

Challenges in CO₂ Capture and Storage: Emphasis on Storage in Geologic Formations

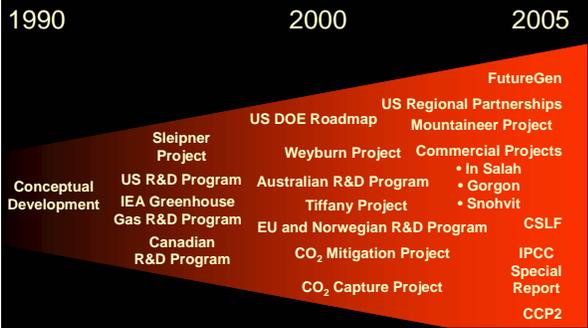
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Overview

- We've come a long way...
- Technical challenges
- Performance requirements
- Public acceptance
- We've come along way... (reprise)

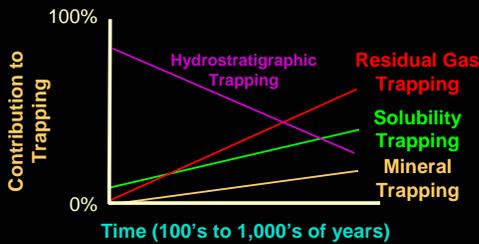
We've Come a Long Way...



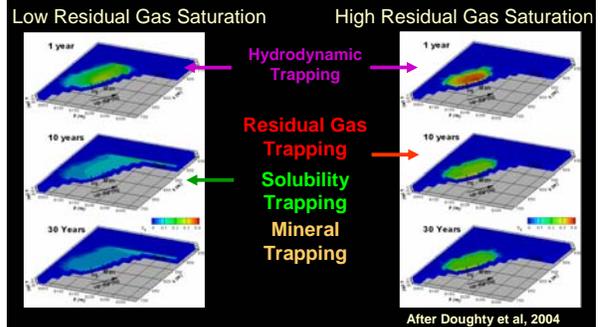
Technical Challenges and Opportunities

- Long term storage security
- Monitoring and verification
- Risk assessment
- Remediation options

Long Term Storage Security



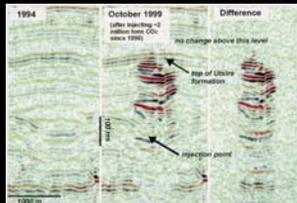
Long Term Storage Security: Frio Formation



Monitoring and Verification

- Safety assurance
- Storage verification
- Early warning of project failure

3-D Seismic Survey from Sleipner



Picture compliments of Statoil

Sleipner – Weyburn – CCP – Frio Formation

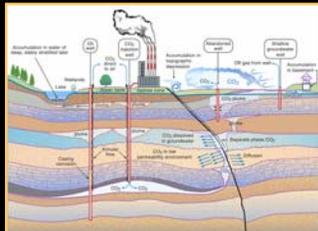
Basic Monitoring Package	Enhanced Monitoring Package
Pre-Operational Monitoring Well Logs Wellhead Pressure Formation Pressure Injection and Production Rate Testing Seismic Survey Atmospheric CO ₂ Monitoring	Pre-Operational Monitoring Well Logs Wellhead Pressure Formation Pressure Injection and Production Rate Testing Seismic Survey Gravity Survey Electromagnetic Survey Atmospheric CO ₂ Monitoring CO ₂ Flux Monitoring
Operational Monitoring Wellhead Pressure Injection and Production Rates Wellhead Atmospheric CO ₂ Monitoring Microseismicity Seismic Surveys	Operational Monitoring Well Logs Wellhead Pressure Injection and Production Rates Wellhead Atmospheric CO ₂ Monitoring Microseismicity Seismic Survey Gravity Survey Electromagnetic Survey CO ₂ Flux Monitoring at limited number of stations (e.g. 10)
Closure Monitoring Seismic Survey	Closure Monitoring Seismic Survey Gravity Survey Electromagnetic Survey CO ₂ Flux monitoring at a limited number of sites (e.g. 10) Wellhead pressure monitoring for 5 years, after which time the wells will be abandoned

Life Cycle Costs: 16¢-19¢/ton
(Discounted @ 10%: 4¢-6¢/ton)

Life Cycle Costs: 27¢-30¢/ton
(Discounted @ 10%: 6¢-9¢/ton)

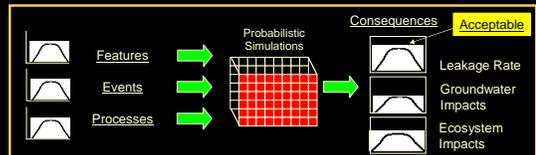
Biggest Risks Have Been Identified

- Leakage through poor quality or aging injection well completions
- Leakage up abandoned wells
- Leakage due to inadequate caprock characterization
- Inconsistent or inadequate monitoring



Risk Assessment Framework

- Modes of failure
- Consequences
- Probability



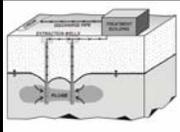
Need for methodology development and validation

Remediation Options to Mitigate Risks

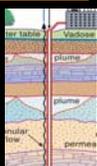
- Storage reservoir leaks



- Groundwater



- Lakes



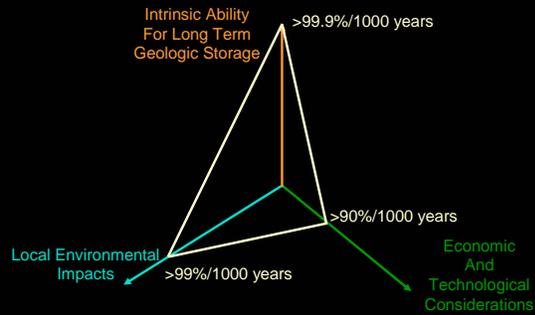
- Leaking wells

Picture taken from <http://www.clu-in.org/download/remed/542r01021b.pdf>

Performance Requirements

- What are they?
 - Specifications that a storage site must meet
 - Permanence of storage
 - Worker health and safety
 - Environmental impacts
 - Well integrity
- Why are they important?
 - Guide for screening and assessing storage sites
 - Basis for obtaining permits
 - Basis for obtaining or trading credits

Performance Requirements or How Long is Long Enough?



Public Opinion

- Favorable public opinion is needed
- CCS is new to the public
- Press has shown recent interest

"A deep underground, ambitious experiment -- called the Weyburn Project -- is underway in the Saskatchewan prairie to determine whether carbon dioxide can be safely buried."

latimes.com



- Public debate will occur in at least 3 venues
 - Government climate policy
 - Environmental NGO's
 - Local communities near storage projects

We've Come a Long Way... (reprise)

- Significant progress in many areas
- Growing interest and investment by the public and private sectors
- Additional R&D is needed:
 - Long term storage security
 - Monitoring and verification
 - Risk assessment
 - Remediation
- Performance requirements must be developed
- Public acceptance is crucial
- Field experiments and demonstrations are needed