

Comparative Summary of Conventional O&G Injectors, CO₂ EOR and CO₂ Storage Injectors

GWPC UIC Annual Forum – September 15 -17, 2019, Oklahoma City, OK, U.S.A.

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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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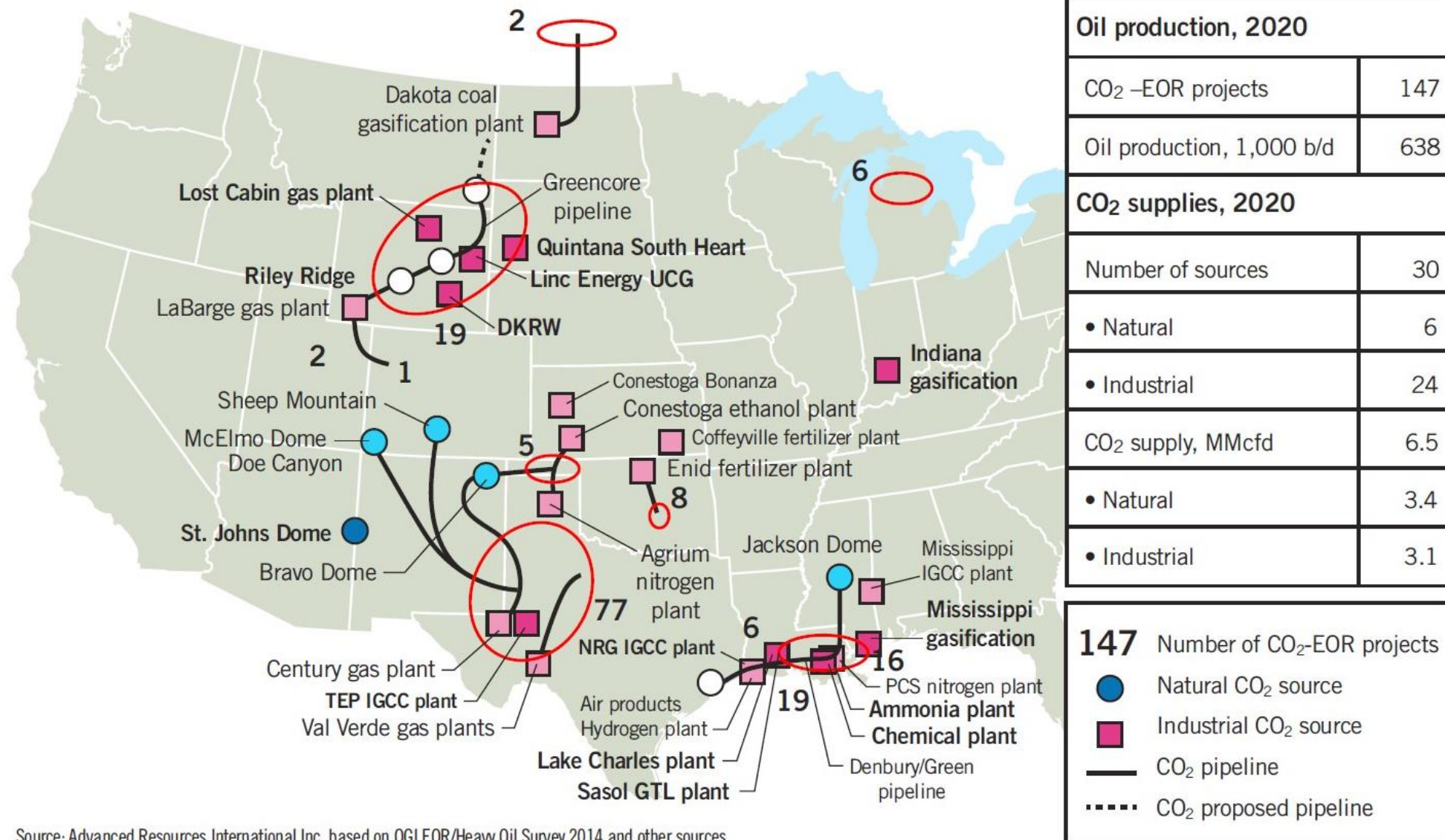


