Carbon Sequestration Leadership Forum
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Challenges in the Transition from of CO_2-EOR to CCS

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Technical Challenges in the Transition from CO_2-EOR to CCS

Policy Group Meeting, London, U.K., June 5th, 2014

Background

Origin of the TG Task Force

- At the CSLF Ministerial Meeting in Beijing, P.R. China, in September 2011, the CSLF Charter was amended to include CO_2 Utilization Technologies (the “U” in CCUS)
- On the Storage side, CO_2 utilization means
  - Use and storage of CO_2 in enhanced oil recovery – proven technology! – the objective of the Task Force on “Technical Challenges in the Transition from CO_2-EOR to CCS”
  - In other enhanced energy recovery operations (gas, coalbed methane, shale gas and oil, geothermal) – unproven and/or untested technology

TG Task Force Findings - 1

- There is sufficient operational and regulatory experience for this technology to be considered as being mature, with an associated CO_2 storage rate of the purchased CO_2 greater than 90%.
- The main reason CO_2-EOR is not applied on a large scale outside west Texas in the United States is the unavailability of high-purity CO_2 in the amounts and at the cost needed for this technology to be deployed on a large scale.
- The absence of infrastructure to both capture the CO_2 and transport it from CO_2 sources to oil fields suitable for CO_2-EOR is also a key reason for the lack of large scale deployment of CO_2-EOR.

TG Key Findings - 2

- There are a number of commonalities between CO_2-EOR and pure CO_2 storage operations, both at the operational and regulatory levels, which create a good basis for transitioning from CO_2-EOR to CO_2 storage in oil fields.
- There are no specific technological barriers or challenges *per se* in transitioning and converting a pure CO_2-EOR operation into a CO_2 storage operation. The main differences between the two types of operations stem from legal, regulatory and economic differences between the two.
- A challenge for CO_2-EOR operations which may, in the future, convert to CO_2 storage operations is the lack of baseline data for monitoring.

Recommendation by TG Task Force to the Policy Group

- **In order to facilitate the transition of a pure CO_2-EOR operation to CO_2 storage, operators and policy makers have to address a series of legal, regulatory and economic issues in the absence of which this transition can not take place.**

- **The Policy Group establish a Task Force to examine and address "Policy, Legal and Regulatory Challenges in the Transitioning from CO_2-EOR to CCS"**

Storage of CO_2 in CO_2-EOR Operations

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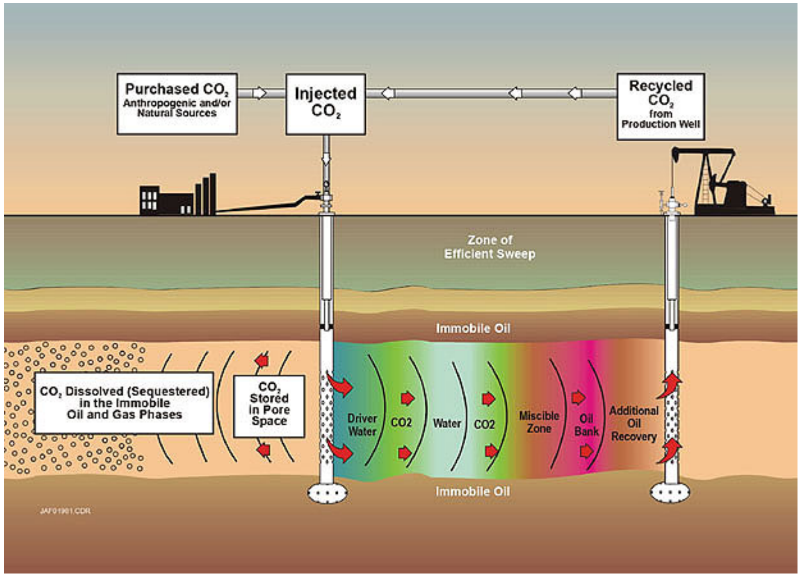
Phases of Oil Production

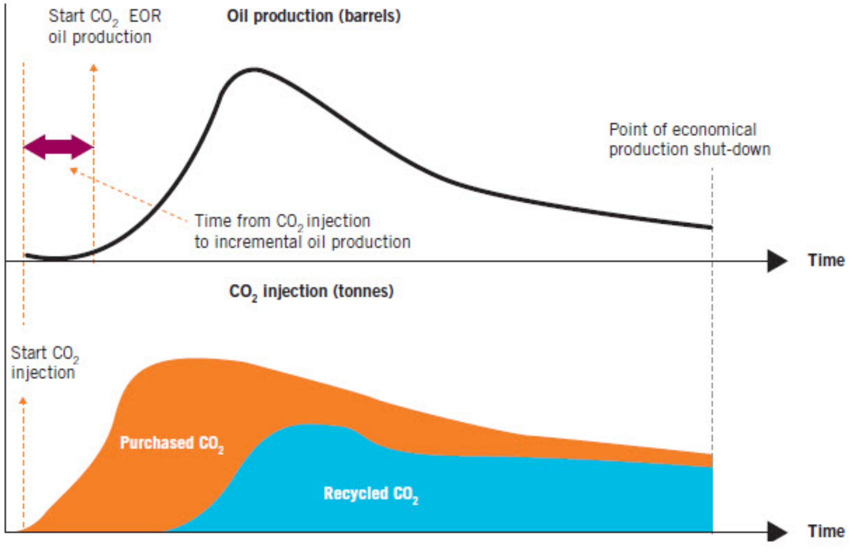
1. **Primary recovery**: oil is produced under reservoir pressure forces. As oil is produced, reservoir pressure declines to the point that production declines. Oil and reservoir water, and gas, if present, are produced at producing wells, separated and:
   a. Oil is sent to market
   b. Gas is vented, flared or captured and sent to market
   c. Reservoir water is disposed off

