Kentucky Consortium for Carbon Sequestration

Organization, Goals, and Future

Warren Anderson    John Hickman
Rick Bowersox     Mike Lynch
Jim Cobb          Brandon Nuttall
Steve Greb        Marty Parris
Jim Drahovzal     Mike Solis
Cortland Eble     Kathy Takacs
Dave Harris       Dave Williams

www.kyccs.org
Acknowledgements

- Governor’s Office of Energy Policy – Talina Mathews
  - Sponsor of today’s meeting
  - Work to pass HB 1 and include carbon management in the bill
  - Funding of CO₂ projects at KGS
- Funding from DOE CO₂ Regional Partnerships: MRCSP, MGSC, and SECARB
- Discussions with industry representatives
- Colleagues in KGS Energy Section
  - Early recognition of the significance of CO₂ research to Kentucky
Outline

- HB 1 funding and directives
- Kentucky Consortium for Carbon Sequestration
- Project organization
- Structure of the industry partnerships
- Deep saline reservoir sequestration projects
- Enhanced oil and gas recovery projects
Why Are We Here?

- Kentucky HB 1 was passed in a 2007 special session and signed into law August 30.
- Provides financial incentives for coal gasification plants
- Provides $5 million for carbon sequestration research in Kentucky
- “The Kentucky Geological Survey is encouraged to use these funds to match available federal and private funds to the extent possible.”
2007 HB 1 Directives

- Quantify the potential for:
  - Enhanced oil and gas recovery
  - Enhanced coalbed methane recovery
- Test the Devonian shale for CO$_2$ enhanced gas recovery and CO$_2$ sequestration potential
- Drilling of deep wells in the eastern and western coal fields to estimate sequestration potential
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- KGS realizes that $5 million is not sufficient to accomplish all these goals
- Today we propose a joint industry-government consortium to carry out the directives in HB 1
- The Kentucky Consortium for Carbon Sequestration (KYCCS) will be administered by KGS at the University of Kentucky
KYCCS

- We hope utilities, energy companies, U.S. DOE, and service companies will share costs, provide in-kind services, and help guide the research.

- KGS to select projects and sites, and allocate funds based on technical merit.

- Project sites may be provided by consortium members or others (such as University land).

- Results to be non-proprietary to benefit the whole industry.
Project Areas

- Major coal-producing area
- Coal field
Project Schedule

- Entire funding to be transferred by the end of the year
- Project to require 3 to 4 years for completion
- Project tasks to run concurrently
- Deep drilling to be first priority due to lead time required, identified partners, and costs
- Partners for EOR and EGR projects being sought
Project Organization

- Western Kentucky Deep Sequestration
  - Lead geologists: Rick Bowersox and Dave Williams

- Eastern Kentucky Deep Sequestration
  - Lead geologists: Steve Greb and Cortland Eble

- Enhanced Gas Recovery, Devonian shale (EGR)
  - Lead geologist: Brandon Nuttall

- Enhanced Oil Recovery (EOR)
  - Lead geologist: Marty Parris

- Public Education and Outreach
  - Mike Lynch
Proposed Program Budget

$5 million available for personnel, drilling, well testing, analyses, CO$_2$ purchases, etc.

<table>
<thead>
<tr>
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<th>Industry Match</th>
<th>DOE &amp; other federal</th>
<th>Total</th>
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<td>State Funds</td>
<td>$5 M</td>
<td>?</td>
<td>$15–20 M</td>
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Well Costs are Significant

- Ohio Deep Sequestration well, Tuscarawas County, Ohio, 8,700 ft total depth
  - $2.3 million budget
- MGSC Phase III well, 7,500 ft total depth
  - $4 million budget for drilling, coring, and testing
- Recent Morgan County, Tennessee wildcat, 7,000-9,500 ft total depth
  - $3 million AFE reported by IHS
Well Design and Engineering

- KGS lacks in-house petroleum engineering expertise
- Outside consultants will be used for design of EOR projects, wells, injection tests, and operations oversight
- Will seek in-kind contributions from service companies
While CO\textsubscript{2} EOR potential is significant, deep saline or Devonian shale storage will be needed to handle expected volumes.
Deep Saline Reservoir Projects

- Tests in eastern and western Kentucky
- Depths >2,500 ft; likely 5,000 to 9,000 ft range
- Injection tests with either water or CO$_2$
- Locations to be chosen to provide most data on multiple target zones
- No sites have been considered yet
- Agreement with mineral owner to buy back the well if hydrocarbons are encountered possible
Deep Wells

- Site characterization by KGS and consortium members
  - Subsurface mapping
  - Purchase existing seismic data; acquire new seismic
  - Evaluation of well logs, cores, and well samples
  - Characterize seals
  - Design monitoring plan (subsurface and surface)
  - Permit wells according to regulations for oil & gas wells or EPA-regulated injection wells.

