Carbon Sequestration

John A. Rupp

Indiana Geological Survey
Indiana University

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Objectives of this talk:

- Provide basic overview of what sequestration is and how it works
- Lend some insight into the issues of scale
- Discuss current research in the Midwest
- Itemize areas of further work and significant challenges

Carbon Sequestration?

What's that?

- "Carbon" is shorthand for CO_2, carbon dioxide.
- "Sequestration" is code for "removed or isolated from the atmosphere and stored away for a long time".

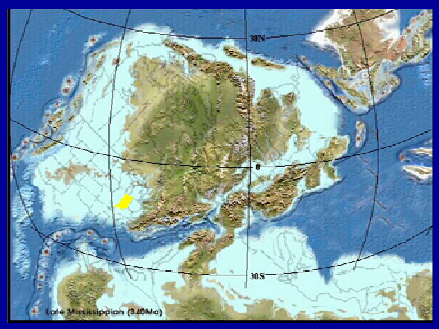
Why sequester CO_2?

- Principle credo = Humans burn fossil fuels which have released ever increasing amounts of CO_2 into the atmosphere causing the mean temperature of the planet to rise ("global warming").
- Theory = Increased CO_2 in atmosphere traps more heat than would normally back reflect out into space.

What is "Global Warming"?

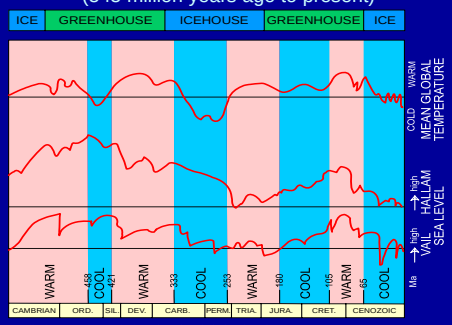
Indianapolis, 10,000 years ago

North America 340 million years ago



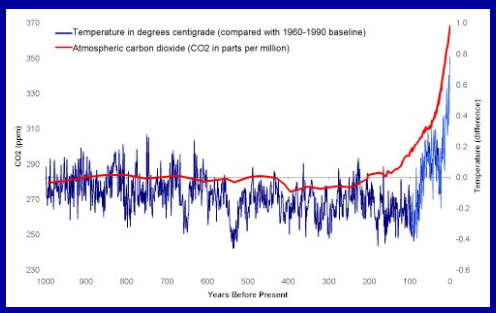
Sea Level and Temperature

(545 million years ago to present)



Modifed from Frakes and others (1992) and Fischer (1981)

Recent Tempurature/CO_2 History



http://www.brighton73.freeserve.co.uk/gw/paleo/paleoclimate.htm

Is it really that simple?

- Is the contribution of *anthropogenic* CO_2 really the "principle driver" (the dominant control) of global climate change?
- Currently there is intense debate in global scientific and policy communities….

Imminent Crisis:

- Climate crisis near 'in 10 years'; "The world may have little more than a decade to avert catastrophic climate change, politicians and scientists say."
  (BBC News, January 24, 2005)

Imminent Denouncement:

- "Climatologist exposes cracks in global warming foundation; even architects of theory now admit they made errors"
  (National Center for Policy Analysis, 7/12/2004)
- "Recalculating the warming trend"
  (Geotimes, 8/04)
- "The denouncement is imminent…"
  (Tech Central Station, 7/21/2004)

Recent News:

- February 16, 2005 Kyoto came into full effect.
- Tony Blair's top priority is climate change
- IPCC findings being re-evaluated

Science and technology

Hotting up

News, cont.

- **Meteorologist Likens Fear of Global Warming to 'Religious Belief'**

  CNSNews.com
  December 02, 2004

  Washington (CNSNews.com) - An MIT meteorologist Wednesday dismissed alarmist fears about human induced global warming as nothing more than '*religious beliefs*.'

  "Do you *believe* in global warming? That is a religious question. So is the second part: Are you a skeptic or a believer?" said Massachusetts Institute of Technology professor Richard Lindzen, in a speech to about 100 people at the National Press Club in Washington, D.C.

