CO_2 Capture Project Phase 2 (CCP2): Storage Monitoring and Verification Program (SMV) An Overview

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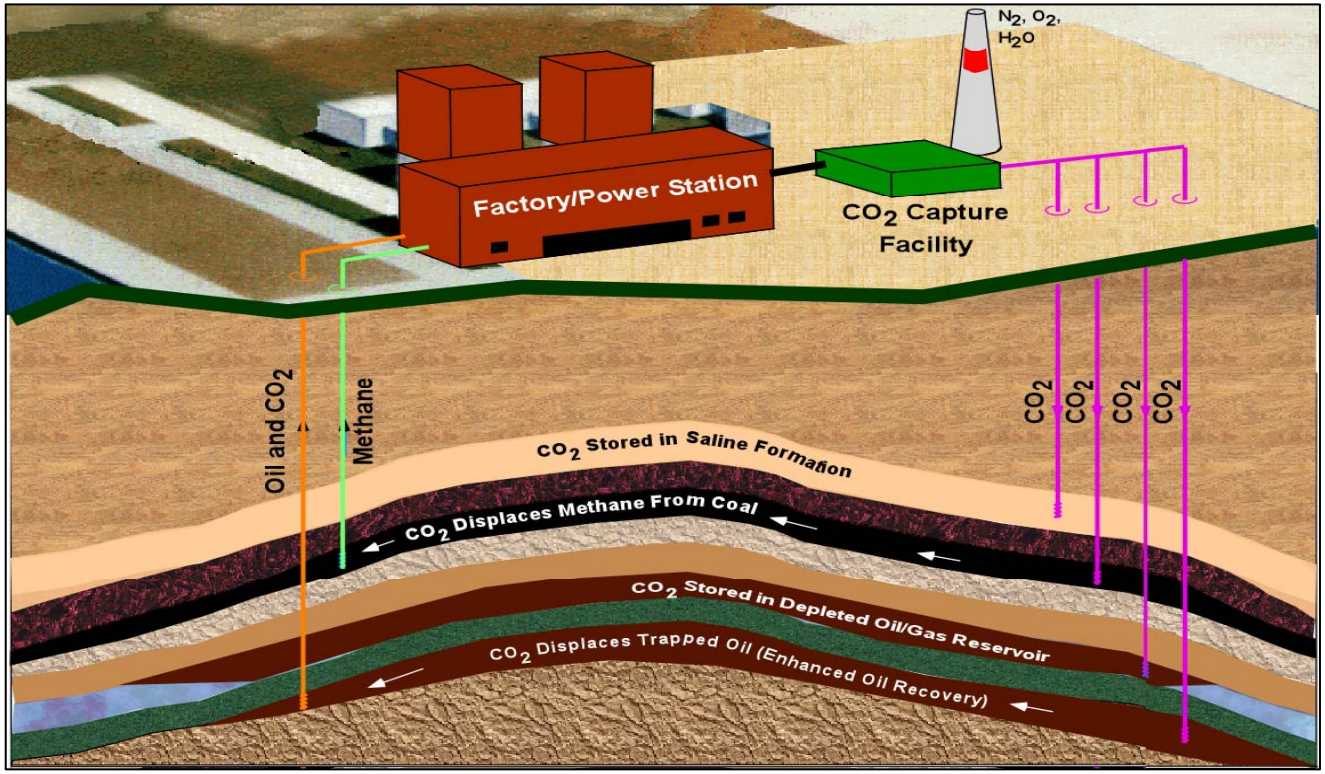
Presentation Outline

Elements of a CO_2 Geological Storage
CCP1-SMV Program Overview
CCP2-SMV Program Overview
Discussion

Elements of Geological CO_2 Storage (1)



Elements of CO_2 Geological Storage (2)

Perceived Priorities

	2001	2006
CO_2 Supply & Purity	L	H
Geological Suitability		
Vulnerable Natural Features	H	M
Well Integrity	L	H
Process Optimization		
Operability	M	M
Offsets	M	H
Monitoring		
Performance	M	H
Unexpected Migration	H	M
Assurance		
HSE Risk Assessment	H	H
Permanence	H	M
Value Chain Economics	L	H