2. **Secondary recovery**: water is injected in the reservoir to increase pressure and also push oil towards producing wells. Same separation and handling processes apply.

3. **Tertiary recovery**: gas or solvent is injected in the reservoir to lower oil viscosity (e.g., CO_2, natural gas, foams, polymers, steam, etc.), increasing oil mobility and also push it to injection wells

Diagrammatic Representation of a CO_2-EOR Operation





Incidental CO_2 Storage in CO_2-EOR Operations

$$CO_2\,Injection\,Retention = \frac{CO_2\,Injected - CO_2\,Produced}{CO_2\,Injected} \approx 50\%\ on\ average$$

$$CO_2\,Storage\,Retention = \frac{CO_2\,Injected - CO_2\,Produced - CO_2 Losses}{CO_2\,Purchased} > 90\%$$

From an oil-producer point of view, CO_2 losses include CO_2 lost in the reservoir, but from a storage point of view this CO_2 is still stored, as opposed to fugitive CO_2 losses

Legal and Regulatory Differences between CO_2-EOR and CO_2 Storage in Deep Saline Formations

CO_2-EOR	CO_2 Storage in Deep Saline Formations
Commercial O&G Model!	Waste Disposal Model!

CO_2-EOR World Experience

1. **USA: 127 miscible and 9 immiscible, since 1974; >7000 CO_2 injection wells**
2. **Canada: 7 miscible, since 1984, > 80 CO_2 and acid gas (CO_2+H_2S) inj. wells**
3. **Brazil: 3 immiscible, since 1991**
4. **Hungary: 1 immiscible**
5. **Turkey: 1 immiscible since mid-1980s**
6. **Trinidad and Tobago: 5 immiscible, since 1974**

The analysis is based on US and Canada's experience, since both have developed legal and regulatory frameworks in place for CO_2-EOR and CCS

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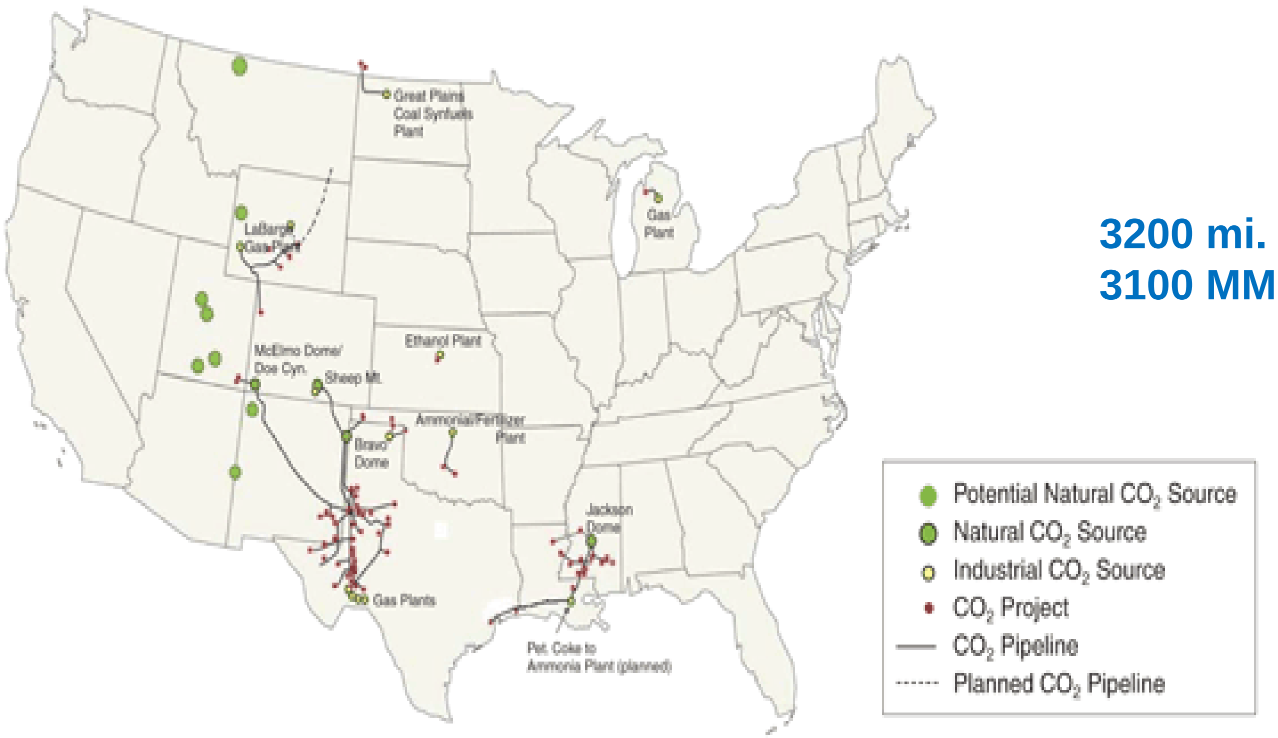
CO_2-EOR in the U.S.



