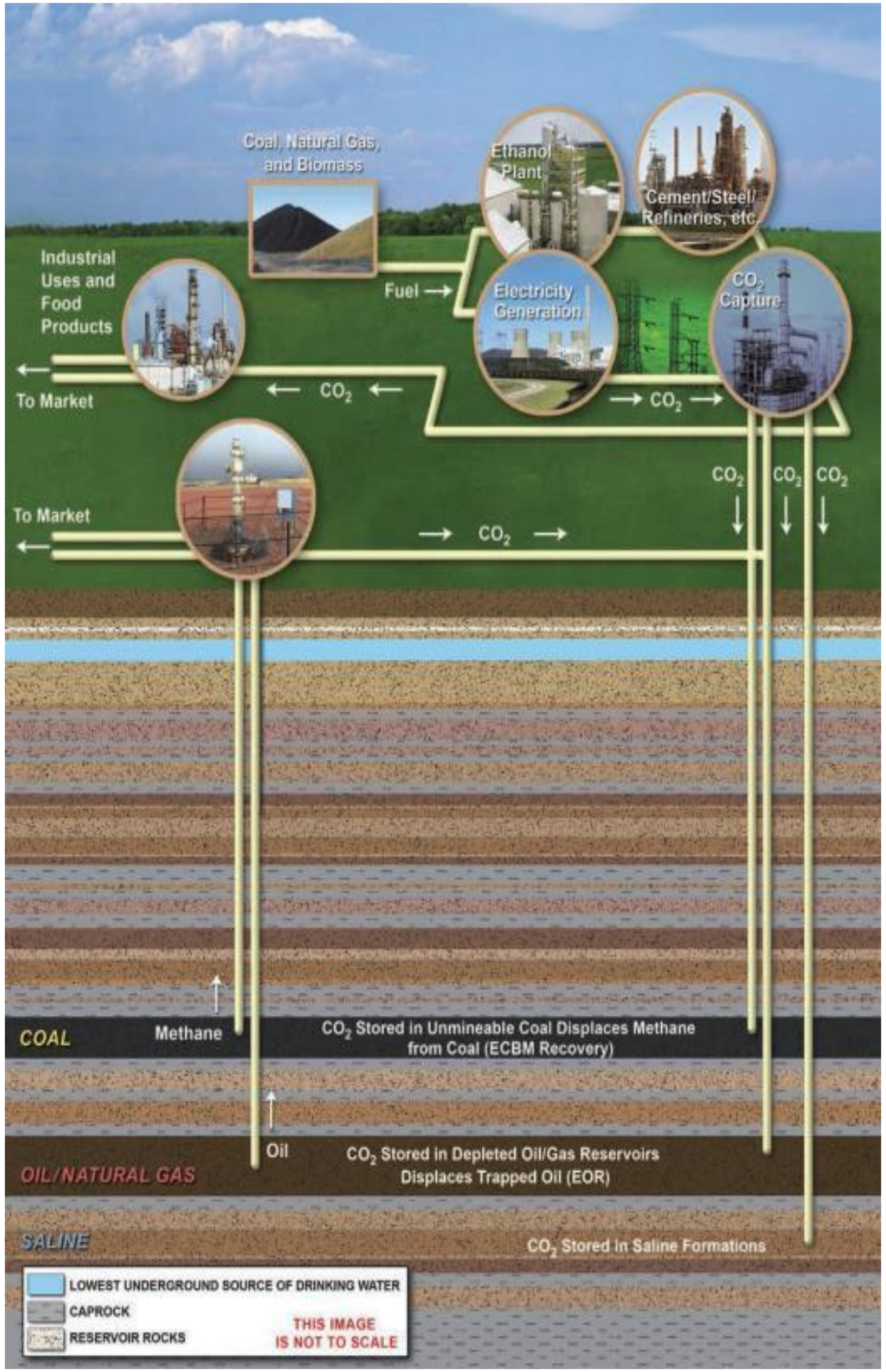
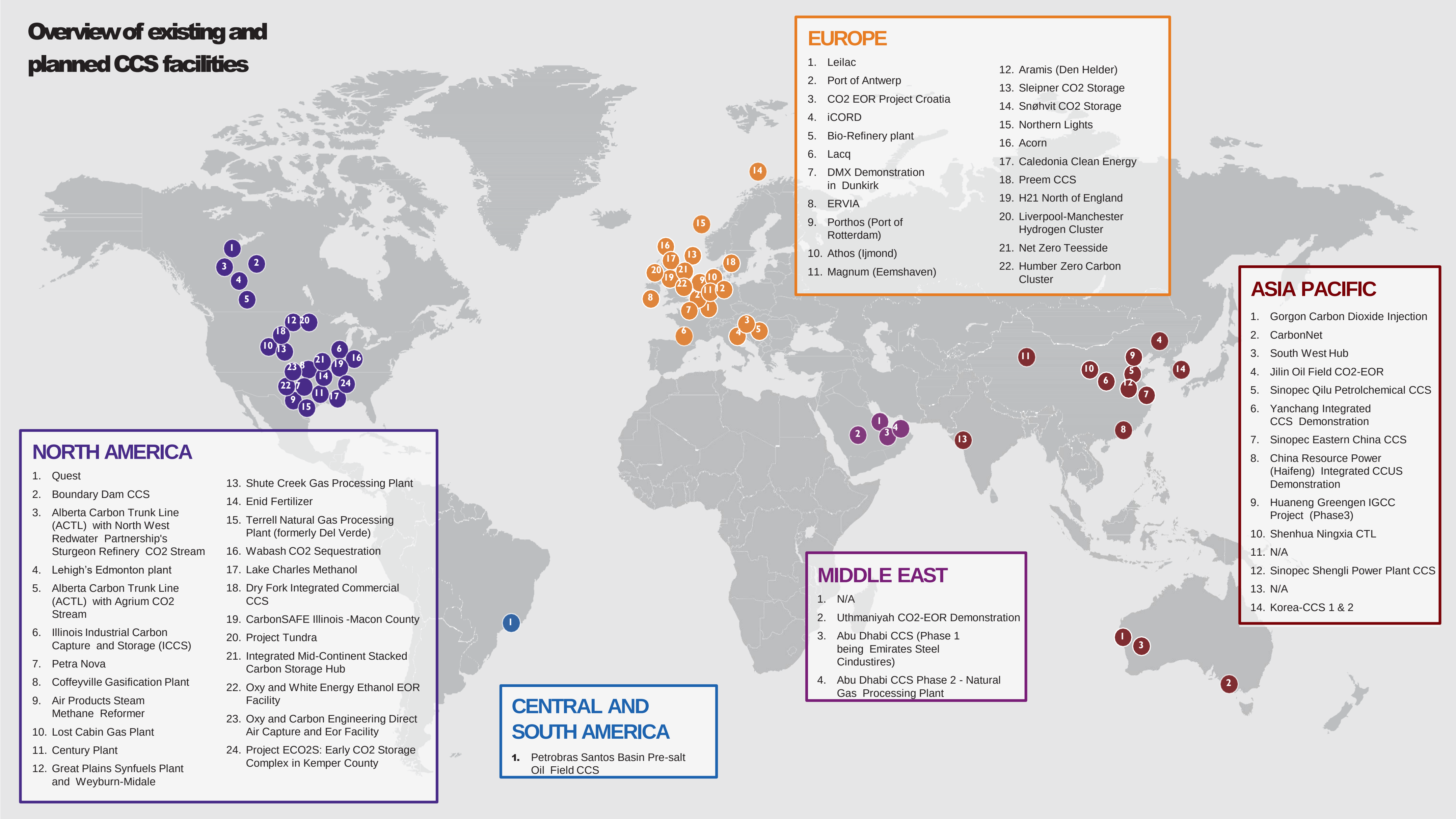