H,M&L – High, Medium & Low

CCP1-SMV Program Overview

CO_2 Capture Project

Four Technical Areas (2000-2004)

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

bp	Christopher (co-lead), Espie, Saunders, Ebrom
ChevronTexaco	Imbus (lead), Woliver, Kieke
Shell	Heidug, Maas
Hydro	Eide, Böe
Statoil	Berger
Eni	Caruso
EnCana	Stachniak
Suncor Energy	Das

CO_2 Capture Project

Integrity

Natural & Engineered Analogs

- CO_2 Reservoirs (ARI)
- Leaky Systems (Utah State)
- Natural Gas Storage Experience (GTI)

Reservoir & Cap Rock Competence

- CO_2 / Rock Changes at Reservoir P&T (GFZ-Potsdam)
- Reactive Transport Modeling (LLNL)

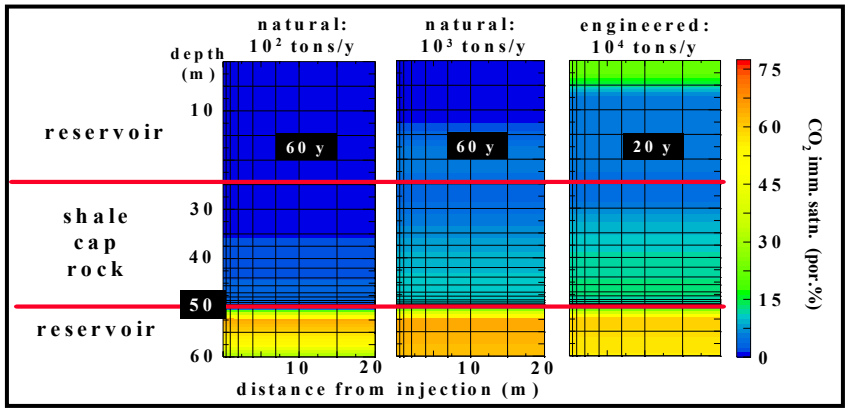
Well Materials

- Cement / Steel Corrosion / Erosion (SINTEF)

Conclusion: 3D geologic models combined with fluid history models address geological integrity although geomechanical effects remain a concern. Well Integrity is more of a concern than geologic integrity.

Natural geyser system in East-Central Utah

Geochemical and geomechanical response to CO_2 injection



CO_2 Capture Project

Optimization

Hydrocarbon Reservoirs
- CO_2 EOR Record (NMT)
- Gas & Condensate Compatibility (TTU)

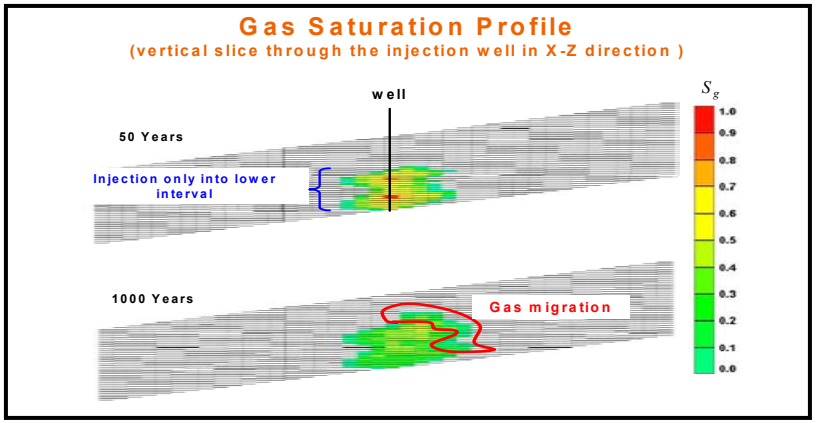
Coal Reservoirs
- CBM Potential & CO_2 Capacity (INEL)

Saline Aquifer Reservoirs
- CO_2 Movement & Immobilization (UT)

