Operational Flexibility of CO_2 Transport and Storage

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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 CO_2 from emission sources that do not have consistent compositions or flow rates.
- Flue gas composition
- Challenges posed by flexible pipeline operation
- Implications for variable CO_2 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

- CO_2 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 CO_2 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

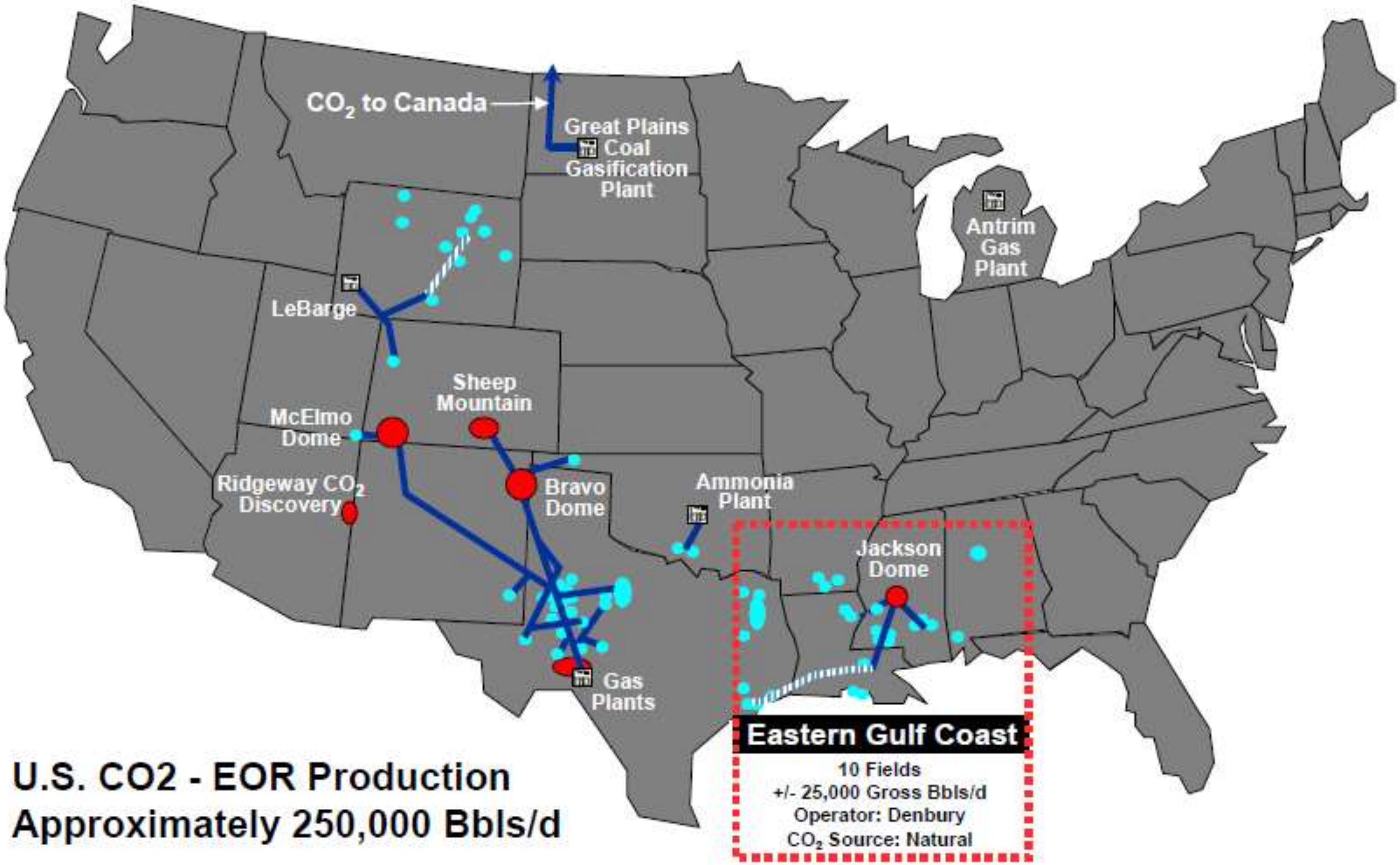
Pipeline Operation: intermittency considerations