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Outline of Presentation

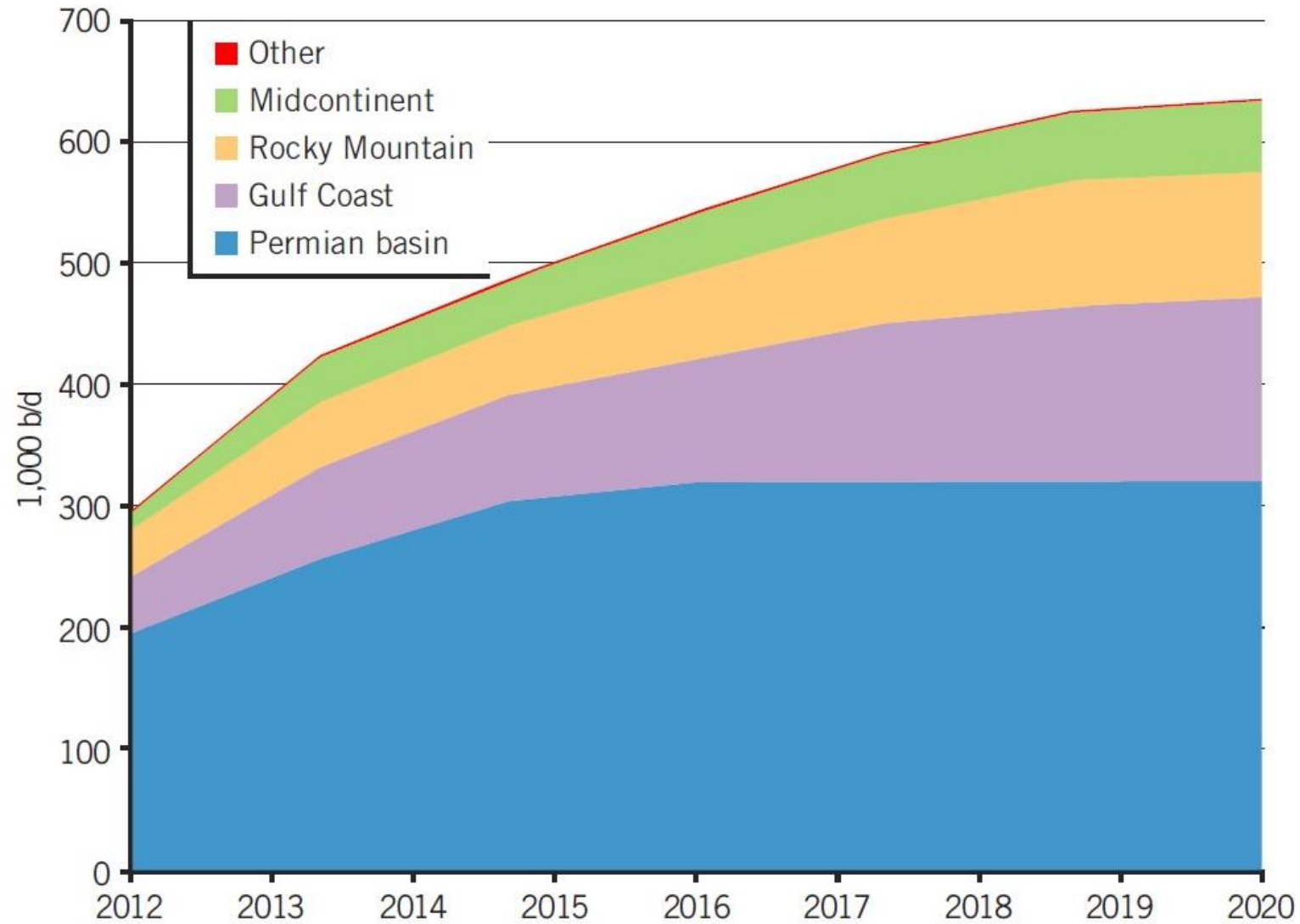
- Increasing Role of CO₂ for Enhanced Oil Recovery (EOR) and Geologic Storage (GS) applications
 - Climate change and reduction in greenhouse gas (GHG) emissions
- Key Comparative Factors – O&G Injectors, CO₂ EOR and CO₂ Storage Injectors
 - High Injection/Operating/Reservoir Pressure Management
 - CO₂ Corrosion
 - Well Design & Construction
 - Well Integrity
 - Material Selection
 - Plugging & Abandonment
- Summary

