

Operational Flexibility of CO₂ Transport and Storage



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Developments of CCS Implementation

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IEA Greenhouse Gas R&D Programme (IEAGHG)



- A collaborative international research programme founded in 1991
- Aim: To provide information on the role that technology can play in reducing greenhouse gas emissions from use of fossil fuels.
- Focus is on Carbon Dioxide Capture and Storage (CCS)
- Producing information that is:
 - Objective, trustworthy, independent
 - Policy relevant but not policy prescriptive
 - Reviewed by external Expert Reviewers

Objectives



- Review extent of the technical challenges posed by capture, transport & storage of CO₂ from emission sources that do not have consistent compositions or flow rates.
- Flue gas composition
- Challenges posed by flexible pipeline operation
- Implications for variable CO₂ injection into storage reservoirs



Flue Gas from variable sources

- Intermittency in supply & composition on transport & storage
- Coal-fired power plants
- Cement (can be highly intermittent)
- Petroleum refineries
- Gas-processing plants
- Ethanol plants



Flue Gas from variable sources

- Coal-fired power plants – high purity post combustion 99.6 – 99.8%
- Flue gas composition fairly constant 10 – 12% across load range.
- Trend towards variable output with response to market demand & increasing penetration from renewables
- Variable supply likely from single plants.



Flexible Pipeline Operation

- CO₂ pipeline capacity will be affected by operating temperature & pressure. These need to be maintained within operating margin.
- Two-phase flow possible under certain conditions forming liquid CO₂ pools
- Pressure oscillations can lead to cavitation
- Low loads <20% unable to maintain supercritical condition



Pipeline Operation: Effects of Impurities

- Impurities (N_2 , CH_4 and H_2) change physical & transport properties of CO_2
- Affects CO_2 hydraulics
- Could lead to fracture propagation, corrosion & formation of hydrates & clathrates
- Change the capacity of pipelines
- Potentially corrosive especially presence of O_2 & H_2O