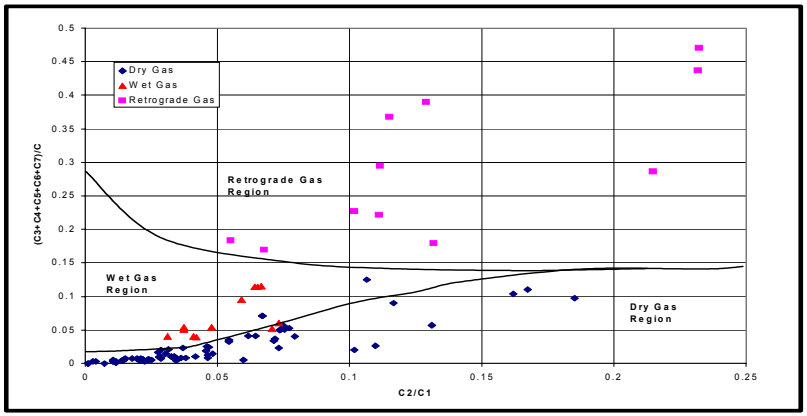
Transportation
- Corrosion & Materials Selection (IFE / Reinertsen)
- CO_2 Impurities (Battelle)

Conclusion: Simulation method development that test avoidance of excessive CO_2 exposure to vulnerable features require further development. New methods for CO_2 enhanced recovery are necessary to take advantage of economic offsets.

Modeling CO_2 immobilization mechanisms



Assessing compatibility of hydrocarbon gases and CO_2



CO_2 Capture Project

Monitoring

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

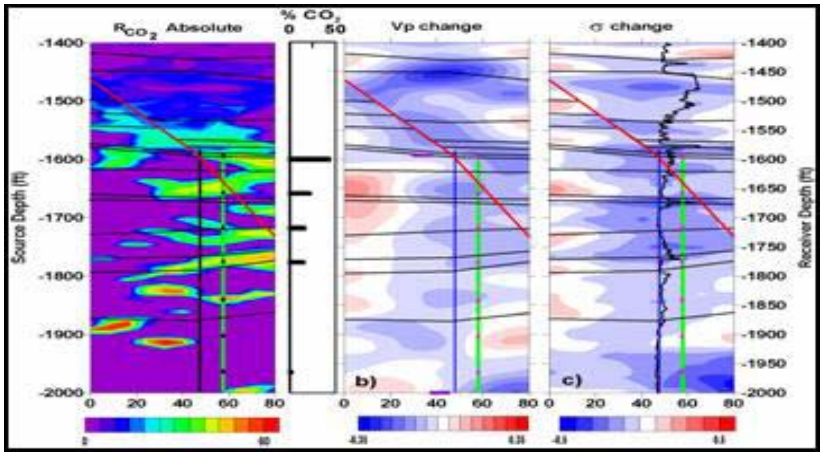
Geochemical
- Noble Gas Tracers & Costs (LLNL)

Satellite & Aerial
- InSAR Resolution (Stanford)
- Hyperspectral Geobotanical (LLNL)

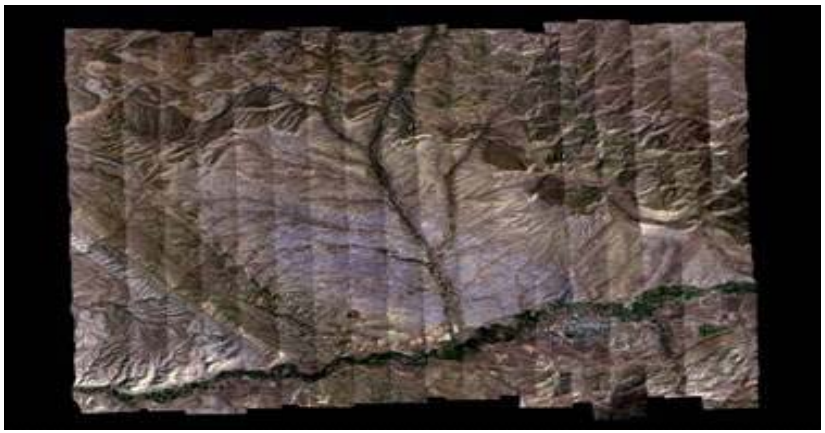
Near Surface & Atmosphere
- State-of-the-Art & Strategies (Caltech)
- Eddy Covariance (Penn State)

Conclusions – Technology exists to monitor CO_2 flood performance and leakage but there are opportunities to reduce costs and improve resolution.