  "Essentially if whatever you are told is alleged to be supported by 'all scientists,' you don't have to understand [the issue] anymore. You simply go back to treating it as a matter of religious belief," Lindzen said. His speech was titled, "Climate Alarmism: The Misuse of 'Science'" and was sponsored by the free market George C. Marshall Institute. Lindzen is a professor at MIT's Department of Earth, Atmospheric, and Planetary Sciences.

News, cont.

- **John McCain's 'Global Warming' Hearings Blasted by Climatologist**

  CNSNews.com
  November 19, 2004

  Washington (CNSNews.com) - Recent U.S. Senate hearings into alleged global warming, chaired by Arizona Republican John McCain, were among the "most biased" that a noted climatologist has ever seen - "much less balanced than anything I saw in the Clinton administration," he said.

  Patrick J. Michaels is the author of a new book "*Meltdown: The Predictable Distortion of Global Warming by Scientists, Politicians, and the Media*." He is an environmental sciences professor at the University of Virginia who believes that claims of human-caused "global warming" are scientifically unfounded.

Sampling of scientific voices in the debate:

"other factors are more important"

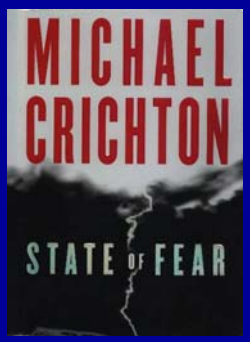
- L. C. Gerhard
- W. Soon
- S. Baluinas
- M. E. Mann

"CO_2 is principle driver"

- S. J. Friedmann
- R. A. Berner
- J. A. Hayes
- S. Tett

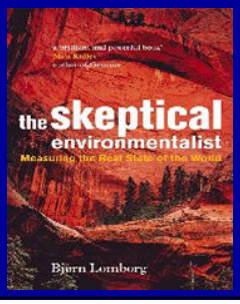
"Fictional" Critic:

- "..the intermixing of science and politics is a bad combination with a bad history.."
- "Critics are few and harshly dealt with"



"Decoupling" (vs. coupling) of the health of the environment with society

Lomborg vs. Diamond



Utilities perspectives:

- "Utilities face the greatest threat since the bulk of the power they generate comes from climate-changing fossil fuels. That's why AEP, Cinergy Corp., and others are probing new technologies that would enable them to capture the carbon as coal is burned. That carbon could then be pumped deep into the ground to be stored for thousands of years."

BusinessWeek, August 16, 2004

Energy industry perspectives:

- "Oil chief: 'my fears for planet'; Shell's boss's confession shocks industry" (Guardian, 6/17/2004)
  - 'Sequestration is difficult but, if we don't have sequestration I see little hope for the world'
- "Exxon head: 'Energy independence is a myth" (Charlotte Observer, 6/8/2004)
  - "as for global warming, Raymond expressed, as he often has, his skepticism about the science"

None the less,

- "U.S. Climate Policy: Toward a *Sensible Center*" (Secretary of Energy, Spencer Abraham, 6/24/2004)
  - "We must address the issue of global climate change. We must act in a serious and responsible way, given the scientific uncertainties. While uncertainties remain, we can begin now to address the human factors that contribute to climate change…"(President G. W. Bush)

GCCI

Economic and emissions growth

- Administration wishes at least 3-4%/yr growth….continued increase in energy demand
- In spite of "increased efficiencies and non-carbon fuels"….need for "*transforming technologies*" (i.e. Sequestration)

Important statistics

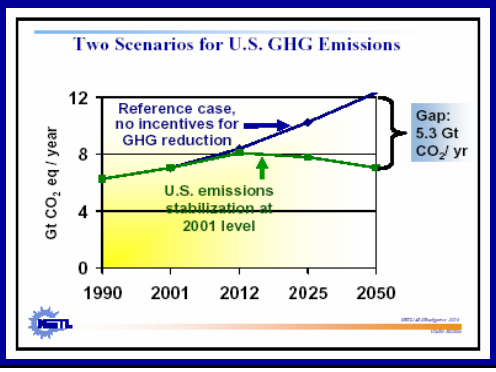
- Globally ~6-7 billion tons of anthropogenic CO_2 (expressed as Carbon equivalent units) emitted into the atmosphere annually
  - 1.5 billion is from U.S.
  - 250 million is from Midwest Region
  - 70 million is from Indiana
- 40% from fossil fuel-powered electricity generation plants (point of "capture")
- Remainder comes from transportation and "agriculture" (burning, harvesting)

