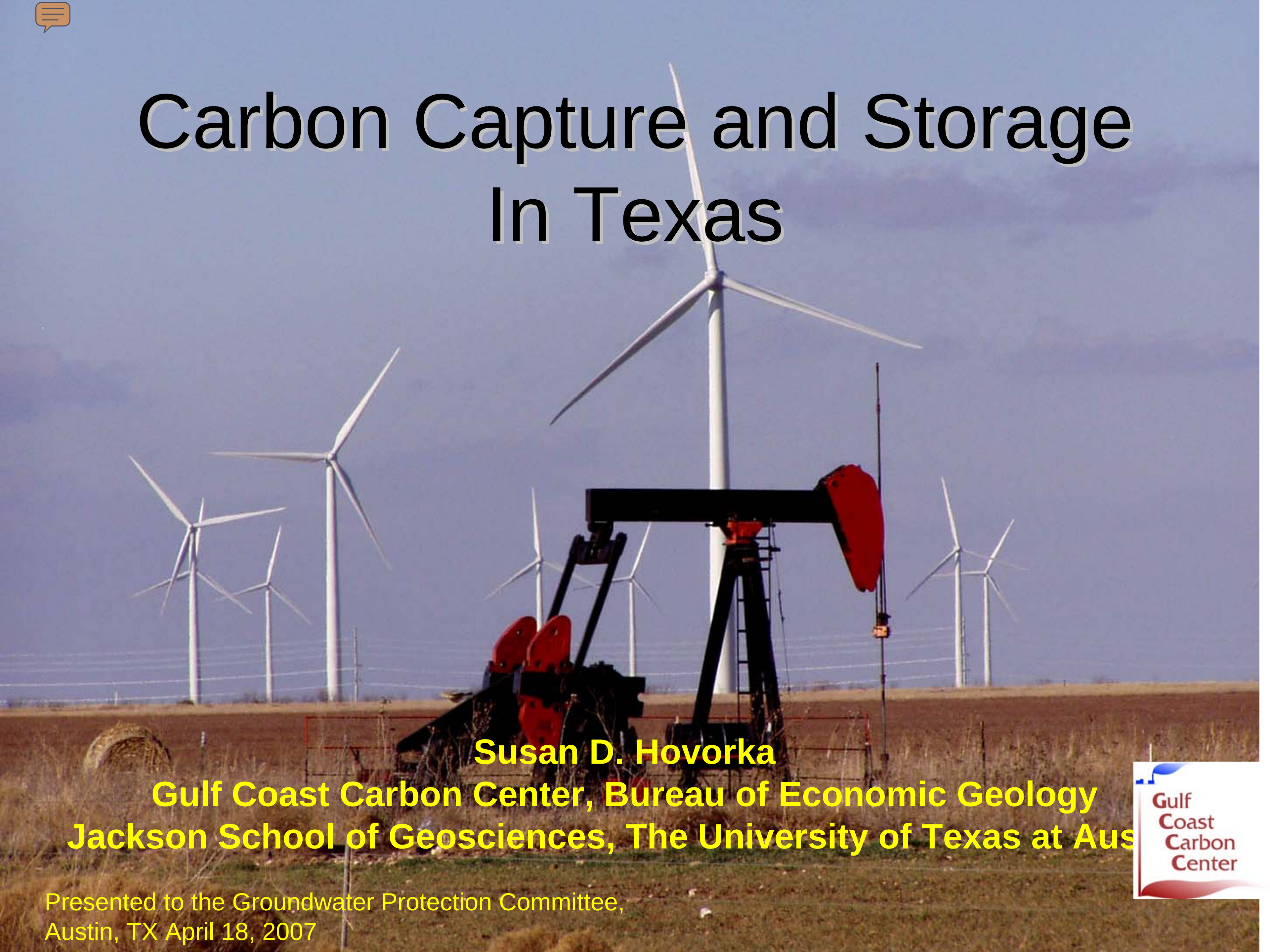

Carbon Capture and Storage In Texas

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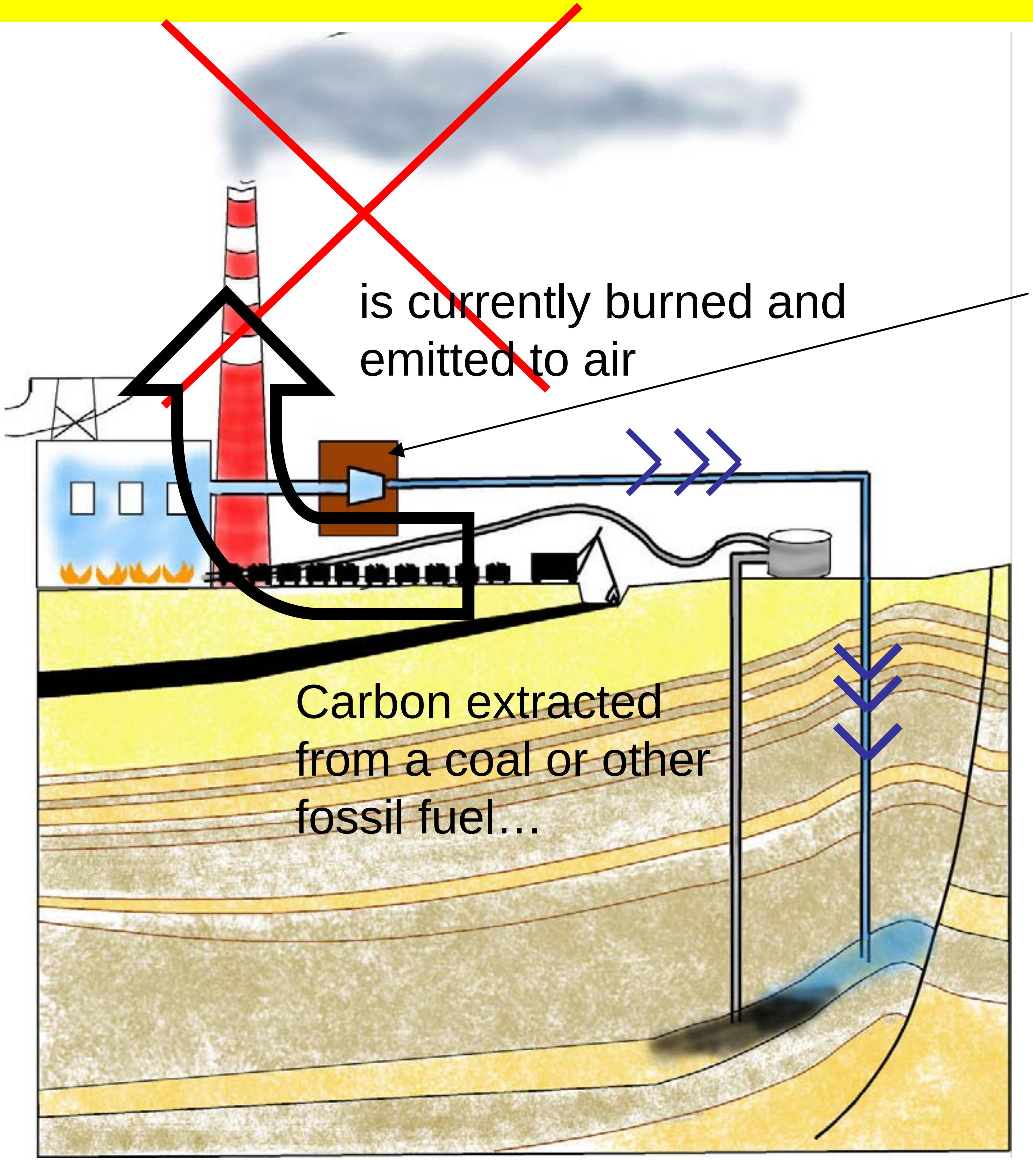
Presented to the Groundwater Protection Committee,
Austin, TX April 18, 2007

What is Geologic Storage?



To reduce CO_2 emissions to air from point sources..

CO_2 is captured as concentrated high pressure fluid by one of several methods..