- Well design and engineering
  - Outside consultants and consortium members
Technical Work: Deep Wells

- Obtain whole core and side-wall cores in reservoir and seal intervals
- Run and interpret extensive suite of well logs
- Collect brine samples from target zones for geochemistry
- Analyze core samples for porosity, permeability, mineralogy, mechanical strength, and other physical properties
- Conduct injection tests using fluid, air or CO₂
- Public education and outreach
- Reporting and technology transfer
Deep Saline Targets

- Strata vary in characteristics
- Some are known reservoirs
- Some are potential reservoirs
- Some are seals
- Deep saline reservoirs shown with arrows

Diagram from MRCSP research
Cambrian Sandstones (rift)

- Sandstones deposited in fault-bounded basins
  - Rome Trough - eastern
  - Rough Creek Graben - western
- Confined to grabens
- Faults create trapping mechanisms
- Good porosity in eastern Ky., poor in west (to date)
Rome Trough, Eastern Kentucky
Irvine-Paint Creek shelf

Kentucky River Fault Zone

1,000 feet

Irvine-Paint Creek Fault Zone

Grenville Basement

Rowan KY
Elliott KY
Morgan KY
Perry KY
Wolfe KY
Breathitt KY
Leslie KY

CONASAUGA

ROME
Kentucky potential deep saline reservoirs

Thick Rome Sandstone Wedge (up to 700’ thick)
4 – 5,000 ft. deep
Pre-Knox Well Location Map

Approximate extent of Rough Creek Graben
Conoco Shain: 11,740-760 ft

- Thick immature lithic sandstones dominate in the Conoco Turner and Shain wells
- Minor porosity observed

Conoco Shain: 11,000-010 ft
Mt. Simon Sandstone

- Important saline reservoir in Illinois and the Midwest
- Only deposited north of rift basins in Kentucky
- Thickens and deepens to west, but porosity decreases
- Tested Mt. Simon injection in Louisville, but tight
- MRCSP sequestration demo well into Mt. Simon in Boone County in 2008
- Should we test the Mt. Simon elsewhere in Ky.?
Kentucky potential deep saline reservoirs

Mount Simon Sandstone Isopach Map

No Mt. Simon south of the Kentucky River and Rough Creek FZs

- Based on ~20 wells
Mt. Simon Ss., Louisville, Ky.

- Dupont waste disposal site
- Mt. Simon ~750 ft. thick
- Depth: ~5,500 ft.
- Poor reservoir quality
- Injected into Knox
Mt. Simon may have better properties to east

Tight Mt. Simon Ss at 14-15,000 ft

Porous Mt. Simon Ss at ~6,500 ft
Mt. Simon Ss., Webster County, Ky.

- Near Rough Creek Fault Zone
- About 750 ft thick at 14,000 ft
- Poor reservoir quality
Porous Mt. Simon Ss east of the Rough Creek Graben, Hart and Larue Counties, Ky.
Mt. Simon Depth-Porosity Plot
Illinois Basin

Figure 11—Porosity-depth relationships for 89 samples of Upper Cambrian Mount Simon Sandstone. Open circle = secondary porosity dominant.

- Poor correlation at shallow depths
- Few deep samples

Hoholick and others, 1984, AAPG Bulletin
Knox dolomite

- Formation underlies the entire state
- Includes thick non-porous confining intervals with thinner vuggy porosity zones
- Two waste disposal sites and several gas storage fields have used the Knox
- Dolomite lithology will be more reactive with CO$_2$-saturated brines
- Porosity is erratic, commonly fracture-related: modeling will be challenging
Knox Dolomite, Louisville, Ky.

- Dupont waste disposal site
- Knox \(\sim 2,600\) ft. thick
- Depth: \(\sim 1,700 - 4,300\) ft.
- Injection into vuggy, cavernous dolomite
Dupont WAD1 Fee well, Louisville
Knox Injection Zone

Injection rate of 150 gallons per minute at 175 psi (5,100 bf/d)
Potential Knox zone, McLean Co.