International Association of Oil & Gas Producers

# Global CCS projects

## Overview of existing and planned CCS facilities



### NORTH AMERICA

1. Quest
2. Boundary Dam CCS
3. Alberta Carbon Trunk Line (ACTL) with North West Redwater Partnership's Sturgeon Refinery CO2 Stream
4. Lehigh's Edmonton plant
5. Alberta Carbon Trunk Line (ACTL) with Agrium CO2 Stream
6. Illinois Industrial Carbon Capture and Storage (ICCS)
7. Petra Nova
8. Coffeyville Gasification Plant
9. Air Products Steam Methane Reformer
10. Lost Cabin Gas Plant
11. Century Plant
12. Great Plains Synfuels Plant and Weyburn-Midale
13. Shute Creek Gas Processing Plant
14. Enid Fertilizer
15. Terrell Natural Gas Processing Plant (formerly Del Verde)
16. Wabash CO2 Sequestration
17. Lake Charles Methanol
18. Dry Fork Integrated Commercial CCS
19. CarbonSAFE Illinois -Macon County
20. Project Tundra
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24. Project ECO2S: Early CO2 Storage Complex in Kemper County

### CENTRAL AND SOUTH AMERICA

1. Petrobras Santos Basin Pre-salt Oil Field CCS

### EUROPE

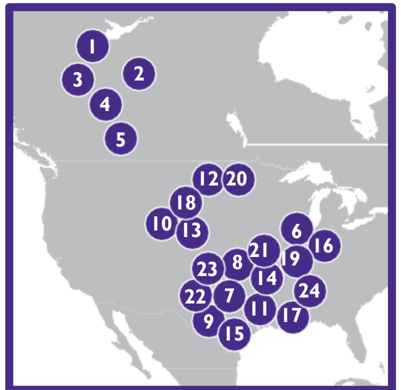
1. Leilac
2. Port of Antwerp
3. CO2 EOR Project Croatia
4. iCORD
5. Bio-Refinery plant
6. Lacq
7. DMX Demonstration in Dunkirk
8. ERVIA
9. Porthos (Port of Rotterdam)
10. Athos (Ijmond)
11. Magnum (Eemshaven)
12. Aramis (Den Helder)
13. Sleipner CO2 Storage
14. Snøhvit CO2 Storage
15. Northern Lights
16. Acorn
17. Caledonia Clean Energy
18. Preem CCS
19. H21 North of England
20. Liverpool-Manchester Hydrogen Cluster
21. Net Zero Teesside
22. Humber Zero Carbon Cluster

### MIDDLE EAST

1. N/A
2. Uthmaniyah CO2-EOR Demonstration
3. Abu Dhabi CCS (Phase 1 being Emirates Steel Cindustires)
4. Abu Dhabi CCS Phase 2 - Natural Gas Processing Plant

### ASIA PACIFIC

1. Gorgon Carbon Dioxide Injection
2. CarbonNet
3. South West Hub
4. Jilin Oil Field CO2-EOR
5. Sinopec Qilu Petrolchemical CCS
6. Yanchang Integrated CCS Demonstration
7. Sinopec Eastern China CCS
8. China Resource Power (Haifeng) Integrated CCUS Demonstration
9. Huaneng Greengen IGCC Project (Phase3)
10. Shenhua Ningxia CTL
11. N/A
12. Sinopec Shengli Power Plant CCS
13. N/A
14. Korea-CCS 1 & 2