- Extendend shutdowns could lead to pressure drops of 6.9 MPa. Supercritical CO_2 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

- CO_2 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.
- Pipeline packing

CO_2 Pipeline Network and Supply Hubs in US



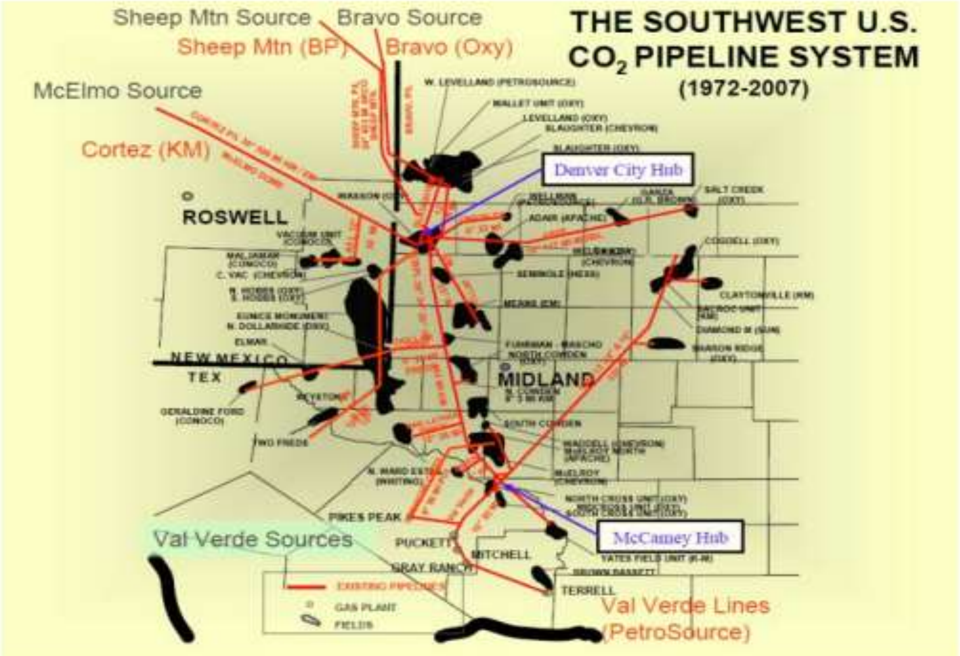
Denbury Resources Inc

Operational Flexibility in Storage

- Variable CO_2 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.
- CO_2 EOR generally well planned & with increased quantities &/or wells included. CO_2 recycled
- Intermittent operation can lead to \$ 10^4 – 10^6 / day in lost production.
- Intermittency can lead to fatigue & corrosion of wellbore materials

CO_2 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 Mett 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. CO_2 intermittency likely to be less important.
- CO_2 EOR established technology in US. Multiple well control enables successful injection particularly for pressure control, water disposal & the ability to deal with variable CO_2 supply.
- Confidence in the use of CO_2 for EOR is reflected in the planned increase in the carrying capacity of the Cortez CO_2 pipeline from 19.2 M tonnes /year to 76.9 tonnes /year

Conclusions

- CO_2 sources review from several different sources, Coal-fired plant can provided CO_2 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 CO_2
- The presence of impurities, particularly O_2 & H_2O, 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.
- CO_2 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 can be achieved.

Implications

- Improvement in the understanding of fundamental properties of CO_2 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 CO_2 that incorporates all industry guidelines and standards
- Experimental research is needed to validate model predictions particularly the behavior of CO_2 with impurities during transient conditions.
- More experience is required to understand the nature of CO_2 flow, including the range of slug speeds and induced stresses on pipelines.
- Improved knowledge of the response of different types of reservoir to intermittent CO_2 flow.

Thank you, any Questions?

References

- IEAGHG CO_2 Pipeline Infrastructure. Report 2013/18, December 2013
- IEAGHG Operation Flexibility of CO_2 Transport and Storage

Variation in System Load