Pipeline Operation: intermittency



considerations

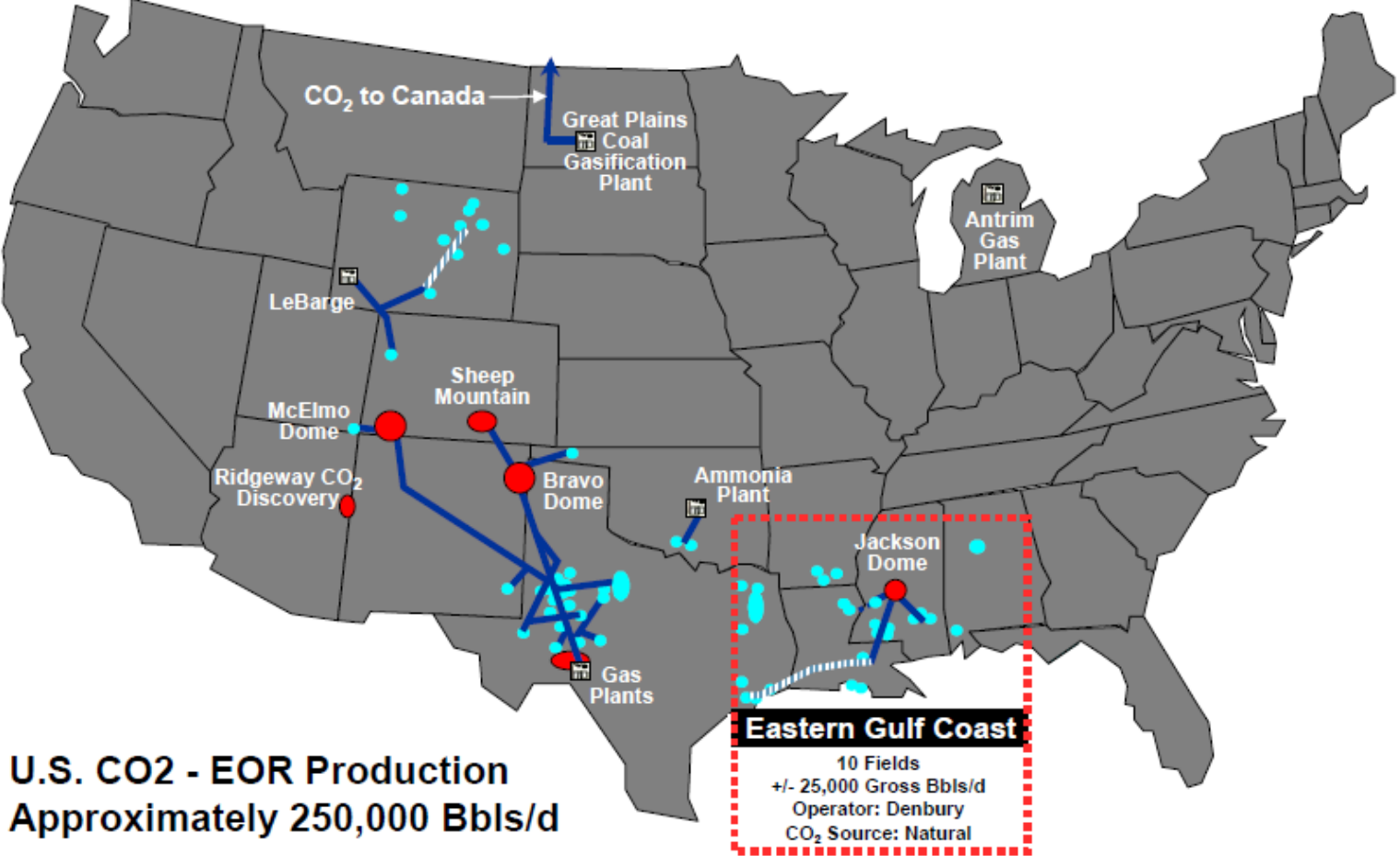
- Extended shutdowns could lead to pressure drops of 6.9 MPa. Supercritical CO₂ freezes at 5.5 – 6.2 MPa so pipeline emptied to avoid embrittlement.
- Depressurisation can only be carried out at compression site for offshore pipelines.
- Hydrate formation possible unless insulation or temperature control applied, or ethylene glycol additive.

Pipeline Operation: Strategies for Flexible Operation



- CO₂ pipeline hubs with multiple sources eg Denver City, McCamey, Rotterdam
- Networks have the option of controlling flow in pipeline if multiple sources are available or dedicated source-sink links – but co-ordination essential.
- Optimised control - avoidance of rapid valve closure, pump shut down or pressure release which could cause damage to pipeline.

