



CO₂ Capture Project



Storage, Monitoring & Verification (SMV) Program of the CCP

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BP

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Coal Seq III
Baltimore, MD



Presentation Outline









- CCP Team and Project Organization
- High Level Message
- Technology “Bucket” Summaries
 - Topics & TPs
 - Key Messages
- SMV Key Messages
- SMV Communication Plan



SMV Program Organization

Four Technical Areas (2000-2003)

- Integrity – Competence of Natural / Engineered Systems
- Optimization – Economic Offsets, Efficiency, Transportation
- Monitoring – Performance and Leak Detection
- Risk Assessment – Probability x Consequences, FEPs, Methodologies, Modeling, Mitigation / Remediation

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Integrity

Natural & Engineered Analogs

- CO₂ Reservoirs (ARI)
- Leaky Systems (Utah State)
- Natural Gas Storage Experience (GTI)

Reservoir & Cap Rock Competence

- CO₂ / Rock Changes at Reservoir P&T (GFZ-Potsdam)
- Reactive Transport Modeling (LLNL)

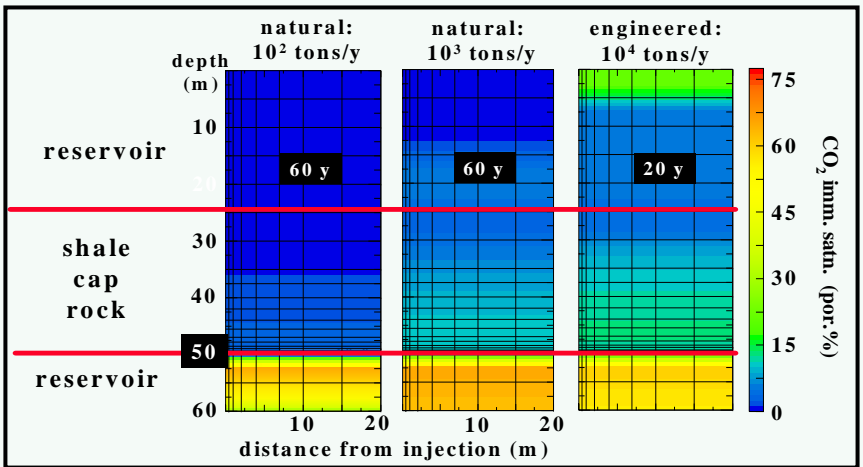
Well Materials

- Cement / Steel Corrosion / Erosion (SINTEF)

Natural geyser system in East-Central Utah



Geochemical and geomechanical response to CO₂ injection





Integrity – Key Messages

- **Geological (Natural) Systems**
 - Competent vs. Leaky Systems are Predictable
 - 4D structural / stratigraphic / hydrogeochemical characterization of analog systems
 - Reactive transport and geomechanical modeling
 - Multiple CO₂ Immobilization Mechanisms Exist
 - Mainly buoyant flow, solubility and relative permeability (hysteresis) trapping
 - Also, brine density convection, long-term mineralization
 - Independent simulations show that most CO₂ is immobilized in 1000-2000 yr.
- **Engineered Systems**
 - Natural Gas Storage Industry is a Favorable Analog
 - Flammability (CH₄) vs. Asphyxiant at high concentrations (CO₂)
 - CO₂ immobilization more effective (solubility & density)
 - CO₂ storage will be deeper and more remote from potable aquifers
 - Installation & operation will involve more safeguards and further from populated areas
 - No seasonal injection and withdrawal
 - Well Integrity is Likely More of a Problem than Geological Features
 - Brownfield – need remediation technique; Greenfield – special materials
 - Abrupt well failure scenarios suggest lower boundary of storage.



Optimization

Hydrocarbon Reservoirs

- CO₂ EOR Record (NMT)
- Gas & Condensate Compatibility (TTU)

Coal Reservoirs

- CBM Potential & CO₂ Capacity (INEL)

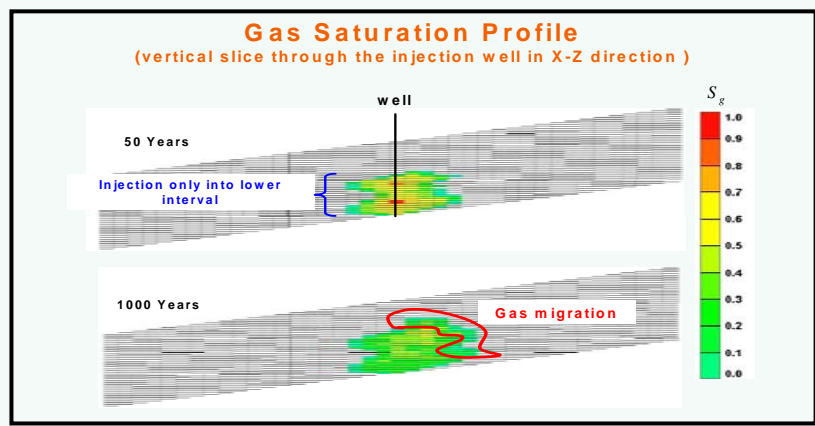
Saline Aquifer Reservoirs

- CO₂ Movement & Immobilization (UT)