EIA and EPA reports 2001; 2002

Important statistics

CO_2 in the earths atmosphere	5.7 X 10^{13} tons/yr
CO_2 emitted by global soil and vegetation	4.7 X 10^{11} tons/yr
CO_2 emitted by the worlds oceans	3.6 X 10^{11} tons/yr
CO_2 emitted globally from fossil fuels	3.2 X 10^{10} tons/yr
CO_2 emitted by worlds fossil fuel power plants	7.4 X 10^{9} tons/yr
CO_2 emitted by global transportation	5.6 X 10^{9} tons/yr
CO_2 emitted by American power plants	2.3 X 10^{9} tons/yr
CO_2 emitted by the world population breathing	3.3 X 10^{9} tons/yr

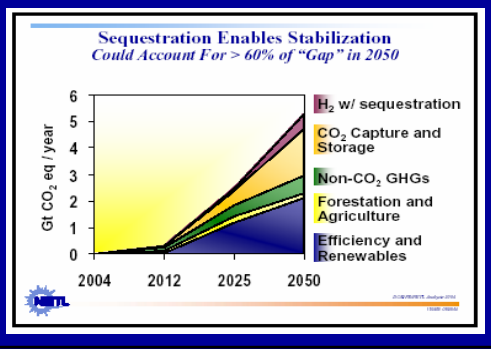
Emissions growth-stabilization



DOE's strategy for reducing CO_2 emissions:

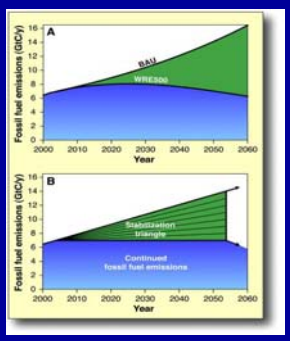
- Efficiency
- Renewables
- Nuclear
- Hydrogen
- "Clean" fossil fuel (i.e. Sequestration)

Addressing the 5.3 Gt "Gap"



Socolow's "wedges"

- Effort needed for 1 wedge (1/7th of total):
  - By 2054, 3500 Sleipners
  - 100 x current U.S. CO_2 injection for enhanced oil recovery (EOR)
  - A volumetric flow of supercritical CO_2 greater than the flow of oil today
- Pacala and Socolow, *Science*, Vol 305, Issue 5686, 968-972 , 13 August 2004



Types of Sequestration

- Basically four types:
  - Oceanic
  - Terrestrial
  - Mineral
  - Geologic

Oceanic

- Inject CO_2 below the depth where pressure keeps it in solution
- Fertilization of algae

Terrestrial

- Soil preservation
- Selective plant cultivation
- Fire suppression

Mineral

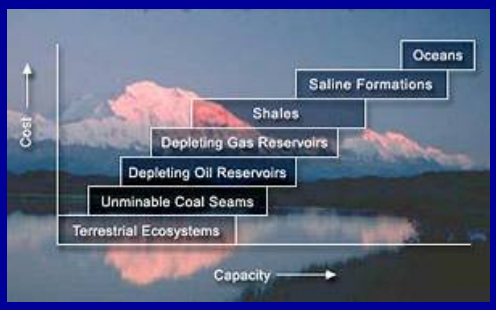
- "Fixing" CO_2 in mineral phases

  (e.g. siderite $FeCo_3$ or calcite $CaCO_3$)

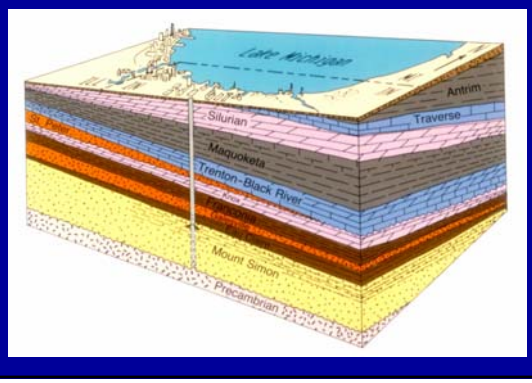
Geological

- Capture, transport and inject into the deep subsurface environment.
  - Brine-filled reservoirs
  - Oil and gas reservoirs
  - Coal seams
  - Organic-rich shales