## CCS projects in NORTH AMERICA

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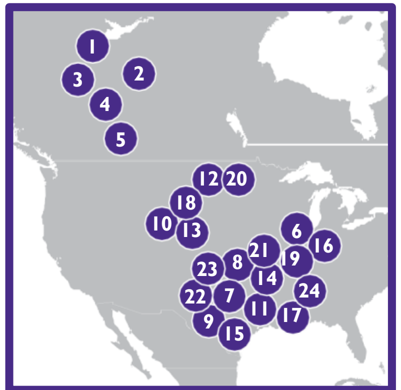
| NO. | LOCATION | PROJECT NAME | PROJECT TYPE | INDUSTRY | DESCRIPTION | CO2 CAPTURED/ YEAR | STARTING DATE (OPERATION) | STATUS OF THE PROJECT | PARTICIPANTS | IOGP MEMBERS INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Canada *Alberta* | Quest | Industrial capture, EOR | Hydrogen production for oil refining | Retrofitted CO2 capture facility to steam methane reformers, transportation via pipeline to a dedicated geological storage | 1 Mtpa | 2015 | Operational | Shell | Shell |
| 2 | Canada *Saskatchewan* | Boundary Dam CCS | Power and capture (post-combustion), EOR | Power generation | It combines post-combustion CCS with coal-fired power generation, some captured CO2 goes for EOR use in the Weyburn oil unit, a portion of the CO2 is stored permanently under the ground at the Aquistore project. | 1 Mtpa | 2014 | Operational | SaskPower | |
| 3 | Canada *Alberta* | Alberta Carbon Trunk Line (ACTL) with North West Redwater Partnership's Sturgeon Refinery CO2 Stream | Industrial capture, EOR | Oil refining | Carbon dioxide captured from Agrium's Redwater fertiliser plant and the North West Redwater Partnership's Sturgeon refinery. CO2 recovered from the fertiliser plant's emission streams put through inlet cooling, separation, compression, dehydration and refrigeration to produce liquefied CO2.The project plans to transport CO2 from a number of sources in the future coming from Alberta's Industrial Heartland. | 1.2-1.4 Mtpa | 2020 | Under construction | Enhance Energy Inc. (and - North West Redwater Partnership) | |
| 4 | Canada *Alberta* | Lehigh's Edmonton plant | Industrial capture | Cement industry | Capture the majority of the carbon dioxide (CO2) from the flue gas of Lehigh's Edmonton, Alberta cement plant | Estimated 600,000 tonnes annually | | Feasibility study | Lehigh Cement and the International CCS Knowledge Centre | |
| 5 | Canada *Alberta* | Alberta Carbon Trunk Line (ACTL) with Agrium CO2 Stream | Industrial capture, EOR | Fertilizer production | At the NWR refinery, CO2 will be captured within the gasification hydrogen supply unit, which will use unconverted petroleum bottoms (asphaltene) as feedstock to create synthesis gas (syngas). | 0.3-06 Mta | 2020 | Under construction | Enhance Energy Inc. | |

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| 6 | USA *Illinois* | Illinois Industrial Carbon Capture and Storage (ICCS) | Industrial capture | Ethanol production | CO2 captured from the fermentation process used to produce ethanol at an industrial corn processing complex in Decatur, Illinois, Transportation to a dedicated geological storage site | 1 Mtpa | 2017 | Operational | Administered by the U.S. Department of Energy's Office of Fossil Energy and managed by the National Energy Technology Laboratory and by a cost share agreement with the Archer Daniels Midland Company, University of Illinois through the Illinois State Geological Survey, Schlumberger Carbon Services, and Richland Community College | |
| 7 | USA *Texas* | Petra Nova | Power and capture (post-combustion), EOR | Power generation | Texas power plant retroffitted with post-combustion CO2 capture facility, transportation near Houston for EOR | 1.4 Mtpa | 2017 | Operational | NRG Energy and JX Nippon Oil | |
| 8 | USA *Kansas* | Coffeyville Gasification Plant | Industrial capture, fertiliser production, EOR | Fertilizer production | Fertilizer plant in Coffeyville retrofitted with CO2 compression and dehydrataion facilities, oil delivery to the North Burbank oil unit in Osage county, Ohklaoma for EOR | 1 Mtpa | 2013 | Operational | Coffeyville Resources Nitrogen Fertilizers, LLC, Chapparal Energy and Blue Source | |
| 9 | USA *Texas* | Air Products Steam Methane Reformer | Industrial capture, EOR | Hydrogen production for oil refinery | Airproducts retrofitted of steam methane reformer within a refinery at Port Arthur, Texas,transportation to oil field in Texas for EOR | 1 Mtpa | 2013 | Operational | Air Products, Covestro | |
| 10 | USA *Wyoming* | Lost Cabin Gas Plant | Industrial capture, EOR | Natural gas processing | Gas plantg in Wyoming supplies CO2 to compression facolity, transport and delivery via pipeline to the Bell Creek oil firld in Montana for EOR | Approx. 1 Mtpa | 2013 | Operational | ConocoPhillips | ConocoPhillips |
| 11 | USA *Texas* | Century Plant | Industrial capture, EOR | Natural gas processing | Natural gas treatment facility in Texas, transportation via pipeline for EOR | 8.4 Mtpa | 2010 | Operational | Occidental Petroleum | |
| 12 | USA *North Dakota* | Great Plains Synfuels Plant and Weyburn-Midale | Industrial capture (pre-combustion), EOR | Synthetic natural gas | The plant in North Dakota produces CO2 as part of a coal gasification process, transportation to the Wyburn and Midale oil units for EOR | 3 Mtpa | 2000 | Operational | Dakota Gasification Company | |

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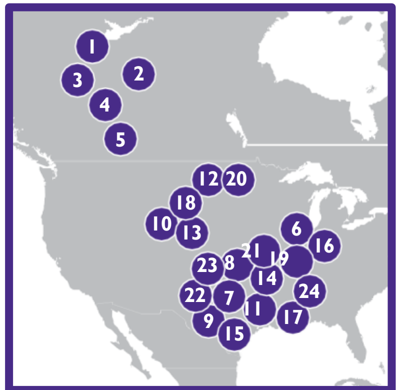