CO_2 is shipped as supercritical fluid via pipeline to a selected, permitted injection site

CO_2 injected at pressure into pore space at depths below and isolated (sequestered) from potable water.

CO_2 stored in pore space over geologically significant time frames.

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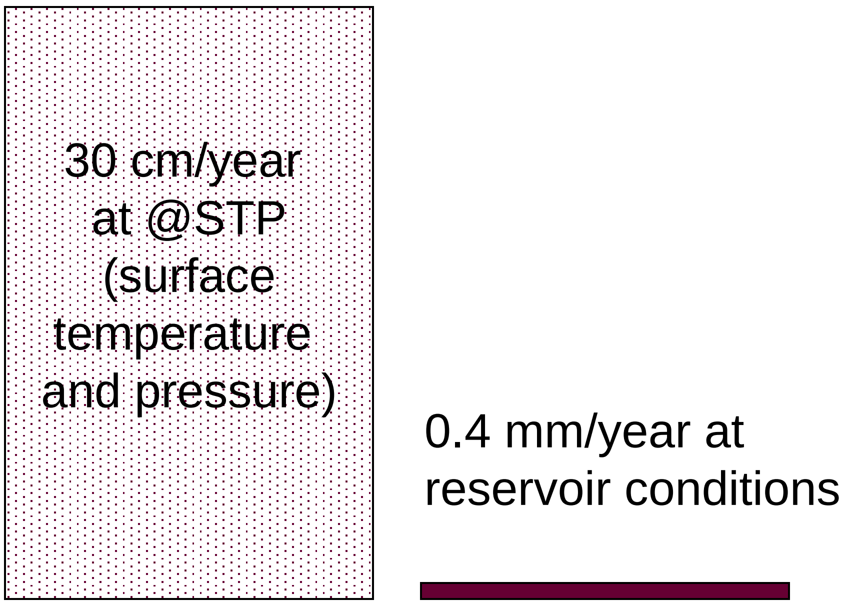
Is geologic sequestration ready to be used as part of a greenhouse gas emissions reduction program?

