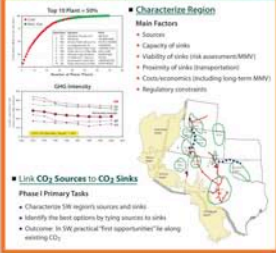
Southwest Regional Partnership – Phase I Analysis and Results

Sixth Annual Conference on Carbon Capture & Sequestration • May 7–10, 2007 • Pittsburgh, Pennsylvania

Presented by Brian McPherson

Who is the Southwest Partnership?

Primary Phase I Goals



Sources of CO_2 in the Southwest

Description of the Southwest Region

Sources

- Electrical power plants
- Cement and other processing plants
- Urban centers
- Non-point sources (agriculture, automobiles, etc.)

Sinks

- Geologic (oil/gas reservoirs, deep saline aquifers, coal beds, natural CO_2 reservoirs, etc.)
- Terrestrial (agriculture, forests, etc.)
- Mineralization engineering (surface)

Infrastructure

- Extensive CO_2 pipeline networks

Point Sources Group

Examine and catalog all point sources of CO_2 in the region, including

- Coal-fired plants
- Gas-fired plants
- Cement plants
- Other processing plants

For Each State in Region

CO_2 Emissions by Source

- Energy usage
- Industry (non-energy)
- Data for 2000

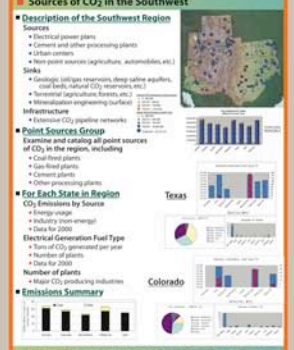
Electrical-Generation Fuel Type

- Tons of CO_2 generated per year
- Number of plants
- Data for 2000

Number of plants

- Major CO_2 producing industries

Emissions Summary



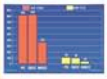
Separating and Capturing CO_2 from the Sources

CO_2 Capture

Reviewed capture literature and capture technologies in use in each state MEA (monoethanolamine) is 'commercial technology'

- Notwithstanding limited data in large coal-fired power plants
- Costs of $40–60 per ton CO_2 captured, including transport + liquefaction
- KJCC is more expensive currently, but results in lower avoided costs when CO_2 capture is required—physical solvents, not MEA are used

CO_2 Capture – New Technology



- New solvents to replace MEA, KS-1 for example, are being commercialized
- Optimized and integrated MEA designs—CO_2 Capture Project—substantial cost reductions
- Oxycombustion—very small-scale testing underway
- IGCC—acceptance despite higher costs
- The avoided cost of CO_2 capture
- Numerous other developments underway—10+ year development time frames

Separating and Capturing CO_2 from the Sources (continued)

Emissions and Capture Summary

- Reviewed capture technologies in use in region
- Capture is expensive—C.O.E. may increase 100% for conventional technology (PC plants, MEA)
- Emerging technology can reduce the adoption costs for CO_2 capture, but COE still goes up 50%
- Incentives, tax credits, emissions trading, technology breakthroughs, additional demonstrations of emerging technology required before CO_2 capture becomes widely employed

Geologic Sinks

Sequestration Themes

- Geologic Systems
- Terrestrial Systems
- Mineralization Engineering

Capacity Results

- Capacity Approach

Pipeline Infrastructure and Major Geologic Sinks

The southwest region has several large geologic basins located on the CO_2 pipelines. These basins also contain numerous power plants. Thus, sources can be readily linked to sinks.

'String of Pearls' Concept

Terrestrial Sinks

What is Terrestrial Carbon Sequestration?

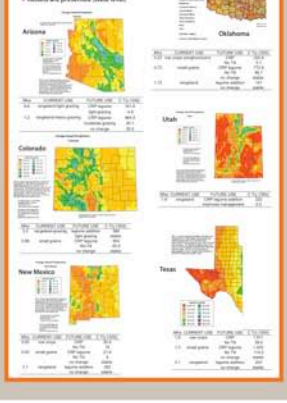
Potential to increase soil carbon storage depends on:

- Precipitation
- Soil fertility
- Soil disturbance
- Land use history

Perhaps the most important point: Sequestering carbon via addition of nutrients or water is reversed when inputs cease

Defining the Potential for Carbon Sequestration

- Yearly annual rainfall must exceed ~25 cm
- Irrigated vegetables not considered
- Forest land (USFS) is not considered; carbon sequestration is tracked by USFS, but land is not managed for carbon
- **Results are presented (state level)**



Education and Outreach

Objectives

1. Identify and respond to needs, fears, and desires
2. Inform about requirements, science, strategies, and technologies
3. Involve in discovery of opportunities
4. Enable negotiation of mutual benefits