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| 13 | USA *Wyoming* | Shute Creek Gas Processing Plant | Industrial capture, EOR | Natural gas processing | Gas treating facility in Wyoming, some CO2 injected for sequestration/disposal, some for EOR | 7 Mtpa | 1986 | Operational | ExxonMobil | ExxonMobil |
| 14 | USA *Oklahoma* | Enid Fertilizer | Industrial capture, fertilizer production, EOR | Fertilizer production | CO2 captured from the manufacture of fertiliser, transportation for use in EOR at the Golden Trend oilfield and the Sko-Vel-Tum oilfield, south of Oklahoma City | 0.7 Mtpa | 1982 | Operational | Koch Nitrogen Company | |
| 15 | USA *Texas* | Terrell Natural Gas Processing Plant (formely Del Verde) | Industrial capture, EOR | Natural gas processing | CO2 capture at natural gas processing plant, CO2 transportation via Valverde pipeline to McCamey, Texas, and the Canyon Reef Carriers CRC pipeline and the Pecos pipeline, CO2 for EOR | Approx 0.5 Mtpa | 1972 | Operational | Blue Source and others | |
| 16 | USA *Indiana* | Wabash CO2 Sequestration | Industrial capture | Fertilizer production | Gasification plant in Indiana to be converted into an anhydrous ammonia production plant and CCS plant, dedicated geological storage in the Wabash carbonSAFE CO2 storage hub | 1.5-1.75 Mtpa | 2022 | Advance development | WABASH Valley Resources (WVR) | |
| 17 | USA *Louisiana* | Lake Charles Methanol | Industrial capture, EOR | Chemical production | Gasification facility in Lousiana capturing from synthetic gas syngas to make methanol and other products, captured CO2 to be used for EOR in Texas | Approx 4 Mtpa | 2024 | Advance development | Leucadia Energy | |
| 18 | USA *Wyoming* | Dry Fork Integrated Commercial CCS | Power and Capture (post-compbustion), EOR | Power generation | Dry Fork coal-fired power station in Wyoming, targeting adjacent geological storage formations currently under study. EOR under consideration | 3 Mtpa | 2025 | Advance development | The Basin Electric Power Cooperative | |
| 19 | USA *Illinois* | CarbonSAFE Illinois -Macon County | Power and industrial capture (post-combustion), EOR | Power genration and ethanol production | CCS integration of a compression and dehydration facilities to an ethanol plant, transportation and injection in a dedicated geological storage | 2-5 Mtpa | 2025 | Advance development | Carbon Storage Assurance Facility Enterprise (CarbonSAFE) of the U.S. Department of Energy National Energy Technology Laboratory (DOE- NETL) | |

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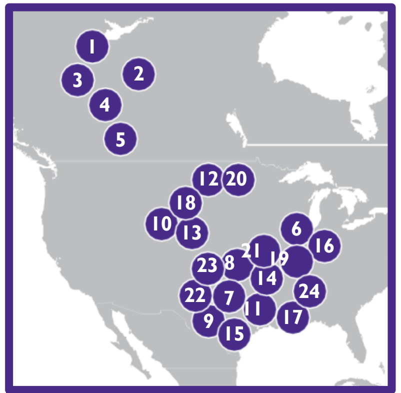


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|---|---|---|---|---|---|---|---|---|---|---|
| 20 | USA *North Dakota* | Project Tundra | Power and capture (post-combustion), EOR | Power generation | Retrofit CO2 capture plant to the MIlton R. Young coal fire power station in North Dakota with a dedicated storage site. EOR under study | 3.1-3.6 Mtpa | 2025-2026 | Advance development | Minnkota Power Cooperative | |
| 21 | USA *Nebraska, Kansas* | Integrated Mid-Continent Stacked Carbon Storage Hub | Ethanol production, power generation and/or refinery, EOR | Ethanol production, power generation and/or refinery | CO2 collection from ethanol plants, power plants and refineries with integrated storage in Kansas and Nebraska | Approx 2 Mtpa | 2025-2035 | Advance development | The team is led by Battelle Memorial Institute and includes: Archer Daniels Midland Company (ADM), the Kansas Geologic Survey (KGS), the Energy and Environmental Research Center (EERC) at the University of North Dakota, Schlumberger, the Conservation and Survey Division (CSD) at the University of Nebraska-Lincoln (UNL) and others | Schlumberger |
| 22 | USA *Texas* | Oxy and White Energy Ethanol EOR Facility | Industrial capture, EOR | Ethanol production | CO2 capture from two ethanol facilities in Hereford and Plainview, Texas. The captured CO2 will be stored via EOR at Occidental's oil fields in Premian basin | 0.6-0.7 Mtpa | 2021 | Early development | Occidental Petroleum Corporation and White Energy | |
| 23 | USA *Texas* | Oxy and Carbon Engineering Direct Air Capture and Eor Facility | Direct air capture, EOR | N/A | CO2 capture from an Occidental oil field in the Permian Basin, and used for EOR | 1 Mtpa | 2025 | Early development | Oxy Low Carbon Ventures and Carbon Engineering Ltd | |
| 24 | USA *Mississippi* | Project ECO2S: Early CO2 Storage Complex in Kemper County | Under evaluation | N/A | Regional CO2 storage hub near the Keper County Energy Facility in Missisipi from power and industrial sources | 3 Mtpa | 2026 | Early development | In identification (capture) - I believe information on companies involved on the storage is also available. (http://www.searchanddiscovery.com/ documents/2018/80638hnottavange-telleen/ndx_hnottavange-telleen. pdf) Project ECO2S, a DOE-supported CarbonSAFE program, | |

# Comparative Summary of O&G, $CO_2$ EOR and $CO_2$ Storage Wells

## Selected Key Comparative Factors:

- High Injection/Operating/Reservoir Pressure Management
- $CO_2$ Corrosion
- Well Design & Construction (Drilling/Workovers)
- Well Integrity
- Material Selection & Specifications
- Injectivity & Regularity
- Plugging & Abandonment (P&A)
- Regulatory – Class II versus Class VI Wells