3200 mi. (5150 km) pipeline;
3100 MMcf/d (65 Mt/yr) CO_2

American Oil & Gas Reporter, May 2014

Basic Differences between CO_2-EOR and CO_2 Storage

CO_2-EOR

1. Driven by profit and market forces
2. CO_2 is a valuable commodity
3. Objective: maximize oil production while minimizing CO_2 purchase
4. Reservoir pressure remains below initial pressure, low risk operation to groundwater and other resources

CO_2 Storage in Deep Saline Formations

1. Driven by regulations
2. CO_2 is “waste” to be disposed of
3. Objective: maximize CO_2 storage
4. Reservoir pressure increases above the initial pressure and is limited by regulatory agencies: higher risk!

Where Are the Main Legal and Regulatory Differences between CO_2-EOR and CCS Operations

- Acquisition and transportation of CO_2 are governed in both cases by basic commercial law, and by federal and/or state/provincial regulations regarding pipeline right of access, construction, operation and safety

- Injection of CO_2 is governed by different laws and regulations regarding acquisition of PNG or Mineral rights versus rights to the pore space, well construction, monitoring and liability

Jurisdictional Differences between CO_2-EOR and CO_2 Storage

CO_2-EOR

1. Governments interested in royalties
2. Under jurisdiction of economic departments (ministries)
3. Tenure and permitting under Oil and Gas (PNG) or Mineral legislation
4. Regulated and monitored by State and Provincial Oil and Gas regulatory agencies

CO_2 Storage in Deep Saline Formations

1. Main concerns: safety and permanence of storage
2. Under jurisdiction of environment departments (ministries)
3. Patchwork tenure and permitting
4. Regulated by federal EPA in the U.S. under the Underground Safe Drinking Water Act, by provinces in Canada under injection regulations

Subsurface Ownership

- Private ownership in the U.S. based on surface land ownership ("to the center of the Earth"), including federal lands
- Surface and subsurface ownership is mostly split in Canada, with the Crown generally owning the subsurface rights and minerals
- In Alberta the Province recently legislated Crown ownership of the pore space (for CCS) regardless of the ownership of the mineral rights

Well Construction Differences between CO_2-EOR and CO_2 Storage

CO_2-EOR	CO_2 Storage in Deep Saline Formations
Class II wells in U.S.	New Class VI wells in U.S. based on higher risk

Same well class in Canada

Common law for damage from injection, financial security (bonds) required for wells

Liability Differences between CO_2-EOR and CO_2 Storage

CO_2-EOR

1. Operator liable during operations
2. Operator liable only for wells after abandonment
3. “Orphan Wells” funds established, into which industry contributes, to take care of wells with no owner
4. No liability for the CO_2 left in the reservoir
5. CO_2 can be withdrawn for reuse

CO_2 Storage in Deep Saline Formations

1. Operator liable during operations
2. Where legislation or regulations have been introduced, the operator is liable for wells and the CO_2 in the ground for the duration of the “Closure Period”
3. In some jurisdictions the government agreed to take over long-term liability, in others did not, or no decision was made

Reporting Differences between CO_2-EOR and CO_2 Storage

CO_2-EOR

Depending on jurisdiction, the operator has to report to the state or provincial oil and gas regulatory agency wellhead injection rate, pressure, temperature and composition of the injected CO_2 stream, and the fluids produced at producing wells (oil, water, CO_2, methane) – **Black box material balance**

CO_2 Storage in Deep Saline Formations

Much more stringent reporting requirements to EPA in the US or to provincial and federal environment departments in Canada, including subsurface parameters - **greenhouse gas accounting**

Policy Issues in CO_2-EOR Transition to CCS

1. Policy and regulatory framework for CO_2 storage in oil reservoirs, including incidental and incremental CO_2 storage, for CO_2-EOR to be considered as CO_2 storage operations
2. Legislation for tenure and permitting of CO_2-EOR operations transitioning to CO_2 storage operations
3. Long-term liability for CO_2 storage in CO_2-EOR operations that have transitioned to CO_2 storage
4. Monitoring and well status requirements for oil reservoirs, including baseline conditions for CO_2 storage
5. Reporting of stored CO_2 (it would include purchased CO_2)
6. Jurisdictional responsibility for CO_2 storage in CO_2-EOR operations:
   a) In regard to national-subnational jurisdiction in federal countries, and
   b) Organizational jurisdiction (environment versus development ministries/departments).

Questions and Comments?