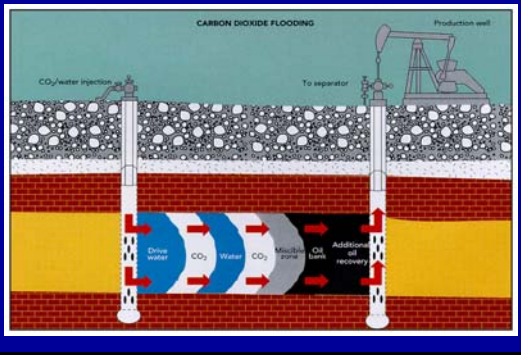
Varying Capacities



Saline Aquifers

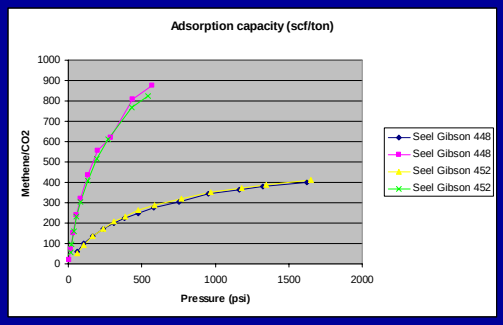


Depleted Oil Reservoirs

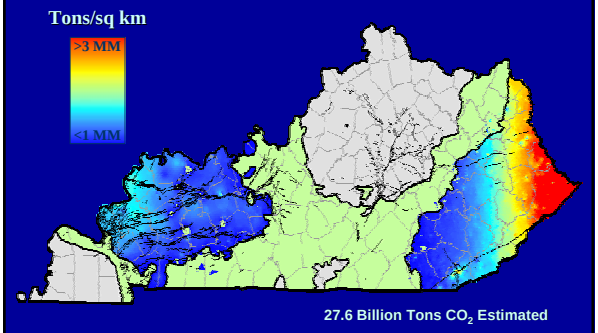


Coal Basin and CBM Reserves

CO_2 vs. CH_4 absorption



Potential for Shale Sequestration



Geological Sequestration Techniques

- All technology is currently available but…
- Currently, costs are very significant
- New capture technologies being developed

Challenges to Deployment

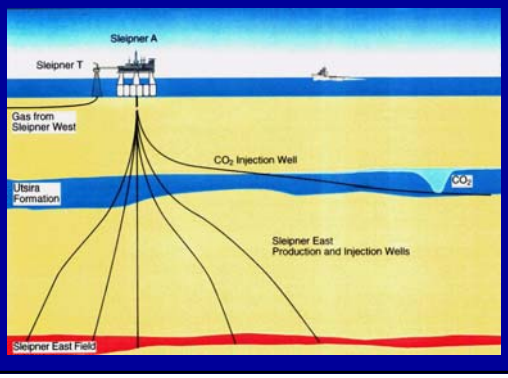
- Scale of deployment needs to be massive
  - therefore cost will be massive
- Significant unknowns in "measuring, monitoring and verification" (MMV)
  - Unknown reactivity in rocks
  - Needs to be secured 99.8% for thousands of years
  - Will it make a difference?

Research to Address Challenges

- Intense research efforts are ongoing in many institutes worldwide
- Large scale experiments ongoing
  - e.g. Sleipner project in North Sea
  - Weyburn project in Canada
  - Coals in New Zealand, Poland