# High Injection/Operating/Reservoir Pressure Management

- $CO_2$ transported and injected at a high pressure (above 1,100 psi)
  - danger from its high coefficient of thermal expansion

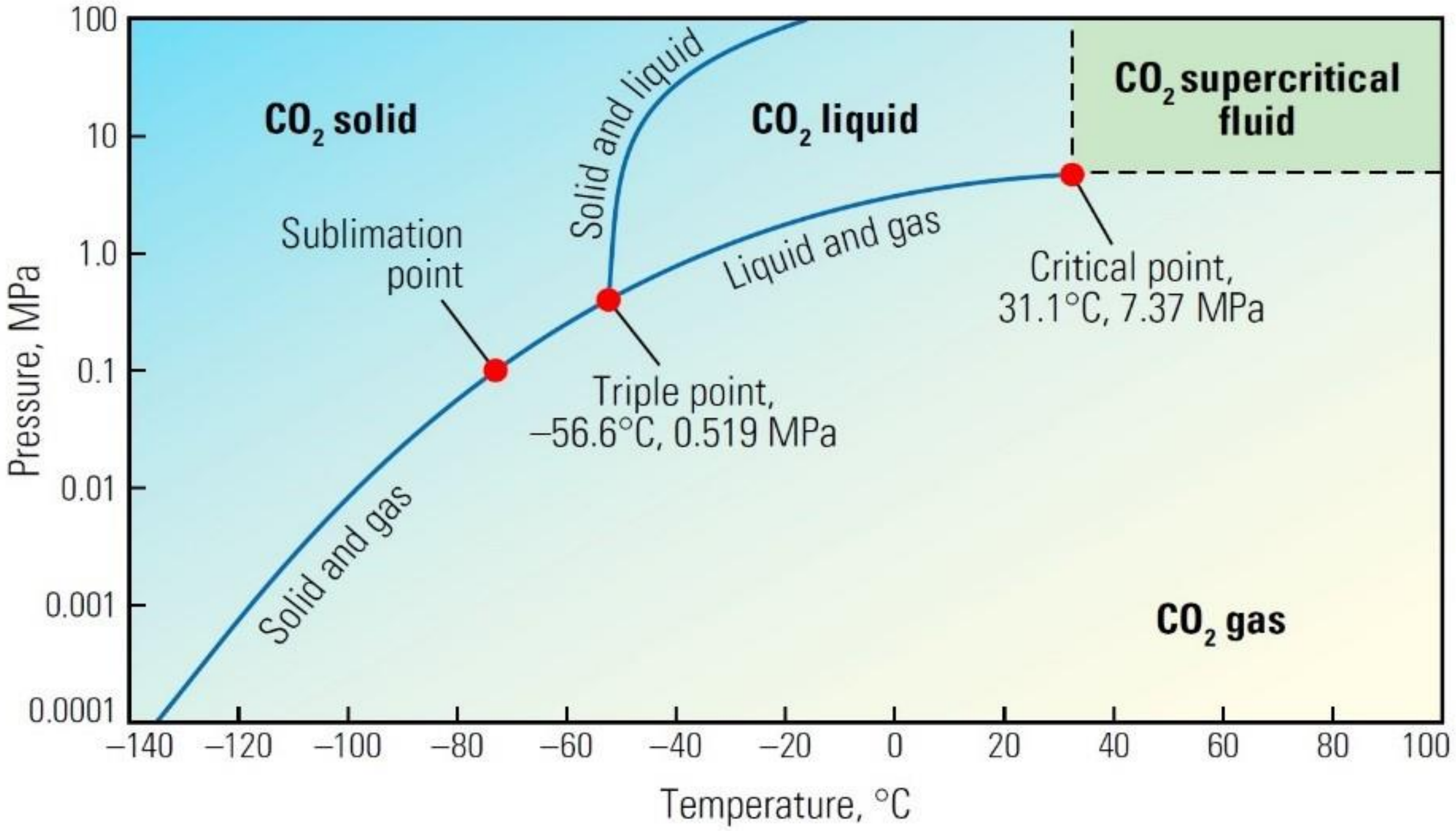
- Loss of well control (LWC)/blowouts during workovers is significant concern from $CO_2$ phase behavior and high pressure
  - Failures from $CO_2$ – related corrosion of well materials can cause LWC

- High injection pressures with low injection fluid temperatures can induce hydraulic fracturing – geo-mechanical models to determine in-situ stresses and fault activation hazard

- Locate $CO_2$ storage wells far away from faults

- Wet $CO_2$ corrodes well tubular and cement. Changes near wellbore reservoir properties
- Low corrosion risk when injected stream is dry ($CO_2$ purity > 95%) and in supercritical stage
- Long-term stability of wellbore materials is complex. Incorporate material and reservoir properties into well design/completion programs
- Equip older wells/ wells converted to $CO_2$ service with corrosion-resistant tubular

***$CO_2$ Phase Behavior (Oilfield Review September 2015)***



# Well Design & Construction (Drilling/Workovers)

- Design/well construction of water injector and $CO_2$ EOR injector is similar (except wellhead). Also, $CO_2$ EOR and $CO_2$ storage well designs are similar, with latter more stringent in some cases ($CO_2$ -resistant tubular and cements)
- $CO_2$ EOR wells either drilled as new wells or re-complete producer or injector in existing fields
- Major differences in remedial workovers between waterflood and a $CO_2$ flood. With large $CO_2$ EOR operations, may need a workover rig on location for routine maintenance – also to deploy a rig for LWC incidents
- $CO_2$ stored for a long period (decades). Specific requirements for well design and monitoring and abandonment (MMV – monitoring measurement and verification) depending on jurisdiction
- Drilling in environments – HPHT, SAGD, deepwater, ERD, shales, arctic, salt zone and $CO_2$ injection results in complex loading conditions on casing/tubular/cements etc. - Casing design software such as WELLCAT™ , DrillPlan™