PROJECTED CO₂, EOR OPERATIONS, AND CO₂ SOURCES: 2020



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

PROJECTED CO₂-EOR PRODUCTION BY REGION



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

UIC 2019 Forum, OKC, Sep 15-17, 2019 - Talib Syed, TSA

Comparative Summary of O&G, CO₂ EOR and CO₂ Storage Wells

Selected Key Comparative Factors:

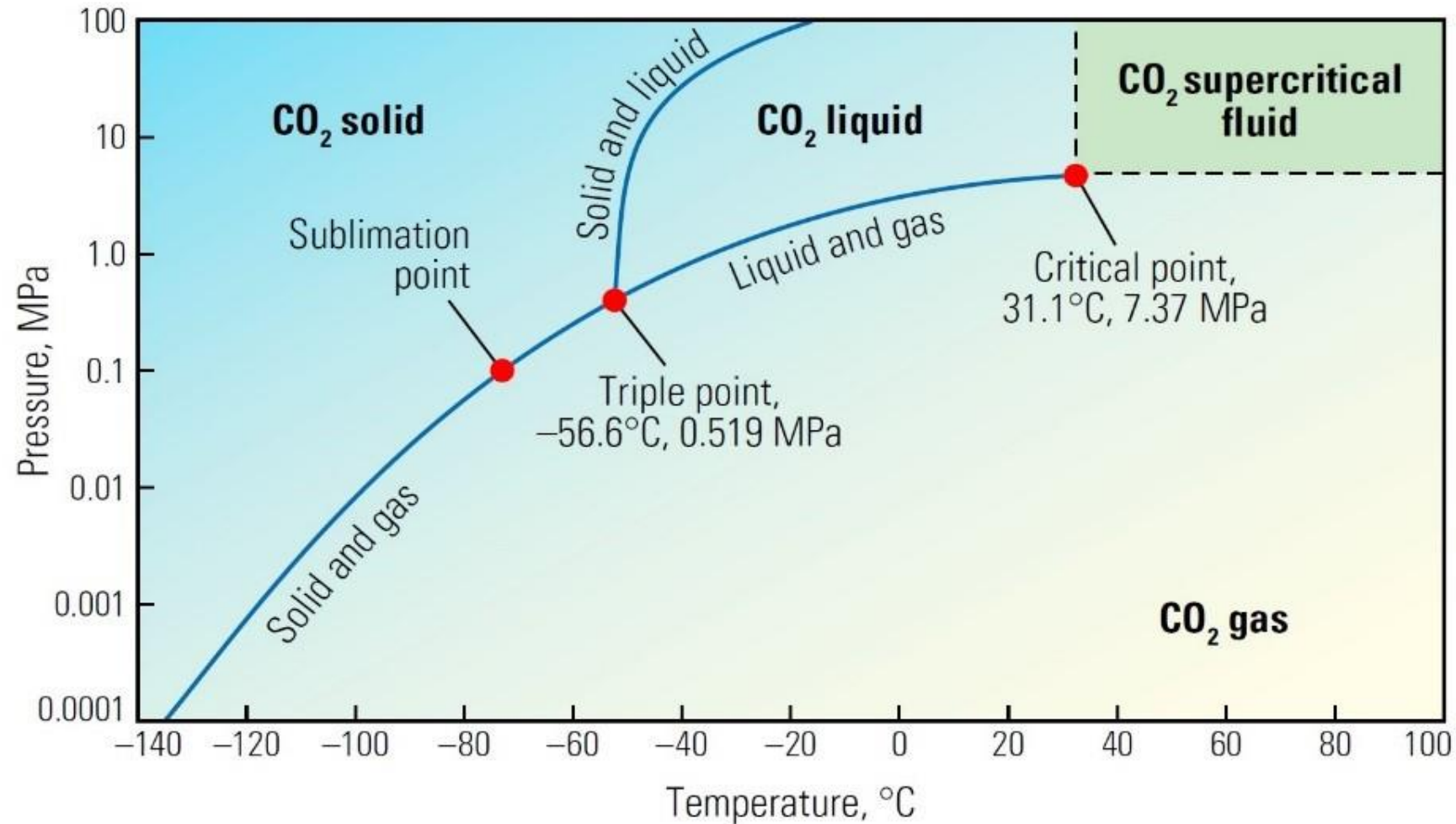
- High Injection/Operating/Reservoir Pressure Management
- CO₂ Corrosion
- Well Design & Construction (Drilling/Workovers)
- Well Integrity
- Material Selection & Specifications
- Injectivity & Regularity
- Plugging & Abandonment (P&A)