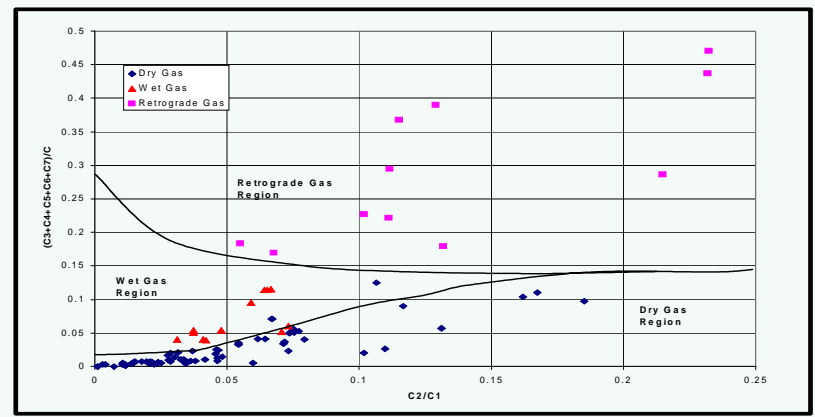
Transportation

- Corrosion & Materials Selection (IFE / Reinertsen)
- CO₂ Impurities (Battelle)

Modeling CO₂ immobilization mechanisms



Assessing compatibility of hydrocarbon gases and CO₂





Optimization Key Messages

Storage Reservoirs

Depleted Oil

- Permian Basin survey shows that oil response, injectivity and breakthrough are biggest problems –
- Need better reservoir characterization;
- Apparently, little is known about CO₂ movement out of zone or to the surface but safety / environmental record is good
- Minimum miscibility pressure & enrichment tool optimizes “solvent design” and anticipates breakthrough composition
- More work is needed on Oil Production vs. ultimate CO₂ storage optimization (economic & technical)

Natural Gas / Condensates

- CO₂ has a large impact on phase behavior thus ECGR and operations
- High compressibility of CO₂ improves storage capacity over that of HC (Are published reports of depleted gas field capacity underestimated?)



Optimization Key Messages

Coal Beds

- Methane content and thus CO₂ storage capacity difficult to predict (N₂ flood data useful)
- Saline Aquifers
- Increasingly sophisticated (and reliable?) simulations predict long term fate of CO₂
- Simulation results appear to converge at “most CO₂ immobilized on the 1000 year timeframe

Transportation

- Current CO₂ Transportation Practices Need to be Challenged Given New CO₂ Storage Venues
- Current model based on US transportation of dry CO₂ under warm conditions
- New model examines wet CO₂ under cold conditions with associated HCs

Corrosion and Materials Selection

- CS corrosion models for hydrated CO₂ at P > 20 bar inadequate; Experiments proved needed data
- Corrosion and hydrate Inhibitor requirements at various PT conditions outlined; Pipeline design alternatives?
- CO₂ Impurities Tradeoffs
- Substantial Effect on Surface Equipment (Amines, Compression Requirements, Pipeline Corrosion)
- Little or no Effect on Injectivity or Reservoir Performance



Monitoring

Geophysical

- Seismic Resolution & Modeling (TNO)
- Seismic Resolution & Costs (LBNL)
- Novel Non-Seismic (LBNL)

Geochemical

- Noble Gas Tracers & Costs (LLNL)