# Well Integrity

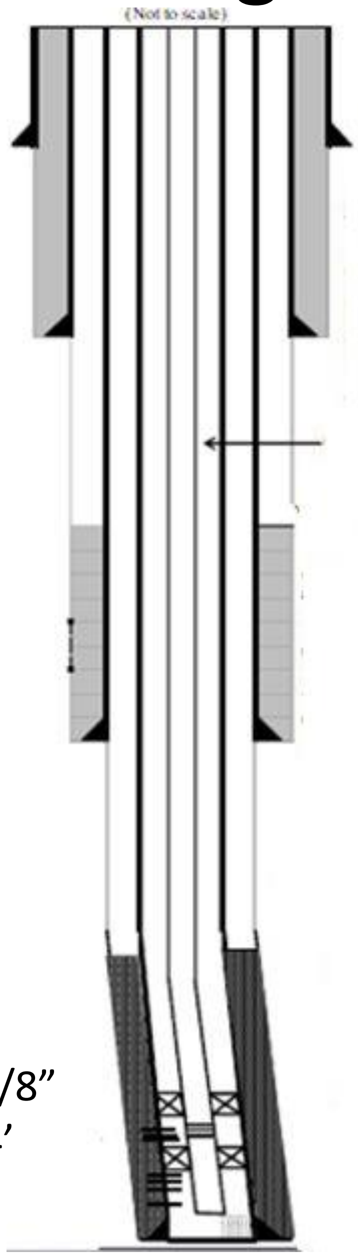
- Large scale $CO_2$ EOR operations (SACROC and Wasson Field) indicate no major concerns with life cycle well integrity management
- Impacts of $CO_2$ corrosion on well tubular and cements handled with appropriate selection of materials of construction (MOC)
- Complex loads/stresses on casing/tubing and cements from $CO_2$ injection handled with appropriate software
- Higher injection rates in $CO_2$ storage wells can impact wells and near wellbore structures
- Proper maintenance of $CO_2$ injection wells necessary – well integrity surveys, improved BOPE maintenance, crew training and awareness, contingency/emergency response
- Minimize thermal cycling (on-off injection and $CO_2$ supply disruption) to avoid cement debonding and injectivity effects
- Gulf of Mexico, North Sea and Alberta studies indicate higher well integrity problems with cased wells compared to drilled and abandoned wells, and injection wells more prone to leakage than production wells

# Well Integrity vs. Wellbore Integrity

- Well integrity differs from Wellbore integrity (Borehole instability) – open hole interval that does not retain its gauge and/or structural integrity
- Types of borehole instabilities:
  - Hole closure/narrowing;
  - Hole enlargement/washouts
  - Fracturing
  - Collapse
- Borehole instability prevention:
  - Maintain proper mud-weight; borehole fluid compatible with drilled formation
  - Use proper hydraulics to control equivalent circulating density (ECD)
  - Select proper hole trajectory

# Injectors - Well Integrity Challenges

- Injectors 2 to 3 times more likely to leak than producer wells
  - Thermal induced higher loads
  - Injectors get less focus
- Injected fluid charging a non-target zone:
  - Potential for kicks drilling offsets
  - Narrow mud windows; difficult reaching TD
- Change of well status/application
- $CO_2$ EOR/$CO_2$ Storage, acid gas injection wells:
  - Risk of $CO_2$ blowout
  - Corrosion resistant tubular and cements
  - Long-term safe storage and abandonment




16” Conductor @ 61’

11 ¾” 42# H-40 STC Surface Casing in 14 ¾” hole @ 993’
Inhibited brine
TOC @ 3050’

8 5/8” J-55 LTC Intermediate Casing @ 4047’ in 10 5/8” hole

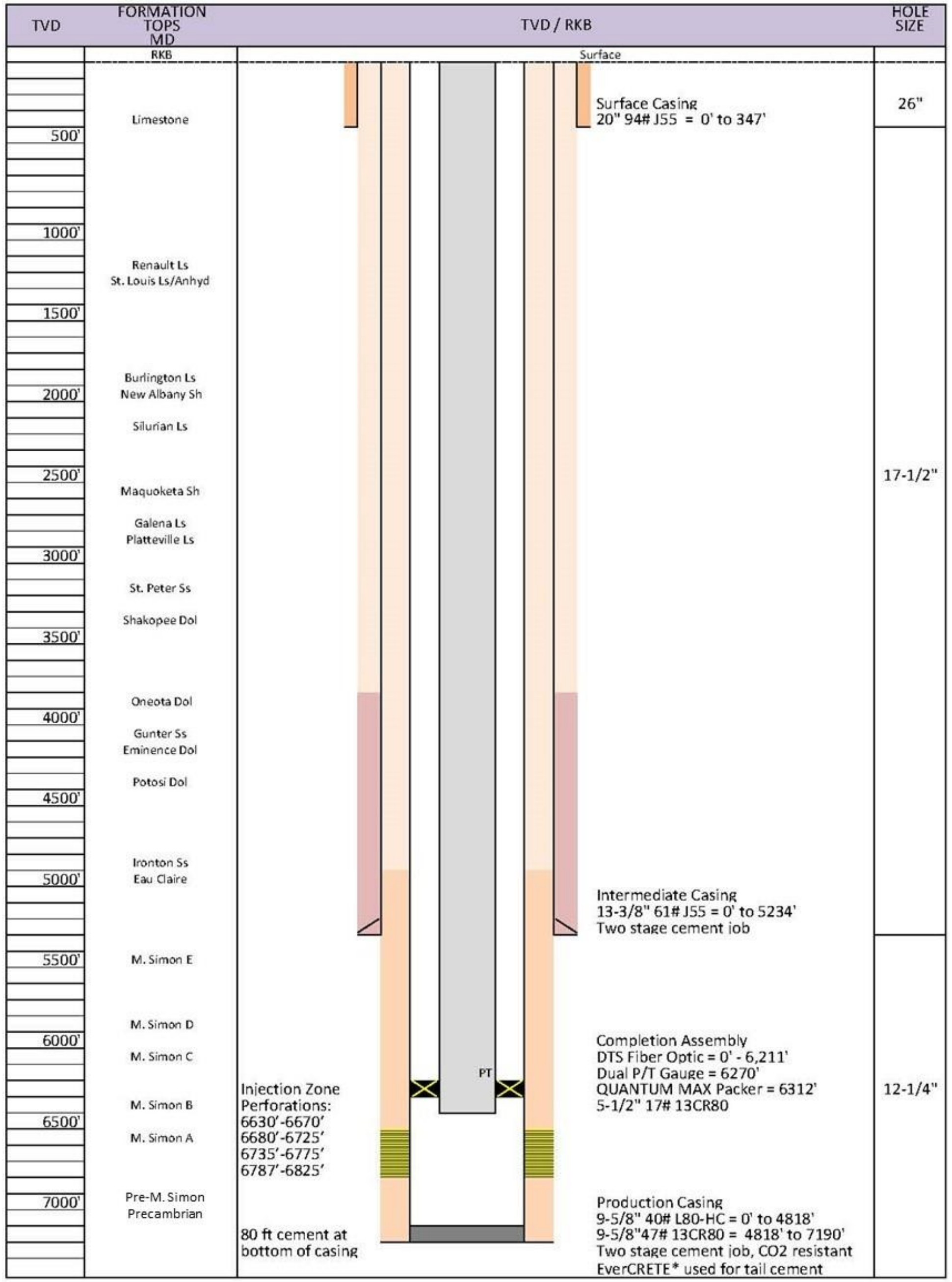
TOC @ 5420’