- Are subsurface volumes are adequate to sequester the volumes needed to impact atmospheric concentrations?
- Is storage security adequate to avoid inducing hazards and to benefit atmospheric concentrations?
- Is the whole system (pipeline, well construction, permitting) mature enough to proceed forward?

Assessing Adequacy of Subsurface Volumes: the Value of Compression

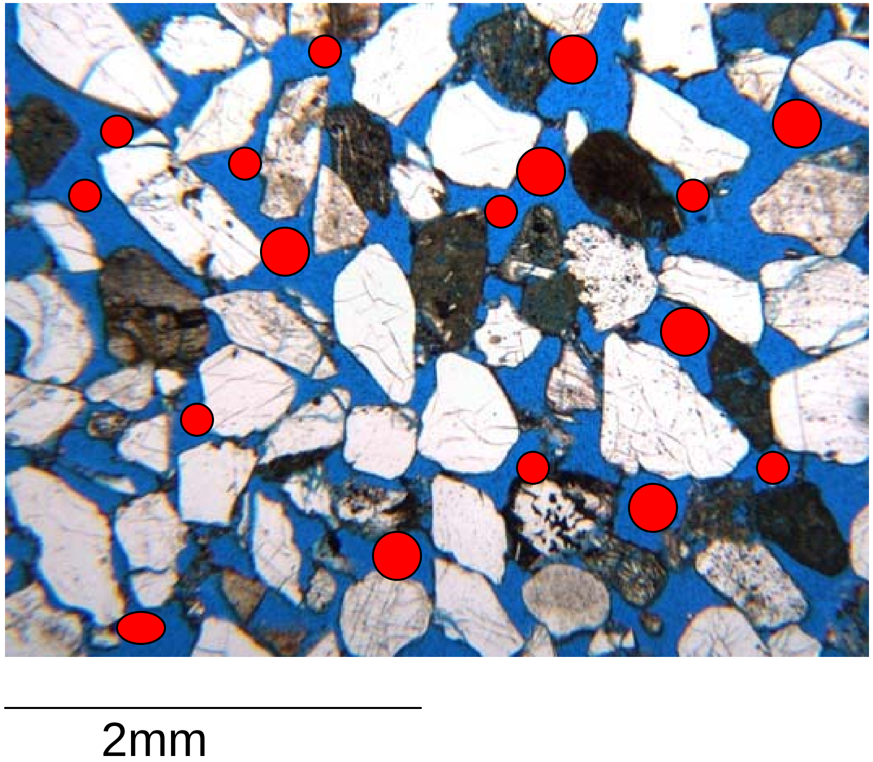
- At depths >800 m CO_2 is stored as a dense phase (1metric ton = about 1.6 cubic m)

Seven Gigatons (7 x 10^9T) CO_2/year US emissions from stationary sources:
if spread evenly over US:



Assessing Adequacy of Subsurface Volumes: Microscope View

- Storage volume is in abundant microscopic spaces (pores) between grains in sedimentary rocks that are now filled with brine (or locally oil or gas)