Image Enhancement Using EM



Aerial hyperspectral image of Rangely CO_2 EOR Field, Colorado



CO_2 Capture Project

Risk Assessment

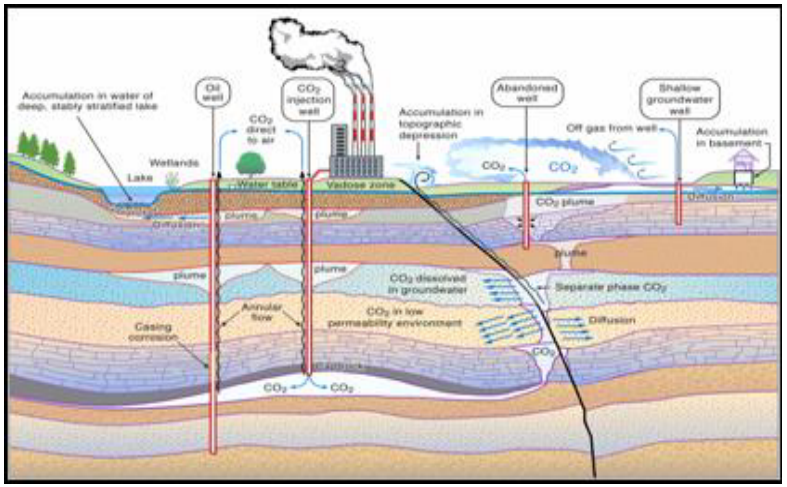
Comprehensive Methodologies
- Tools, Scenarios, Models (TNO, INEL)
- Testing On & Offshore Aquifers (TNO)
- Leakage Risk & Failure Scenarios (INEL)

Mitigation & Remediation
- Leak Scenarios & Response (LBNL)

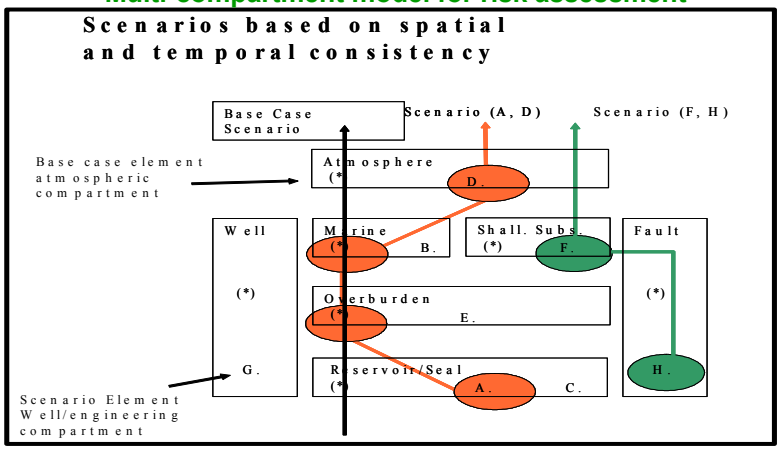
NGO / Regulatory / Public Perception
- HSE Review (LBNL)
- Effect on Subsurface Ecosystems (LBNL)
- Lessons on Honesty & Transparency (MSCI)

Conclusions – Methodology development should be simplified and benchmarked while incorporating input from stakeholders. A link needs to be established between technical assessment of risk and regulatory / policy development.

Leakage and seepage scenarios



Multi-compartment model for risk assessment



European Union | Norges forskningsråd | US Department of Energy | bp | ConocoPhillips | Chevron | Eni | HYDRO | PETROBRAS | Shell | SUNCOR ENERGY

CO_2 Capture Project

CCP2-SMV Program Overview (2004-2008)

CO_2 Capture Project

The CCP2-SMV Team

BP	Charles Christopher (co-Lead) Dan Ebrom Venkataramanan Muralidharan
ConocoPhillips	Chip Feazel Alan Rezigh
Chevron	Scott Imbus (Lead) Dan Kieke
Eni	Antonio Pellagrino
Hydro	Lars Ingolf Eide
Petrobras	Rodolfo Dino
Shell	Nigel Jenvey Tom Mikus
Suncor	Cal Coulter