Sleipner Project

Sleipner Injection

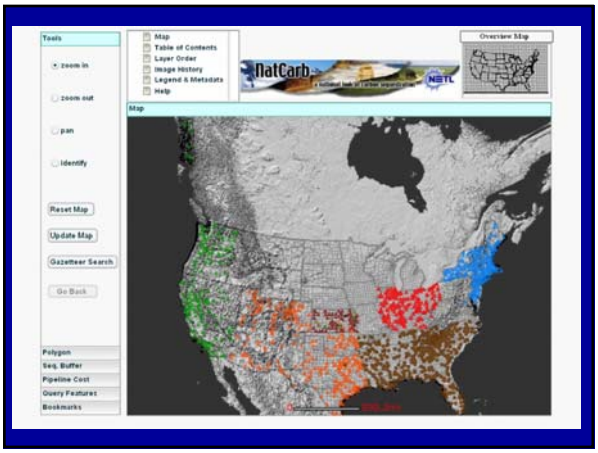


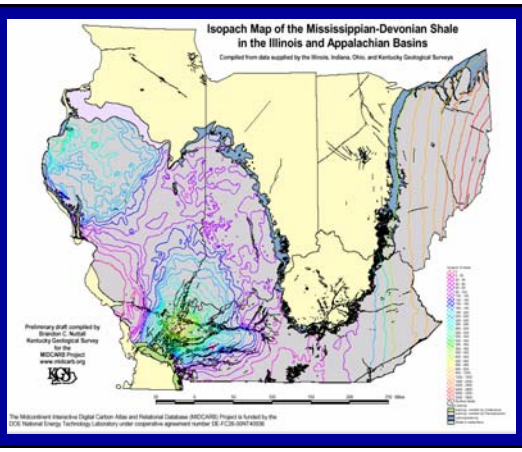
Carbon Sequestration research projects currently ongoing at Indiana Geological Survey:

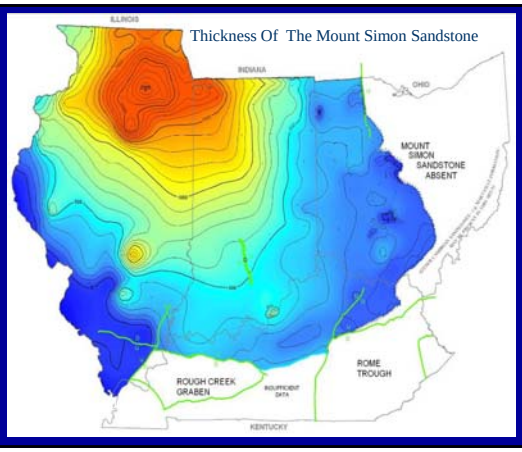
1) MIDCARB (Midcontinent Interactive Digital Carbon Atlas and Relational dataBase) based in Kansas involving KS, IL, IN, OH, and KY.
http://www.midcarb.org

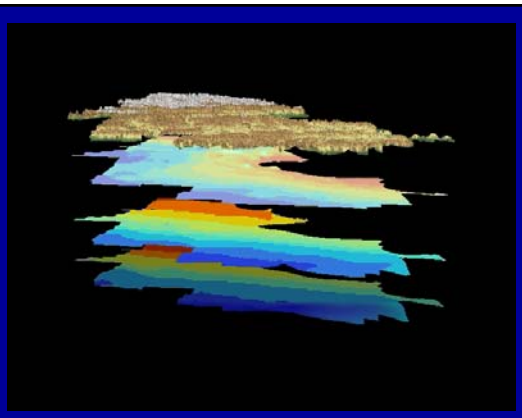
1) MGSC (Midcontinent Geological Sequestration Consortium) based at Illinois Geological Survey involving IL, IN, and KY.
http://www.isgs.uiuc.edu/mgsc

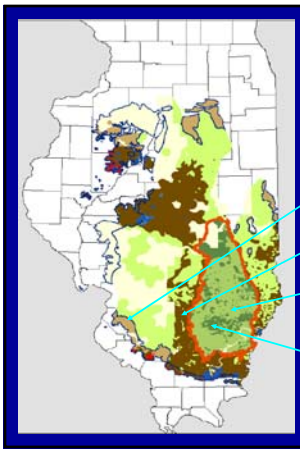
2) MRCSP (Midwest Carbon Sequestration Partnership) based with Battelle in Ohio involving OH, IN, PA, WV, and KY
http://projects.battelle.org/mrcsp/default.stm