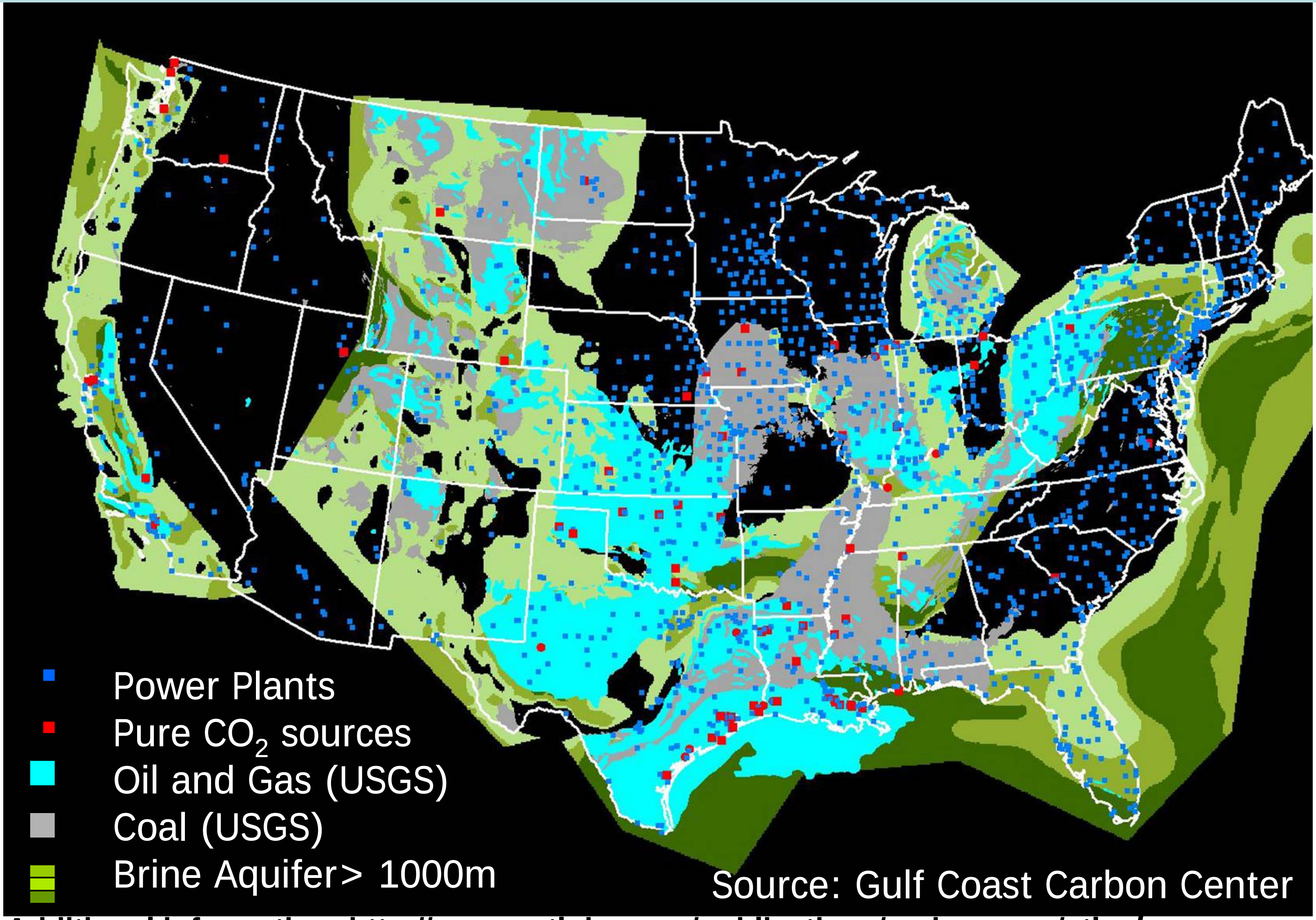


Sandstone thin section photomicrograph, Frio Fm.
Blue areas were filled with brine
now are 10-30% filled with CO_2

Assessing Adequacy of Subsurface Volumes: Distribution

- Pores to store and seals to prevent leakage upward are typical of sedimentary rocks found widely in the US and globally
  - Economically acceptable estimation of pore space commonly done for oil and gas reservoirs using available tools is adapted to brine-filled volumes
  - Not all sedimentary rocks are equally well known – confidence of estimates of storage volume is variable.