CO_2 Capture Project

CCP2-SMV Program

Project Slate

- Well Integrity
- Certification Framework
- Operational Parameters
  - Coupled Geochemical / Geomechanical Simulation
  - Efficiency and HSE Limits
- Monitoring
  - Direct Remote Sensing of CO_2 & Methane
  - Novel Geophysical Concepts
  - Well-Based *In Situ* detection
- Pilots & Demos (In Collaboration with US DOE Regional Partnerships)
- Other
  - Integration with Policies & Incentives and Communications

CO_2 Capture Project

Well Integrity

SMV is developing a well "autopsy" and "prognosis" study for use on a decommissioned well that has been CO_2-exposed for 2-3 decades. Scoping is in progress.

- Well selection based on design, production history and logging assessment
- Extensive sampling / analysis of solids and fluids to assess current state
- Experiment on well materials to infer reaction kinetics
- History model developed for alteration over time
- Forward simulation to predict well stability over extended time
- Identification of engineering solutions to vulnerabilities in well design and materials with insight into intervention and remediation efforts

The well integrity study will provide quantitative information on well stability during the operational phase and a realistic prognosis for long term stability. Insight into well design and materials and options for remediation, intervention and abandonment will provide appropriate regulatory criteria.

CO_2 Capture Project

Certification Framework

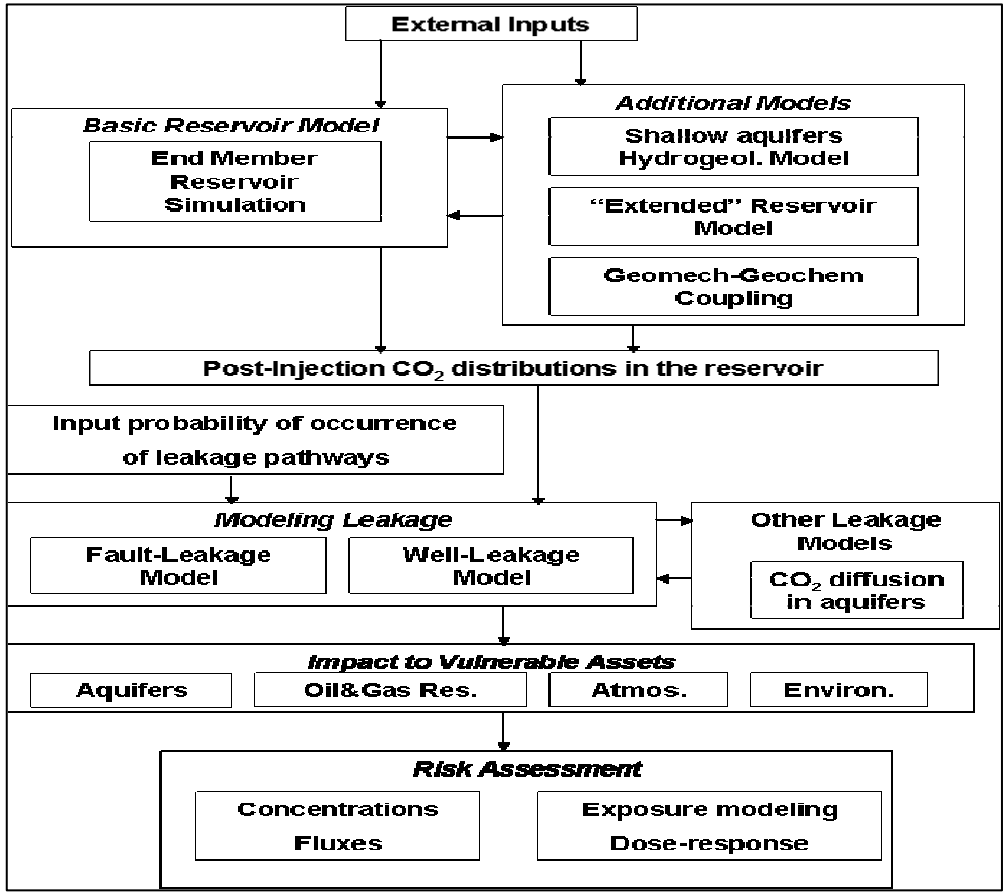
SMV recognized the need for a simple, transparent and systematic process for storage site assessment, including risk assessment. Contracting with Lawrence Berkeley NL and the University of Texas complete with work starting in early 2006.