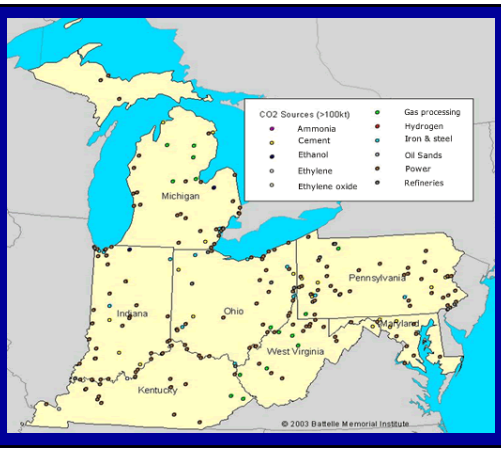




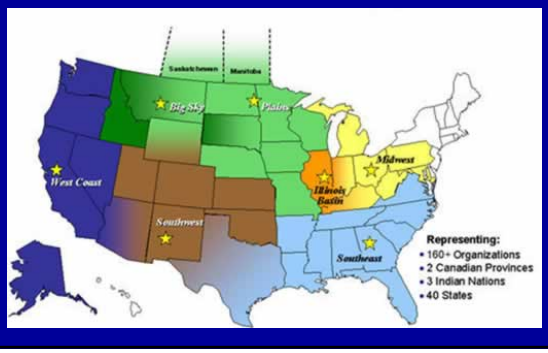


Springfield Coal Resources

- Mined areas at basin margin
- Shallow coals are strippable at < 200 ft
- Coal > 42 in thick is minable at 200 to 900 ft
- Coal > 42 in thick and > 900 ft probable for sequestration
- Coal <42 in thick and > 900 ft most likely sequestration target



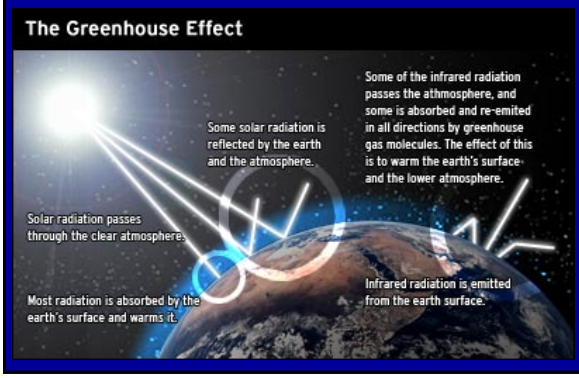
DOE Regional Partnerships



Summary

- Major questions outstanding on the role of CO_2 and relation to global warming
- Mitigating anthropogenic CO_2 emissions will take a very large scale global effort
- Significant challenges face the deployment and use of sequestration technologies
  - Economic
  - Technical
- Research efforts can address some of the challenges but…not comprehensively. Significant unknowns will remain

Conclusion?



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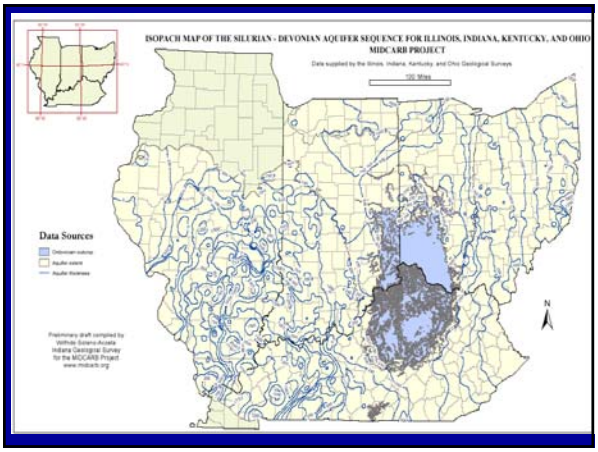
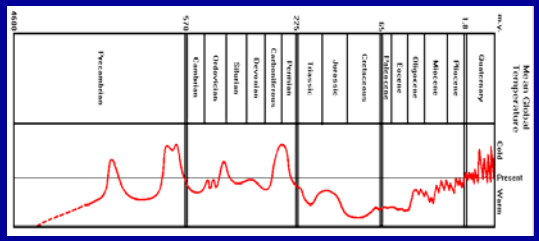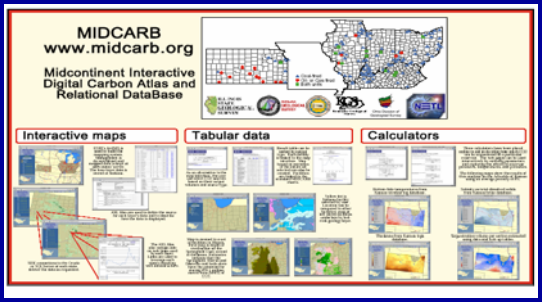
What is “Global Warming”?