Assessing Adequacy of Subsurface Volumes

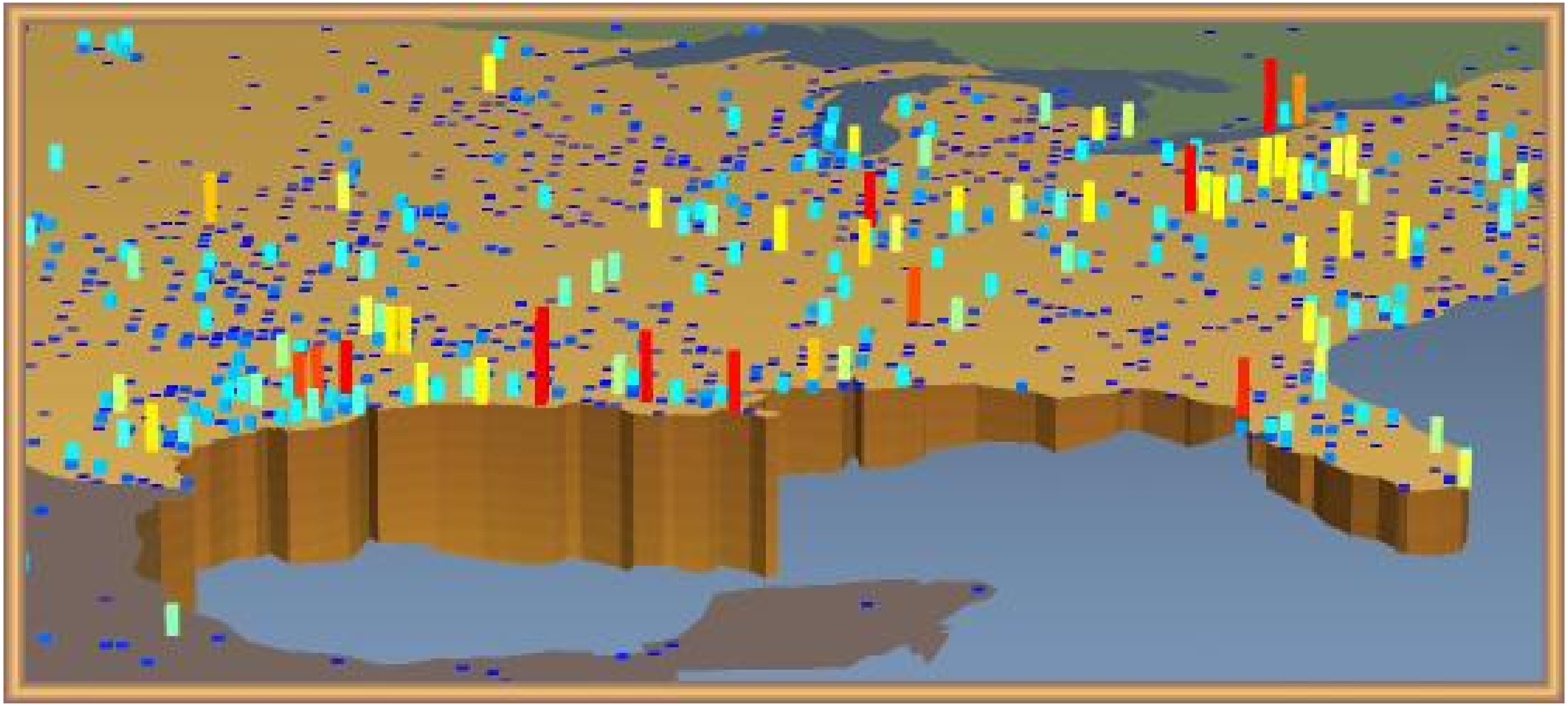


Additional information: http://www.netl.doe.gov/publications/carbon_seq/atlas/

Assessing Adequacy of Subsurface Volumes

- New study of capacity by DOE - NETL Regional Carbon Sequestration Partnerships **http://www.netl.doe.gov/publications/carbon_seq/atlas/**
- Major result: making conservative assumptions*: Space for 1000 Gigatons CO_2 at reservoir conditions - adequate space for >120 years of all CO_2 at current point source emission rates
  - * only fairly well known rock volumes assessed
  - * Assume that CO_2 fills 1% of the volume
- Uncertainty is risks incurred when very large volumes are injected

Texas Perspective



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What are the risks?

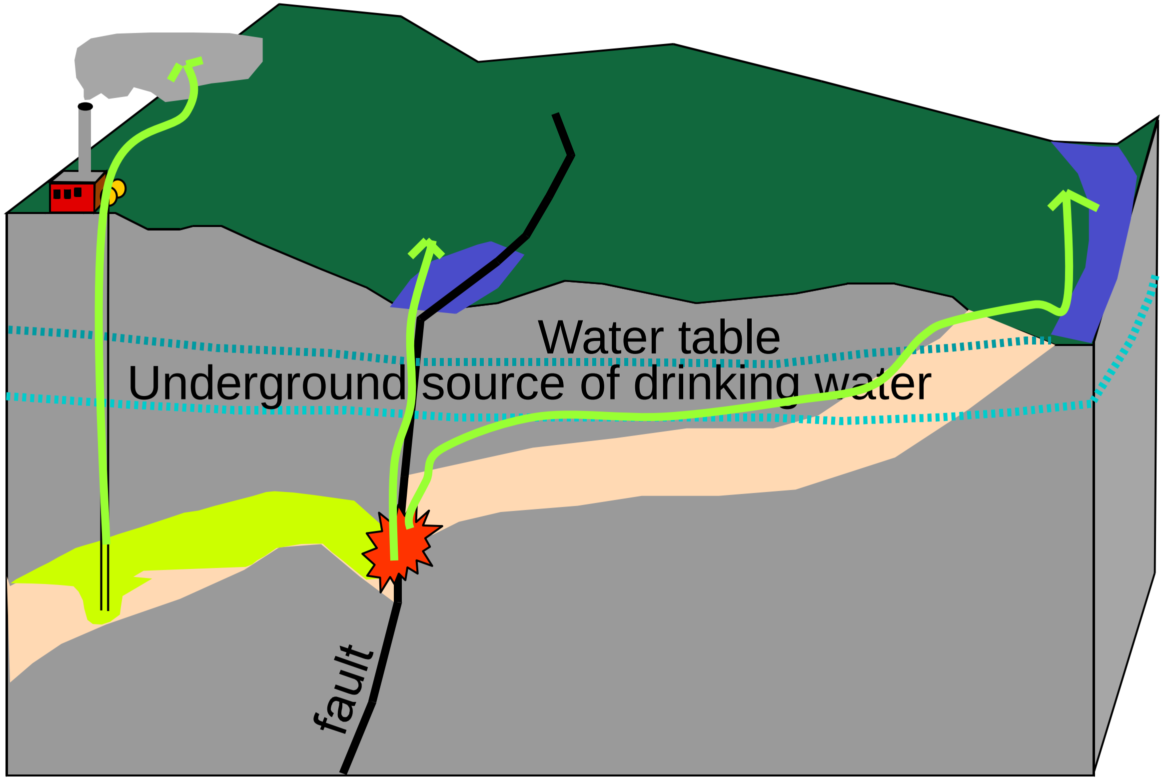
Substitute underground injection for air release