High Injection/Operating/Reservoir Pressure Management

- CO₂ 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 CO₂ phase behavior and high pressure
 - Failures from CO₂ – 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 CO₂ storage wells far away from faults

- Wet CO₂ corrodes well tubular and cement. Changes near wellbore reservoir properties
- Low corrosion risk when injected stream is dry (CO₂ 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 CO₂ service with corrosion-resistant tubular

CO₂ Phase Behavior (Oilfield Review September 2015)



Well Design & Construction (Drilling/Workovers)

- Design/well construction of water injector and CO₂ EOR injector is similar (except wellhead). Also, CO₂ EOR and CO₂ storage well designs are similar, with latter more stringent in some cases (CO₂-resistant tubular and cements)
- CO₂ 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 CO₂ flood. With large CO₂ EOR operations, may need a workover rig on location for routine maintenance – also to deploy a rig for LWC incidents
- CO₂ 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 CO₂ injection results in complex loading conditions on casing/tubular/cements etc. - Casing design software such as WELLCAT™, DrillPlan™

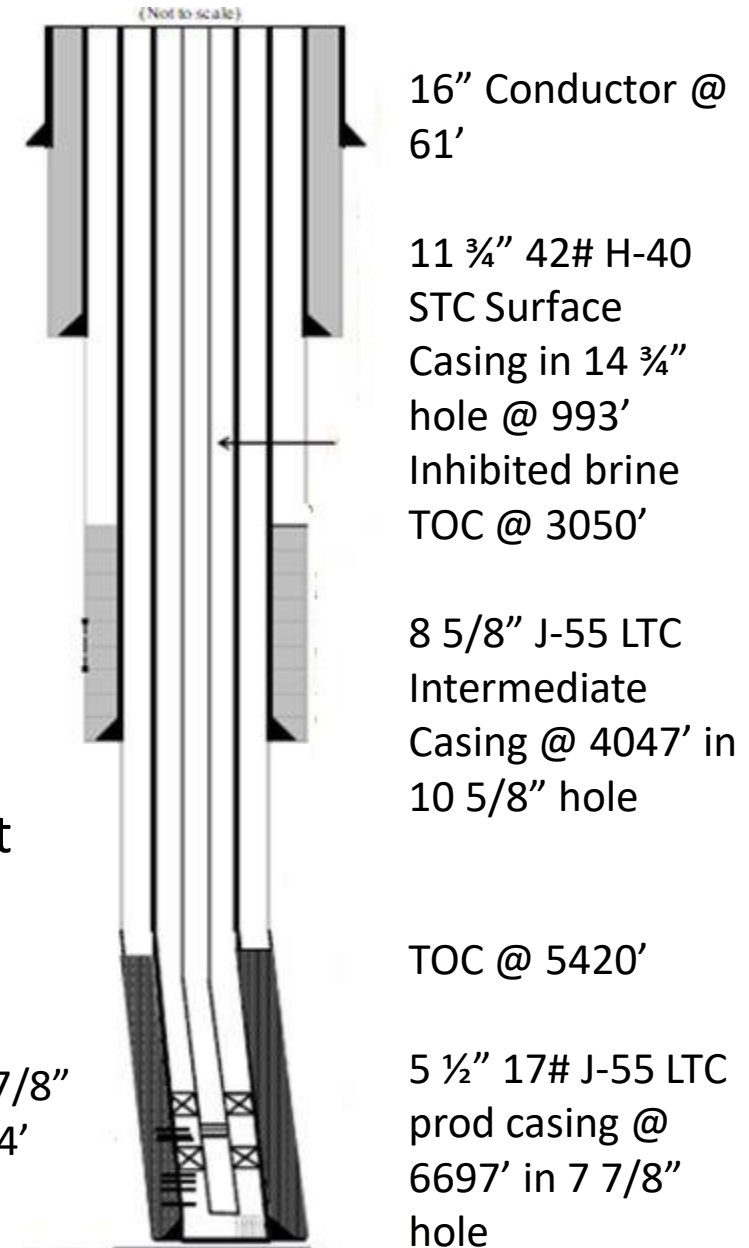
Well Integrity

- Large scale CO₂ EOR operations (SACROC and Wasson Field) indicate no major concerns with life cycle well integrity management
- Impacts of CO₂ corrosion on well tubular and cements handled with appropriate selection of materials of construction (MOC)
- Complex loads/stresses on casing/tubing and cements from CO₂ injection handled with appropriate software
- Higher injection rates in CO₂ storage wells can impact wells and near wellbore structures
- Proper maintenance of CO₂ injection wells necessary – well integrity surveys, improved BOPE maintenance, crew training and awareness, contingency/emergency response
- Minimize thermal cycling (on-off injection and CO₂ 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