54 ft. zone (>4% porosity)
Porosity range 4-17%
Maximum Porosity 17.4%
Mean Porosity 9.3%
Assumed Perm.: 60 md
Injection pressure: 4,800 psi

Modeled injectivity, matrix porosity only:
5 million cf CO₂ per day
274 metric tonnes CO₂ per day
100,000 metric tonnes CO₂/year

FutureGen would require
10 wells
Deep Saline Summary

- Numerous potential deep saline targets
- All need verification by injection testing
- Where we drill will determine what targets are evaluated
- Plan to include 2-3 zones in each well
CO₂ Enhanced Gas Recovery Project

- Focus on Devonian shale
- Unconventional gas reservoir
- Methane adsorbed onto organic matrix
- CO₂ behaves similarly
Adsorption at 400 PSIA

Average CH₄: 8.1 scf/ton

Average CO₂: 42.9 scf/ton

CO₂ = 5.3 x CH₄

Data from B. Nuttall
CO$_2$ Adsorption at 400 PSIA

\[ \text{CO}_2 \text{ scf/ton} = 7.9 \times \text{TOC} + 20.7 \]

Data from B. Nuttall
Devonian Black Shale Sequestration Potential
(speculative)

Tonnes/sq km

Total:
25.1 billion tonnes

1.2 m³/tonne (40 scf/ton) thickness weighted average
CO₂ EOR Project

- CO₂ injection has been used to enhance oil recovery for over 30 years in other areas
- Limited use of CO₂ in Kentucky to date despite very good results

Problems:
- CO₂ sources, cost, and pipeline infrastructure
- Nature of our oil reservoirs
  - Size, depth, temperature, degree of fracturing
New Sources of CO$_2$ in Kentucky

- Proposed coal gasification plants could provide a CO$_2$ source closer to our producing areas.

- "Waste" CO$_2$ has value, and could improve production in Kentucky oil and gas fields.

- KGS is currently characterizing oil fields for CO$_2$ EOR suitability.
CO\textsubscript{2} for Enhanced Oil Recovery

- CO\textsubscript{2} floods proven to recover 7-25\% additional oil
- Permanent sequestration of some CO\textsubscript{2} in the reservoir
- Produced CO\textsubscript{2} can be captured and recycled
- **Miscible** CO\textsubscript{2} flood:
  - depths > 2,500 ft
  - 10 - 15\% additional recovery
- **Immiscible** CO\textsubscript{2} flood:
  - depths < 2,500 ft
  - 6 - 7\% additional recovery, but can be higher
Oil and Gas Fields of Kentucky

- OOIP: 2.4 billion barrels*
- Gas resource: 125 Tcf
- Production
  - 780 MMbo produced
  - 5.6 Tcf produced

* Does not include 3.4 billion barrels tar sand/heavy oil in W. Ky.
TORIS Database

- Not all reservoirs suitable for CO$_2$ EOR
  - Good reservoir characterization required
- TORIS has detailed oil reservoir data for 46 reservoirs in 36 fields
- Original oil: 1.7 billion bbl
- Remaining oil: 1.3 billion bbl (~75%)
TORIS Fields by Depth

Reservoir Depth (Oil)
- Red: > 2,500 feet
- Blue: < 2,500 feet
- Surface Faults

Map of Kentucky with marker points indicating reservoir depth.
EOR Summary

- Effectiveness of CO$_2$ EOR will vary: screening is important
- Immiscible CO$_2$ floods will be important in Kentucky
- Economics in smaller fields will have to be evaluated
- Problems:
  - Fracturing and other heterogeneities
  - Improperly abandoned wells
- At least one EOR demonstration will be conducted
- Seeking partner(s) to work with
What’s Next?

- Participation decisions requested by Jan. 15
  - Consortium will remain open after that date
- We expect the level of industry funding will vary
- In-kind participation is welcomed
- A company’s participation and funding level cannot be held confidential
- Project results to be released immediately
Impact of Results

- Kentucky geology is not a homogenous “layer cake”
- Research sites will be as representative as possible, however:
  - A successful project will not prove sequestration is possible everywhere, and an unsuccessful project will not condemn the entire state
- This research will be a major step along the path toward carbon management, not the final chapter
Contact Information

- www.kyccs.org
- Dave Harris, dcharris@uky.edu

Kentucky Geological Survey
228 MMRB
University of Kentucky
Lexington, Kentucky 40506-0107

Phone: 859-257-5500
Fax: 859-257-1147