Is storage security adequate?

Escape of brine or CO_2 to groundwater, surface water, or air via long flowpath

Earthquake

Escape of CO_2 or brine to groundwater, surface water or air through flaws in the seal



Failure of well cement or casing resulting in leakage

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Is Security of Sequestered CO_2 Adequate? Types of Risks:

- Catastrophic or rapid escape of CO_2 or brine – death or damages
  - Well–known volcanogenic CO_2 outgassing: examples at Lake Nyos, Cameron; Mammoth Lakes, CA,; industrial confined space risks
- Slow escape of CO_2 – storage becomes ineffective for atmospheric benefit, cost without benefit
  - Slow leakage of either CO_2 or brine within ranges of normal variability is probably acceptable in environmental and resource conservation context
  - However leakage rates < 0.1% of stored volume/year are required to benefit atmosphere

Is Security of Sequestered CO_2 Adequate?

- Pores to store and seals to prevent leakage upward are typical of sedimentary rocks found widely in the US and globally
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Techniques to Assure Safe Injection of CO_2 Used Currently

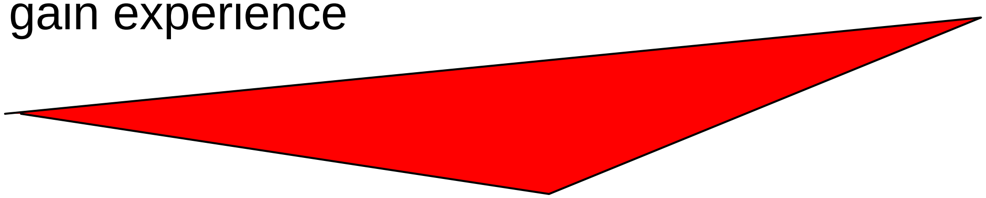
- Health and safety procedures for CO_2 pipelines, shipping, handling, and storing
- Pre-injection characterization and modeling
- Isolation of injectate from Underground Sources of Drinking Water (USDW)
- Maximum allowable surface injection pressure (MASIP) to prevent earthquakes.
- Mechanical integrity testing (MIT) of engineered system
- Standards for well completion and plug and abandonment in cone of influence and area of review around injection wells.
- Reservoir management; extensive experience in modeling and measuring location of fluids

How can Security of Sequestration be Better Assured?

- Rigorous site selection requirements
- Comprehensive monitoring requirements and mitigation plans
- Additional research
- Need for a balanced and phased approach

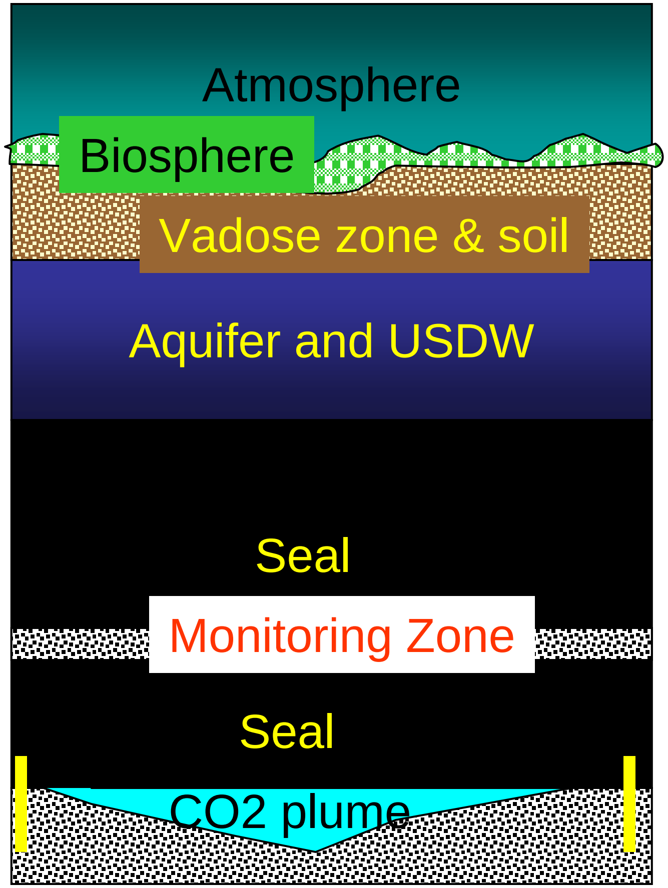
Not too restrictive: encourage early entry into CCS – gain experience