- Develop generic model
- Simulate CO_2 injection in model reservoir
- Screen leakage and accumulation scenarios at vulnerable assets (e.g., potable aquifers and surface water, soil zones, hydrocarbon deposits)
- Simulate impacts to vulnerable assets
- Risk assessment
- Visualization and stakeholder outreach (convene review panel)

The application developed could comprise the frame work for screening prospects, a ”certification” protocol for regulators and a means of defining success criteria to justify field decommissioning.

Certification Framework (cont.)

Study Work Flow



CO_2 Capture Project

Operational Parameters - Coupled Geochemical-Geomechanical Simulation

Short- and long-term interactions between CO_2 (and its phases) and reservoir-seal fluids and rocks is recognized as near-term operability and lifecycle containment issue. An assessment tool will be developed by the University of Bergen (with a possible inclusion of a second EU technology provider).

- Literature variables and geomechanics code inserted into ATHENE Geochemical effects on porosity / permeability and geomechanics
- Test case 1 (Utsira) and test case 2 (TBD)
- TBD integration with EU effort to assess in addition thermal and hydraulic effects

Coupling of geochemical and geomechanical simulations will be predictive of reservoir-seal integrity and thus guide regulatory field operational and abandonment parameters. The application developed will become public domain once tested.

Co-Funder: Norway Climit

Operational Parameters – Efficiency and HSE Limits

Efficient operating conditions are needed to ensure the technical and economic success of CO_2 storage projects within HSE limits. A coal seam / cap rock simulation program is underway with Sproule associates.

- Data acquisition and initial simulations
- Secondary simulations and model development
- Final simulations and optimal settings / strategies

The operational parameters study is relevant to coal but an analog study could be applied to siliciclastic reservoirs and aquifers. The results of the study may be used to regulate operational parameters and establish system "preservational" conditions necessary for secure field decommissioning.

Co-Funder: US DOE

CO_2 Capture Project

Monitoring – Direct Remote Sensing of CO_2 & Methane

Development of direct aerial CO_2 and methane detection methods would be a cost-effective means of monitoring leakage from CO_2 large storage projects. Study underway at University of California – Santa Cruz.

- Site identification and characterization (landfill calibration and controlled release at Teapot Dome)
- Thermal hyperspectral imaging (adaptation of existing NASA-Ames sensor)
- Data processing, anomaly identification and mapping

This project has high technical risk, but if successful will be useful for GHG monitoring of diverse settings over field-scale.

Co-Funder: US DOE

Monitoring – Novel Geophysical Concepts

Non-seismic geophysical techniques may be of sufficient resolution to monitor CO_2 flood performance and leakage. Coal-bed case study conducted by Lawrence Berkeley NL (with seam model used in Sproule Assoc. "Operational Parameters" study)

- Generation of 3D geophysical models
- Geophysical models run and simulations inverted
- Direct inversion of test data

Non-seismic monitoring methods, if proven, will be a cost-effective and environmentally benign alternative to surface seismic methods. A parallel saline aquifer case is being conducted in collaboration with the Australian CO2CRC.

Co-Funder: US DOE

CO_2 Capture Project

Monitoring – Well-Based *In Situ* Detection

A novel well design that allows accumulation of CO_2 in the subsurface with detection using conventional logging tools. A pressurized vessel containing water saturated sand will be injected with supercritical and vapor phase CO_2. The study is a continuation of the CCP1 2004 study conducted by Schlumberger.

- Design, specifications and materials
- Vessel construction & testing at reservoir T&P
- CO_2 charging and testing of logging tools
- Optimization of fluid accumulation and detection
- Final testing with deployment recommendations

This is a unique approach to CO_2 flood performance and leakage detection that involves modest modification of standard well designs. Early detection of leakage will facilitate intervention decisions and methods.