CO₂ Pipeline Network and Supply Hubs in US



U.S. CO₂ - EOR Production
Approximately 250,000 Bbls/d

Operational Flexibility in Storage

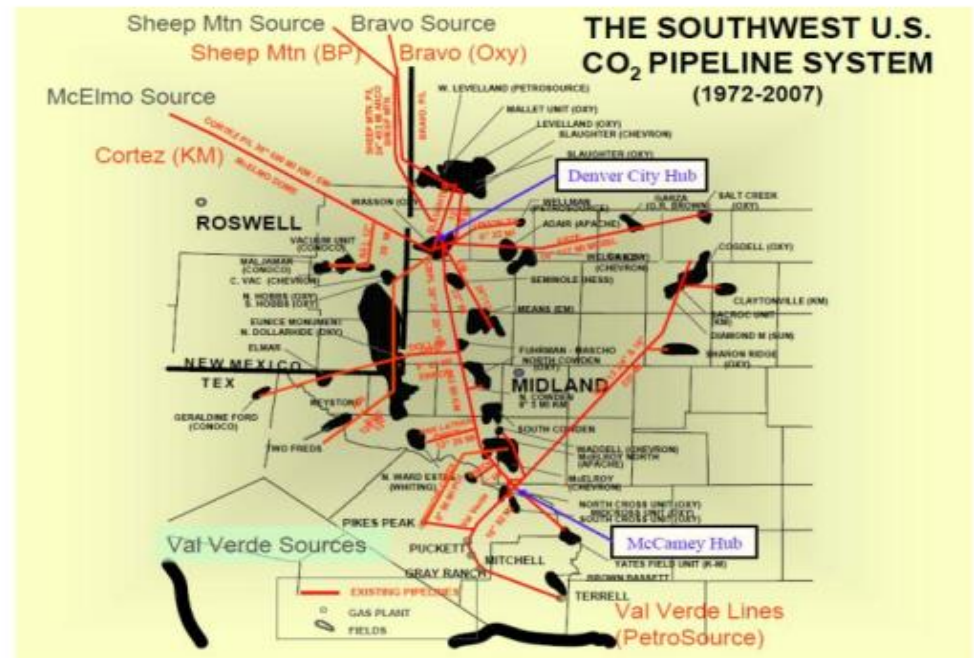


- Variable CO₂ injection into a reservoir for EOR – but unplanned shut-down could affect reservoir pressure, oil miscibility or even precipitation of asphaltenes causing reduction in permeability.
- EOR operators are confident in cyclical or intermittent operations.
- CO₂ EOR generally well planned & with increased quantities &/or wells included. CO₂ recycled
- Intermittent operation can lead to \$ 10⁴ – 10⁶ / day in lost production.
- Intermittency can lead to fatigue & corrosion of wellbore materials

CO₂ EOR Operations in West Texas



Permian Basin oilfield, from Texas Oil: Landscape of an Industry. CLUI photo



Denver City and McCarney CO₂ Hubs (Melzer, 2007) CO₂ Transport – Building on the Current Framework to Meet the Demands of Widely Deployed, Commercial Scale CCS Systems. Pittsburgh, s.n. (CO₂ Pipeline Infrastructure, IEAGHG Report: 2013/18, January 2014).

Operational Flexibility in Storage



- Five full-scale transport-storage examples (Sleipner, Snøhvit, InSalah, Weyburn & Decatur) have each experienced mass flow variability or interruption in flow.
- In DSAs operations fluid production used to control plume shape. CO₂ intermittency likely to be less important.
- CO₂ EOR established technology in US. Multiple well control enables successful injection particularly for pressure control, water disposal & the ability to deal with variable CO₂ supply.
- Confidence in the use of CO₂ for EOR is reflected in the planned increase in the carrying capacity of the Cortez CO₂ pipeline from 19.2 M tonnes /year to 76.9 tonnes /year

Conclusions



- CO₂ sources review from several different sources, Coal-fired plant can provide CO₂ at high purity, post-combustion, but intermittent supply more evident.
- Pressure / temperature conditions need to be maintained within operational margins. Two-phase flow and cavitation is possible.
- Low loads (<20%) should be avoided to sustain supercritical condition.
- Extended shut-downs could mean depressurization and loss of CO₂
- The presence of impurities, particularly O₂ & H₂O, should be minimized to limit physical and chemical damage and hydrate formation.
- There are a number of options for flexible operation to limit the impact of intermittent supply: hubs, linked networks, optimized control, line packing – but co-ordination and planning essential.
- CO₂ EOR has demonstrated that flexible operation can be successful, but unplanned operations present commercial and technical risks

Large scale demonstration has established that intermittent injection

Implications



- Improvement in the understanding of fundamental properties of CO₂ mixtures with impurities and their impact on costs associated with pipeline transport, injection and storage.
- A need for recommended practice and guidance on transmission of supercritical CO₂ that incorporates all industry guidelines and standards
- Experimental research is needed to validate model predictions particularly the behavior of CO₂ with impurities during transient conditions.
- More experience is required to understand the nature of CO₂ flow, including the range of slug speeds and induced stresses on pipelines.
- Improved knowledge of the response of different types of reservoir to intermittent CO₂ flow.



Thank you, any Questions?

References

- IEAGHG CO₂ Pipeline Infrastructure. Report 2013/18, December 2013
- IEAGHG Operation Flexibility of CO₂ Transport and Storage

Variation in System Load