Adequate rigor to assure that early programs do not fail



Mature = standardized, parsimonious but adequate approach

Assuring Security: Monitoring Options

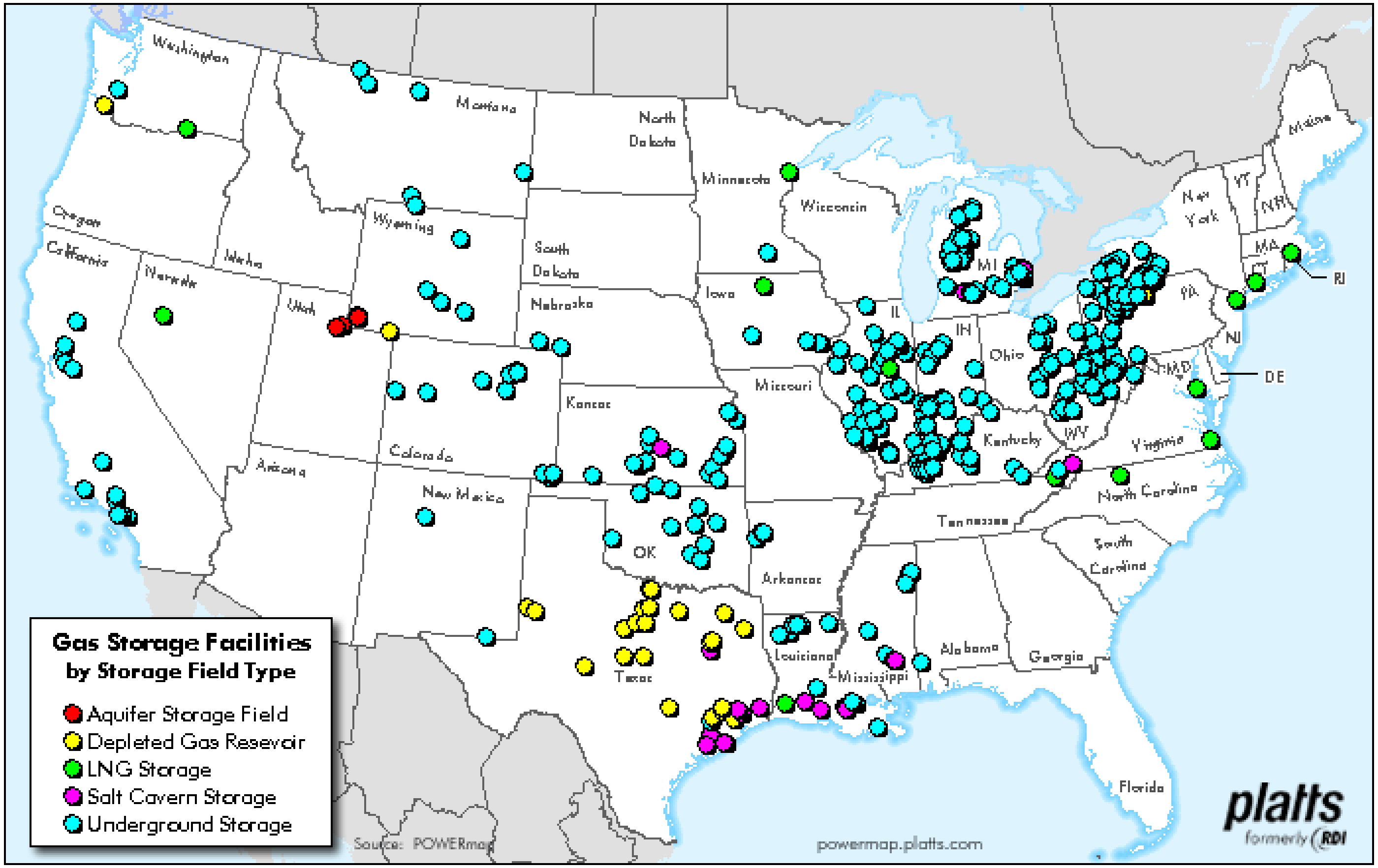


- Atmosphere
  - Ultimate integrator but dynamic
- Biosphere
  - Assurance of no damage but dynamic
- Soil and Vadose Zone
  - Integrator but dynamic
- Aquifer and USDW
  - Integrator, slightly isolated from ecological effects
- Above injection monitoring zone
  - First indicator, monitor small signals, more stable.
- In injection zone - plume
  - Oil-field type technologies. Will not find small leaks
- In injection zone - outside plume
  - Assure lateral migration of CO_2 and brine is acceptable