CO_2 Capture Project

Monitoring – Well-Based *In Situ* Detection (Cont.)

Well-Based In Situ CO_2 Accumulation Chamber (3.5m tall; 16 tonnes when loaded)

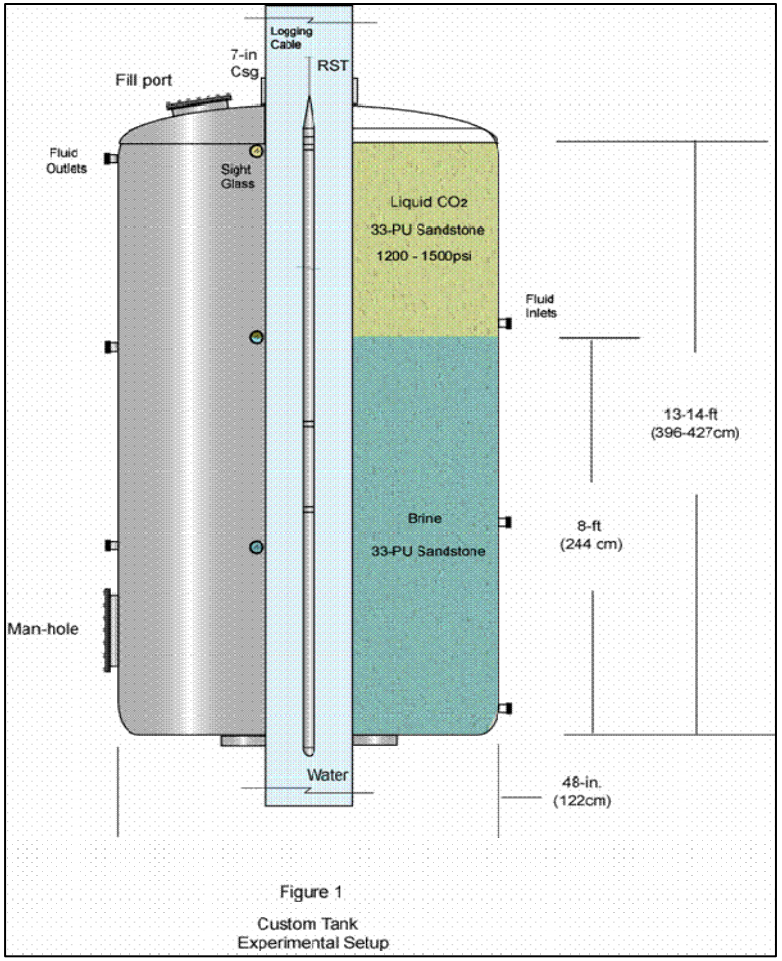


Figure 1
Custom Tank
Experimental Setup

Pilots / Demonstrations

SMV is seeking to engage in pilot / demonstration projects, operated by other organizations, that meet criteria such as:

- coverage of key issues in geological storage,
- match with CCP2 timeframe and objectives and
- opportunity to test CCP2 technologies / protocols

At present, we have agrees to collaborate with two US DOE Regional Partnerships (WestCarb & SECARB)

CO_2 Capture Project

Summary

The CCP2-SMV Team has developed a slate of projects aimed at:

- Addressing remaining and emerging critical issues in containment assurance, particularly wells
- Simplifying models, simulations and protocols to facilitate a systematic assessment of storage sites and regulation thereof
- Continue to develop novel R&D monitoring technologies that, if successful, will reduce costs and leave a smaller environmental footprint.

Established collaborative relationships for pilot / demonstration project involvement that address key technical issues and CCP2 objectives

The SMV team is interested in the NGO and regulatory perspective and is willing to modify project scopes (as it did in CCP1-SMV) to accommodate major concerns

Discussion

- Technical Questions and Clarifications?
- Stakeholder Feedback
  - Does the program address current, high priority issues?
  - How can we best engage stakeholders in the "Certification Framework"?
  - How do we best communicate risk (probability X impact) to stakeholders?
    - Record of Analogs?
    - Familiar Hazards?