5 ½” 17# J-55 LTC prod casing @ 6697’ in 7 7/8” hole

2 7/8” tbg @ 6533’, 5 ½” x 2 7/8” pkr @ 5971’, Perfs 5892’-6284’

Source: Core Energy, IEAGHG, 2018

# ADM CCS # 2 Class VI-GS Well, Decatur, Illinois, U.S.A.



# Material Selection & Specifications

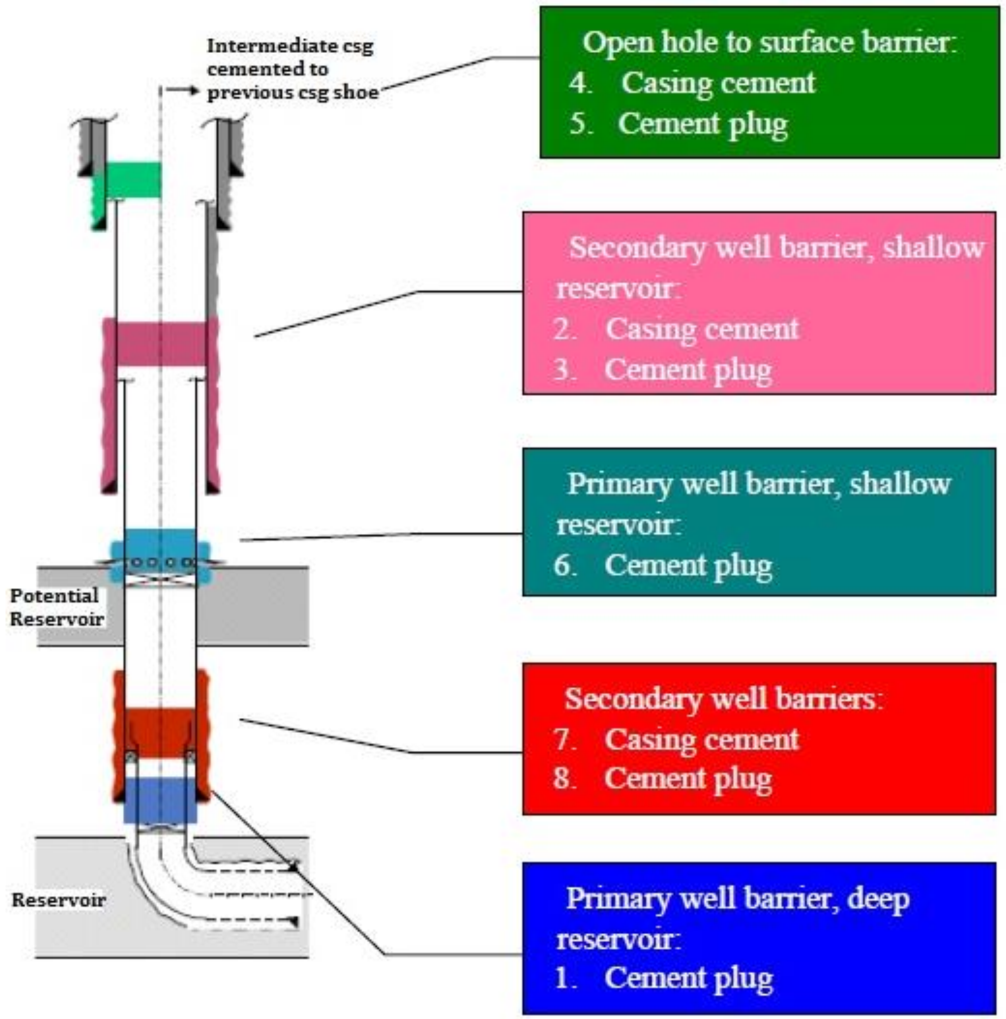
- Material selection for $CO_2$ injection wells depends on high strength combined with high corrosion resistance
- Run chemical analysis of reservoir fluids; also temperature and pressure profiles and stresses on tubulars
- Consider contact with wet $CO_2$ especially in deeper sections of well
- Consider performance at low temperatures (brittle materials may not stop $CO_2$ leakage), and $O_2$ – related impacts
- Use appropriate corrosion resistant metallurgy
- Cementing is critical for mechanical performance and life cycle well integrity.
- Use appropriate cements/specialty cements for zonal isolation and well integrity.
- Use current industry best practices for successful cement design, execution and evaluation