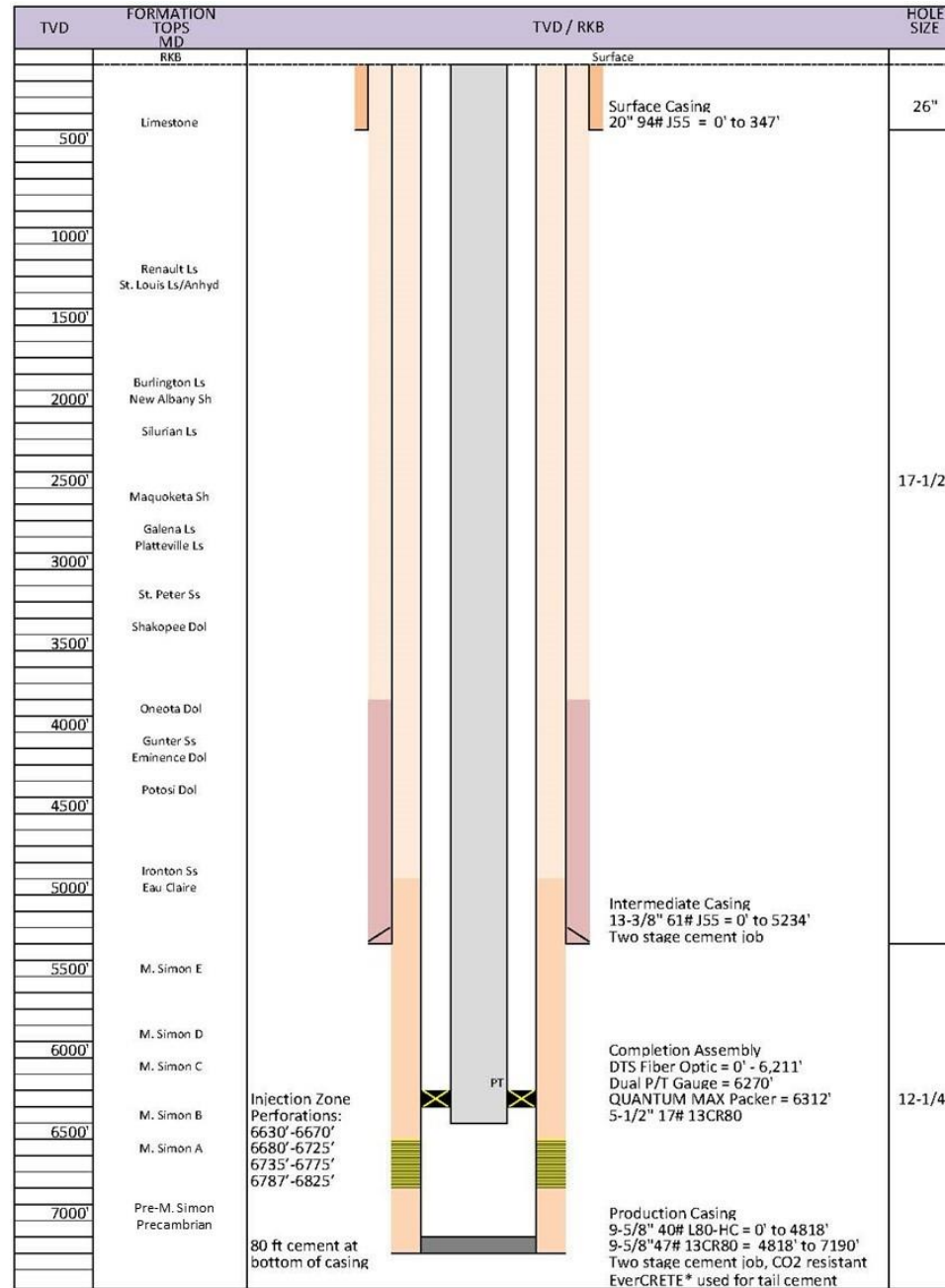
Injectors - Well Integrity Challenges

- 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
- CO₂ EOR/CO₂ Storage, acid gas injection wells:
 - Risk of CO₂ blowout
 - Corrosion resistant tubular and cements
 - Long-term safe storage and abandonment

2 7/8" tbg @ 6533', 5 1/2" x 2 7/8"
pkr @ 5971', Perfs 5892'-6284'