Challenges

- Engaging specific stakeholder groups
- Environmental interests are site specific
- Disengaged stakeholders do not see immediate benefit
- Time restrictions (people lack the time to be involved)
- Number of states involved and travel distance

Outreach and Public Involvement Goals Identify

- Capacity of sink

Enable

- Public to evaluate costs and benefits associated with carbon sequestration

Tools

- Web page (dissemination, dialogue)
- Information packet (dissemination)
- Town hall meetings (dissemination, dialogue)

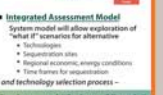
Mediated modeling workshops (dialogue, dissemination)

- In-person interaction
- Information transmission
- Participation by "Industry Advisory Panel"

Integrated Assessment Model

Main Factors

- Sources
- Proximity of sinks (transportation)
- Capacity of sinks
- Viability of sinks (rigorous risk assessment/MMV)
- Costs/economics (including long-term MMV)
- Regulatory constraints
- Public education and approval



Other Screening Criteria

Integrated Assessment Model

System model will allow exploration of "what if" scenarios for alternative

- Technologies
- Sequestration sites
- Regional economic, energy conditions
- Time frames for sequestration

– Support candidate site and technology selection process –

Best Demonstration Options and "String of Pearls"

Choosing the Best Pilot Study Sites

- Over 80 sites considered
- Evaluated and ranked using many criteria

Some criteria included

- Storage capacity
- Diversity of geologic attributes
- CO_2 availability for testing purposes

3 of the 7 Geologic Options were Selected as the Most Promising Opportunities for Evaluation in Phase II

- EOR and deep saline sequestration, **Paradox Basin, Utah**
- ECBM and sequestration, **San Juan Basin, NM**
- EOR and sequestration, **Permian Basin, TX**

"String of Pearls" Concept

Southwest Regional Partnership – Phase II Demonstrations

Sixth Annual Conference on Carbon Capture & Sequestration • May 7–10, 2007 • Pittsburgh, Pennsylvania

Presented by Brian McPherson
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Introduction – *Concept: "String of Pearls"*

In the southwest USA, practical "**first opportunities**" for sequestration lie along existing CO_2 pipelines.

Pilot demonstrations will test short-term strategy: sequester along pipelines

The **demonstrations** include **5** pilot tests of geologic sequestration and **2** terrestrial sequestration analyses –

I. **Aneth Unit, UT** - Deep saline seq.
II. **Aneth Unit, UT** - EOR seq.
III. **SACROC Unit, TX** - EOR seq.
IV. **Claytonville Field, TX** - EOR seq.
V. **San Juan Basin, NM** - ECBM seq.
VI. **San Juan Basin, NM** - Local terrestrial analysis combined with ECBM seq.
VII. **San Juan Basin, NM** - Regional terrestrial analysis

Injection minimum at each site is 75,000 tons per year CO_2 for four years

I & II - Utah Sequestration Demonstrations

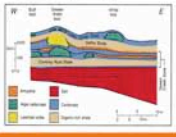
2 Demonstrations –

I. Deep Saline Reservoir Demo - *20,000 tons*

- Injection of CO_2 into Mississippian carbonate Leadville Limestone formation
- Scalability: the Leadville Limestone represents a possible region-wide sequestration target

II. EOR and Sequestration Demo - *150,000 tons/year*

- "Tired" reservoir (Desert Creek Fm.)
- Medium-scale injection (150,000 tons/year for 3 years)



Major Aneth Tasks and Timeline

- Construction of new pipelines (water and CO_2) and facilities began in March 2006
- First phase of CO_2 injection into the main reservoir will begin June 2007
- Deeper Mississippian saline injection may begin Sept 2007
- CO_2 expansion injection stages 2 and 3 (in different parts of field) to begin Sept 2007

III & IV - Texas Sequestration Demonstrations

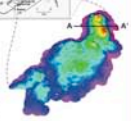
2 Demonstrations –

III. EOR and Sequestration Demo - *350,000 tons/yr*

- Detailed analysis of SACROC Unit, site of 30 yrs of CO_2 injection for EOR
- History match to determine what happened to CO_2 at SACROC

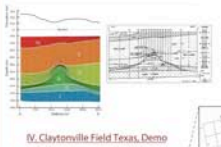
IV. EOR and Sequestration Demo - *300,000 tons/yr*

- New CO_2 injection for EOR and sequestration analysis at the nearby Claytonville field
- Field never previously subjected to CO_2 injection