# Injectivity and Regularity

- Injectivity and injection regularity critical for success of a CCS storage project (storage of millions of tons of $CO_2$ in a 50-year time frame)
- For $CO_2$ EOR objective is to maximize oil recovery, while for storage wells is to maximize injection volumes/storage capacity with minimum number of wells
- Large scale $CO_2$ storage requires good/sufficient capacity reservoirs with good petrophysical properties (dissipate pressure buildup and avoid interference with adjacent O&G operations, if present)
- Injection can alter mechanical rock properties by inducing chemical reactions
- $CO_2$ EOR project economics greatly impacted with injectivity loss and corresponding reservoir pressure loss
- Injectivity loss factors: wettability, trapping, salt/halite precipitation, increased scaling, paraffin and asphaltene precipitation. Additional factors: fines migration, borehole deformation, fault intersection, facies variation and shale swelling

# Typical Well Plugging & Abandonment

- Quality of a P&A evaluated by type of plugging material and plug placement technique
- Plugging materials: cements, formation, grouts, thermosetting, gels, metals (bismuth/thermite)
- Placement techniques: Balanced plug, Dump-bailer, Two-plug and Jet grouting
- Successful P&A protects environment, with downhole integrity, regulatory compliance




Source: Randhol and Carlsen/SINTEF, 2001

# Regulatory Requirements – Class II vs Class VI $CO_2$ Wells

| Requirements | Class II | Class VI |
| --- | --- | --- |
| • Permit Required | Yes, except for existing EOR wells authorized by rule | Yes, cannot be authorized by rule |
| • Seismicity Information | None | Determine that if seismic sources are identified, the seismicity would not interfere with containment |
| • Area of Review (AOR) Corrective Action | For new wells, a ¼ fixed radius or radius of endangerment. CA plan required for improperly P&A'd wells | Designates larger AOR, based on CO2 pressure front and plume extent. AOR review every 5 years and CA on all wells within AOR if required |
| • Financial Responsibility (bond, letter of credit etc.) | Financial assurance to properly P&A well(s) | FA to cover CA, injection, P&A, post-injection site care, and emergency/remedial response |

# Regulatory Requirements – Class II vs Class VI $CO_2$ Wells

| Requirements | Class II | Class VI |
|---|---|---|
| • Well Construction | Casing and cementing to prevent flow into or between USDWs | Class II plus use of materials of construction (tubular/cements) for life cycle well integrity |
| • Logging/Sampling/ Testing prior to Operation | Mechanical Integrity (MIT) prior to operation | Class II plus verify formation physical and chemical characteristics |
| • Operating Requirements | Injection pressure not to exceed permit max WHIP and prevent flow into USDWs | Class II plus max surface WHIP < 90% of formation fracture pressure. Continuous monitoring of pressures/CO2 stream etc. |
| • MIT Testing | Once every 4-5 years (Internal) External – logs/cement records etc. | Specific standards for demonstrating MIT Including annual testing and pressure monitoring to detect fluid movement |

# Regulatory Requirements – Class II vs Class VI $CO_2$ Wells

| Requirements | Class II | Class VI |
|---|---|---|
| • Testing/Monitoring | Annual fluid chemistry as per permit. Injection pressure/rates and volumes as per permit | Class II plus verifying compliance with permit. Monitor $CO_2$ plume and pressure front during injection and post-injection and groundwater quality during injection |
| • Well Plugging and Abandonment | P&A'd as per industry standards | Class II plus more specific plugging and site-closure requirements to prevent $CO_2$ leakage post-injection |
| • Reporting and Recordkeeping | Annually. Report non-compliance | Semi-Annually. Report non-compliance within 24 hrs. Class II plus more specific on injection fluid stream and pressure data. Retain records for project life plus 10 years post- closure and monitoring data for 10 years after collection |

# Regulatory Requirements – Class II vs Class VI $CO_2$ Wells

| Requirements | Class II | Class VI |
| --- | --- | --- |
| • Post-Injection | None | Continue monitoring of $CO_2$ plume and pressure front (may be up to 50 years) |
| • Emergency and Remedial Response | None | Submit and Emergency and Remedial Response Plan. Notification and implementation in event of $CO_2$ release |
| • Permitting Period | For life of well or life of project<br>Each permit reviewed every 5 years | Lifetime of facility plus 50-year post-injection period<br>Each permit must be reviewed at least once every 5 years |
| • Area Permits | Generally allowed | Not allowed |

# 45Q Carbon Storage Tax Credit

- Section 45Q establishes tax credits for $CO_2$ storage through both EOR and geologic sequestration (26 U.S.C. §45Q)
- For EOR, only $CO_2$ used as tertiary injectant and remains in reservoir qualifies for tax credit – not $CO_2$ recaptured or recycled. Tax credit is currently @ $35/ton
- Tax credit is $ 50/ton for sequestered $CO_2$
- Taxpayer must claim credit over 12-year period after operations begin (facility must start operations or begin construction before 2024 - or by January 1,2025 proposed)
- Tax credit to reduce federal tax revenue by estimated $ 2.3 billion (FY 2020-2029 period)
- As of May 2019, stored carbon oxide*claimed for 45Q tax credit since 2011 is ~ 63 million tons

# Summary

- Imperatives for Success in $CO_2$ Injection Operations: O&G industry has the technology, knowledge, experience:
    - To safely handle and manage $CO_2$ operations; to avoid potential catastrophic impacts to safety, environment, reputation, economic loss; and maintain Social License to operate
    - Original well design and conversions must meet critical casing and cementing requirements with appropriate materials of construction (tubular and cements)
    - Implement best practices/sound engineering for well design/construction/injection
    - Implement appropriate well integrity testing and monitoring procedures and compliance with stringent regulatory requirements (will also reduce risks from legacy wellbores)