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



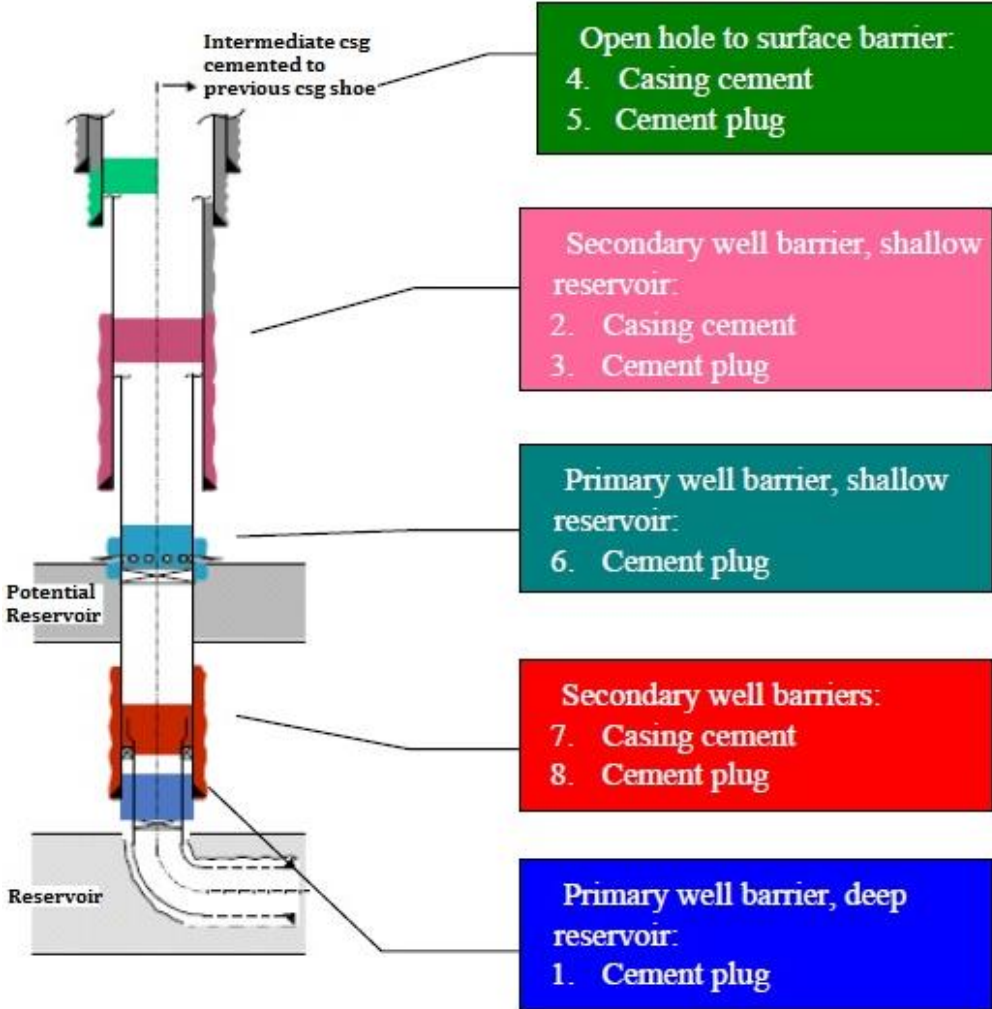
Material Selection & Specifications

- Material selection for CO₂ 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 CO₂ especially in deeper sections of well
- Consider performance at low temperatures (brittle materials may not stop CO₂ leakage), and O₂ – 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

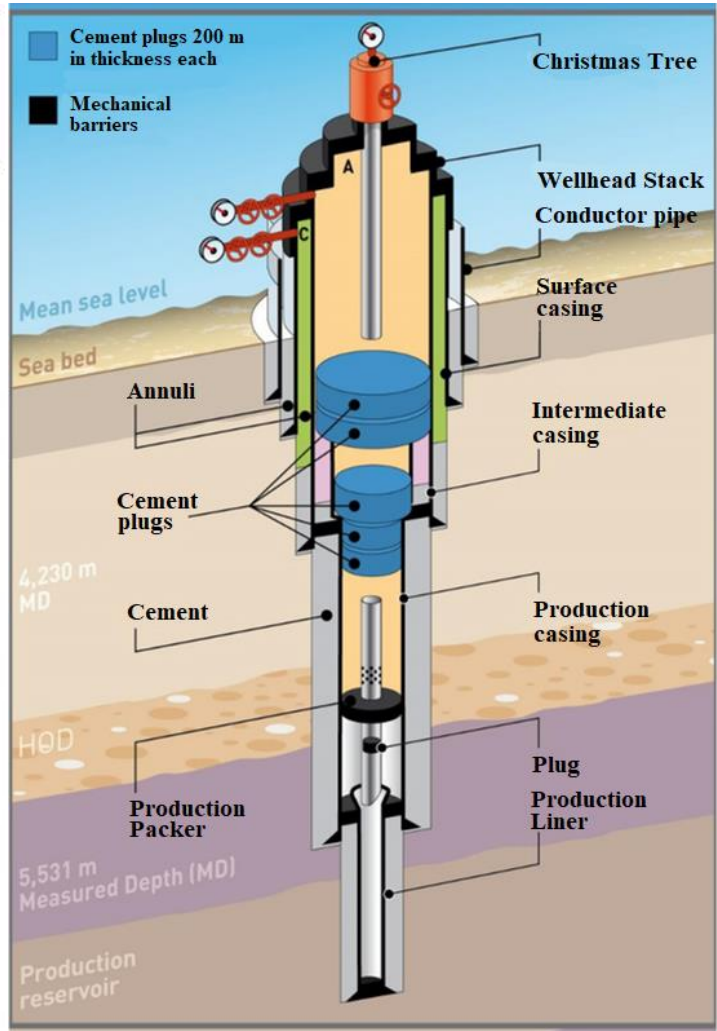
Injectivity and Regularity

- Injectivity and injection regularity critical for success of a CCS storage project (storage of millions of tons of CO₂ in a 50-year time frame)
- For CO₂ 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 CO₂ 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
- CO₂ EOR project economics greatly impacted with injectivity loss and corresponding reservoir pressure loss
- Injectivity loss factors: wettability, trapping, increased scaling, paraffin and asphaltene precipitation. Additional factors: fines migration, borehole deformation, fault intersection, facies variation and shale swelling

Plugging & Abandonment



(Randhol and Carlsen/SINTEF, 2001)



(Source: Gibson, 2016)

Summary

- Imperatives for Success in CO₂ Injection Operations: O&G industry has the technology, knowledge, experience:
 - To safely handle and manage CO₂ 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)