III. SACROC Unit, Texas, Demo

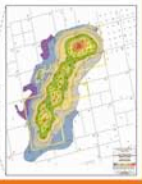
Unit	Formation	Lithology	Horizontal Perm.	Vertical Perm.	Porosity
I	Lower Strawn	Limestone	1.00E-16	1.00E-17	0.20
II	Upper Strawn	Limestone	1.00E-15	1.00E-16	0.20
III	Uncle Canyon	Limestone	1.00E-16	1.00E-19	0.19
IV	Wolfcamp A4	Shale	1.00E-17	1.00E-19	0.10
V	Wolfcamp A1 & A4	Sandstone & Shale	1.00E-16	1.00E-17	0.20
VI	Wolfcamp LS	Limestone	1.00E-16	1.00E-17	0.27



- Current operations inject ~13.5 Mt CO_2/yr, withdraw and reuse ~7 Mt CO_2/yr; net storage of ~6.5 Mt CO_2/yr
- The site has accumulated ~55 Mt CO_2
- In comparison, Sleipner injects ~1 MT CO_2/yr since 1996
- History matching analysis extremely valuable in understanding fate of CO_2

IV. Claytonville Field Texas, Demo

- Geology very similar to that of SACROC (Claytonville is not on Horseshoe Atoll, but is isolated reef buildup on Easter Shelf)
- Planned injection of ~150,000 tons per year of life of project
- Target Reservoir: Canyon Reef Fm - 1737 m depth below surface
- Reservoir has only been subjected to waterflooding
- CO_2 injection will begin March 2007
- This field represents a potentially huge CO_2 storage site

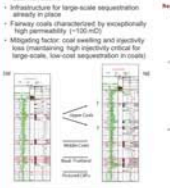


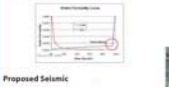
V &VI - New Mexico Sequestration Demonstrations

V. ECBM/CO_2 Test in San Juan CBM "Fairway" - 75,000 tons

Assessed by ARI in DOE-sponsored Coal-Seq project as one of top US coal basins for sequestration:

- Potential storage capacity (12 Gt CO_2, 12% of US total)
- ECBM potential (16 TCF, 10% of U.S. Total)
- Potential value-added storage (predicted net profit of $4–8/ton of CO_2)
- Scalability: results of demo directly scalable to much of San Juan and other coal-rich basins
- Infrastructure for large-scale sequestration already in place
- Fairway coals characterized by exceptionally high permeability (~100 mD)
- Mitigating factor: coal swelling and injectivity loss (maintaining high injectivity critical for large-scale, low-cost sequestration in coals)





Proposed Seismic

- 2-D seismic lines for pre- and post-injection
- Limited area (1/4W around well) VSP is being considered
- Purpose of surveys, in part, is to gain information on geologic structure above coal seams

Ongoing Baseline Monitoring
(full year study began Summer 2006)

- Perfluorocarbon tracers (PFTs)
- Soil gas depth profiles up to one meter (to determination of CO_2 and hydrocarbon concentrations 0% of CO_2 create isotope ratios)
- CO_2 and CH_4 Soil flux measurements
- Radon and Thoron concentrations in soil gas
- Water well monitoring

VI. San Juan Basin Local Terrestrial Demonstration

The ~10 km scale pilot will be conducted in tandem with the ECBM-sequestration pilot: produced water from the ECBM test will be desalinated and used to restore riparian lands

- Two-pronged strategy: enhance existing woody plant species along riprian areas and re-establish native grasses and shrubs in upland areas
- Limiting factor: water, both quality and quantity
- Desalinate CBM/ECBM produced water using zeolite RO membrane (or other technology) for application to rangeland riparian ecosystems
- SWP collaborating with Big Sky Partnership

VII. Regional Terrestrial Analysis

Focus for Phase II will be on Continued Regional Analysis of Terrestrial Sequestration – including Land-use Patterns and Evolution

MMV - Soil Carbon Analyses LIBS %C in soil (mm scale)

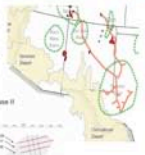
- Monitor differences through time
- Use to calibrate remote sensing

Phase II is focusing on reducing high levels of uncertainty associated with analysis in areas outside the High Plains, including improper land characterization

Phase II will continue evaluation of evolving carbon policy and WTO farm subsidies, which will both impact land-use trends and incentive programs

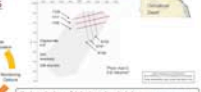
Chihuahuan and Sonoran desert land degradation may be losing C at ~ 1 T C/ha/y

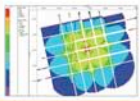
- These lands are roughly ~2.6 Mha in US
- Losses through wind erosion one being evaluated in Phase II



Current work for all sites

- Continued Site Characterization
- MMV
- Risk Assessment
- Regulatory
- Integrated Analysis
- Outreach and Education





Schedule of Major Activities