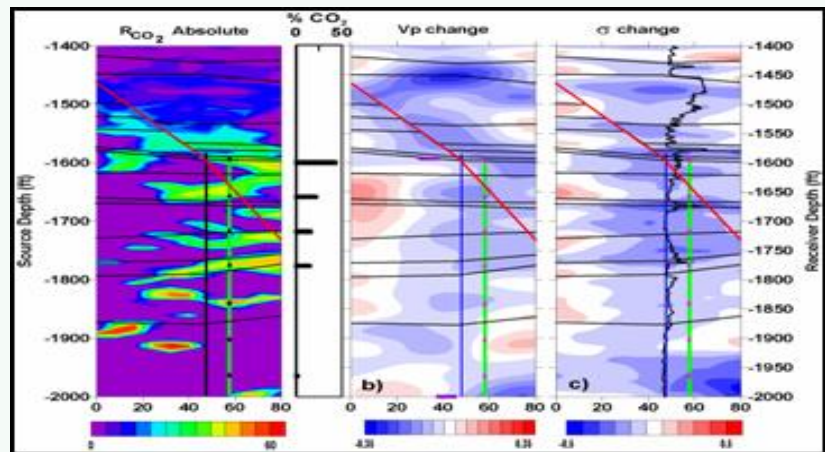
Satellite & Aerial

- InSAR Resolution (Stanford)
- Hyperspectral Geobotanical (LLNL)

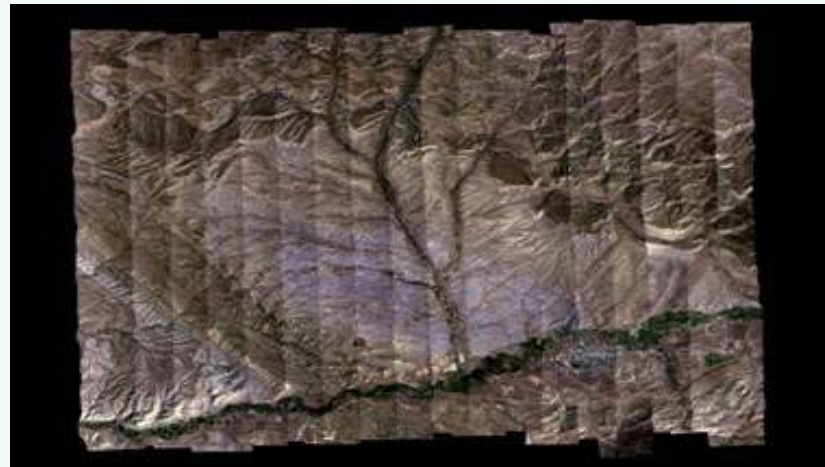
Near Surface, Surface & Atmosphere

- State-of-the-Art & Strategies (Caltech)
- Eddy Covariance (Penn State)

Image Enhancement Using EM



Aerial hyperspectral image of Rangely CO₂ EOR Field, Colorado





Monitoring – Key Messages

- General – Overview of Systems and Their General Applicability to Different Venues and RA
- Geophysical
 - Seismic – Seismic Modeling to Test Resolution of Tools to Different Venues
 - Non-Seismic – Cost-Effective Techniques Stand Alone or with Others (Seismic & Non Seismic)
 - Borehole gravity may be effective upto 1X reservoir thickness
 - EM may be detect 0.5-1.0% anomalies; Used with borehole gravity, best for monitoring two phase systems
 - SP is a low cost approach that deserves further investigation
- Geochemical
 - a. Noble Gas Tracers -Proper Selection may Provide Cost-Effective Performance and Leakage Monitoring
 - b. Other Geochemical Techniques Need Development (Soil, Water)
- Satellite & Aerial
 - InSAR – Preliminary Suggestions that Necessary Resolution to Detect Injection-Induced Ground Movement
 - Hyperspectral Geobotanical
 - Very effective in heavily vegetated areas with high, persistent CO₂ flux using “botanical bands”
 - Application in arid areas with lower or intermittent CO₂ will require use of “mineral bands”
- Near Surface Detectors
 - Assessment of Monitoring Instrumentation Given Site-Specific Parameters Available
 - Diffuse leak detection may have to rely on other techniques (e.g., soil gas collection)
 - Point source leak detection cost-effective using open-path approach
 - Eddy Covariance Method is Well-Established for CO₂ Flux Detection
- Verification will Demand More Rigorous Monitoring Design and Quantification (e.g., Mass Balance)



Risk Assessment – Key Messages

- Comprehensive Methodologies
 - TNO (SAMCARDS)
 - Scenario development is sound and FEP database comprehensive
 - Individual system components tested successfully but whole system testing will come late (natural gas seep; on-/off-shore aquifer)
 - Test of reference saline aquifer shows no leakage over 10000 yr.(1000 realizations)
 - INEL
 - Fundamental data on coal properties and what can be learned from N₂ flooding
 - Consequence analysis on individual elements of system successful
 - Practical information on well placement relative to outcrops and water table
- Near Surface
 - EOR & Natural Gas Storage Have Excellent HSE Records
 - LBNL
 - Scenario development and simulations comprehensive and credible
 - Development of modeling package interface will allow more broad application
- Mitigation / Remediation
 - LBNL
 - Comprehensive, generic classification of leakage scenarios
 - Remediation solution well thought out and will comprise basis for future R&D
- Environmental / Regulatory / Public Perception
 - > 1 Comprehensive RA Methodology Pointing in Same Direction Adds Credibility
 - Scenario development, FEP Database and Calculation Tools May be Major Contribution
 - LBNL Surface Models will be the First / Primary Work Scrutinized by NGOs / Regulators / Public
 - Remediation Study is a First and Provides Opportunity to Draw on Existing Technology and Scope for New Technology Development



CO₂ Capture Project

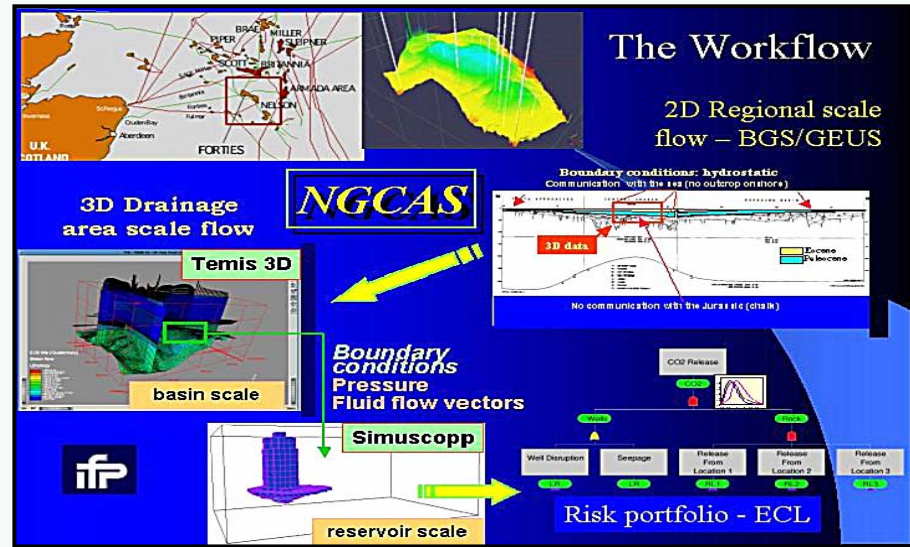
NGCAS

Objective – Need to reduce CO₂ emissions from Grangemouth Refinery. Initiation of 3 yr. JIP to model storage options in Scottish coal fields and in the offshore UK Forties Field in combination with CO₂ WAG.

Results

- BP – Coordination, financial, reporting & technical oversight
- Statoil – Self-funded participant
- BGS – Midland Valley and offshore & Forth Approaches CO₂ capacity
- IFP+GEUS – Basin modeling to determine long-term CO₂ storage integrity due to reservoir / basin changes
- ECLT – CO₂ storage in the Forties Field reservoir simulation RA
- IEA-GHG+CIEMAT+FZJ – Workshops for technology transfer & publication of EU-funded Clean Coal Technology Newsletter (CCTN)

Assessment - Insufficient information



Activity Duration												Deliverable from activity	
NGCAS Yr1			Oct-02 2003			Oct-02 2004							
Oct-02	Q4/01	Q1/02	Q2/02	Q3/02	Q4/02	Q1/03	Q2/03	Q3/03	Q4/03	Q1/04	Q2/04	Q3/04	
[Gantt chart showing activity bars for various tasks across the timeline]												GEOLOGICAL STORAGE TECHNOLOGY 1.1 Methodology for Optimizing storage Volume 1.2 Comparison of storage options 1.3 Risk assessment for long term geological storage 1.4 Options for mitigation of Carbon dioxide leakage 1.5 Report on Costs and Issues TECHNOLOGY TRANSFER AND PROJECT MANAGEMENT 2.1 Quarterly and Annual Progress Reports 2.2 Technical Progress reports 2.3 Technology Transfer Workshops 2.4 Final Technical Reports and Monographs 2.5 Commercialization Strategy 2.6 Socio-economic benefits statement CCP Newsletters Project Coordination	
CCP → EU →													



SMV Communications (LLNL: Benson & SMV Team)

Objective – Publicizing the results of CCP-SMV to the scientific / engineering community and stakeholders

Results

- Literature – 5 publications
 - a. technical volume
 - b. general scientific / engineering review
 - c. high impact article
 - d. general interest
 - e. pamphlet / website
- NGO Focus Group (WDC 11/5/03)
- GHGT7
- NETL
- US & European CCP rollouts
- Film / documentary

Assessment – Some tasks accomplished but a tremendous amount of effort needed to complete