System mature enough to proceed: Global experience in CO_2 injection

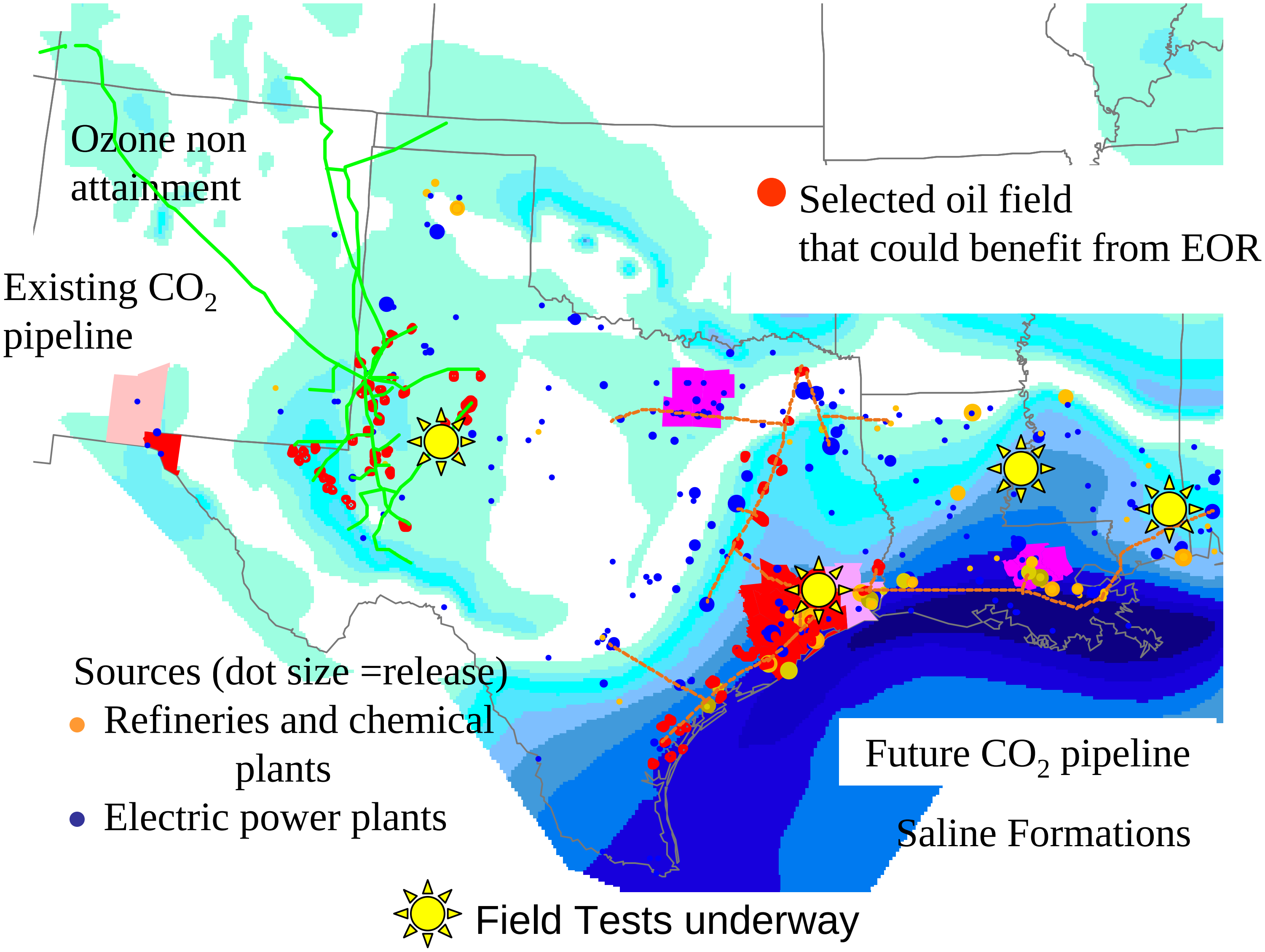
From Peter Cook, CO2CRC

System mature enough to proceed: US experience in gas storage



Slide from Sally Benson, LBNL

Vision for the Future in Texas



Field Tests in the Gulf Coast

- Frio Test – 2004 and 2006 injections
  - Permitted by TCEQ as Class 5 experimental injection well
  - Short, small volumes, well into the post injection monitoring, focus on subsurface processes
- SACROC/Claytonville
  - What is it environmental effect of >30 years injection for EOR? Surface and groundwater significant focus
- Stacked Storage @ Cranfield Mississippi
  - Initial injection for enhanced oil recovery hosted by Denbury
  - Document sweep efficiency and retention of CO_2 in injection zone (adequacy of MS O&G board regs on well completions in greenhouse gas context
  - Above zone monitoring
- Southern Company's Plant Daniels
  - Coal-fired electric generator experience

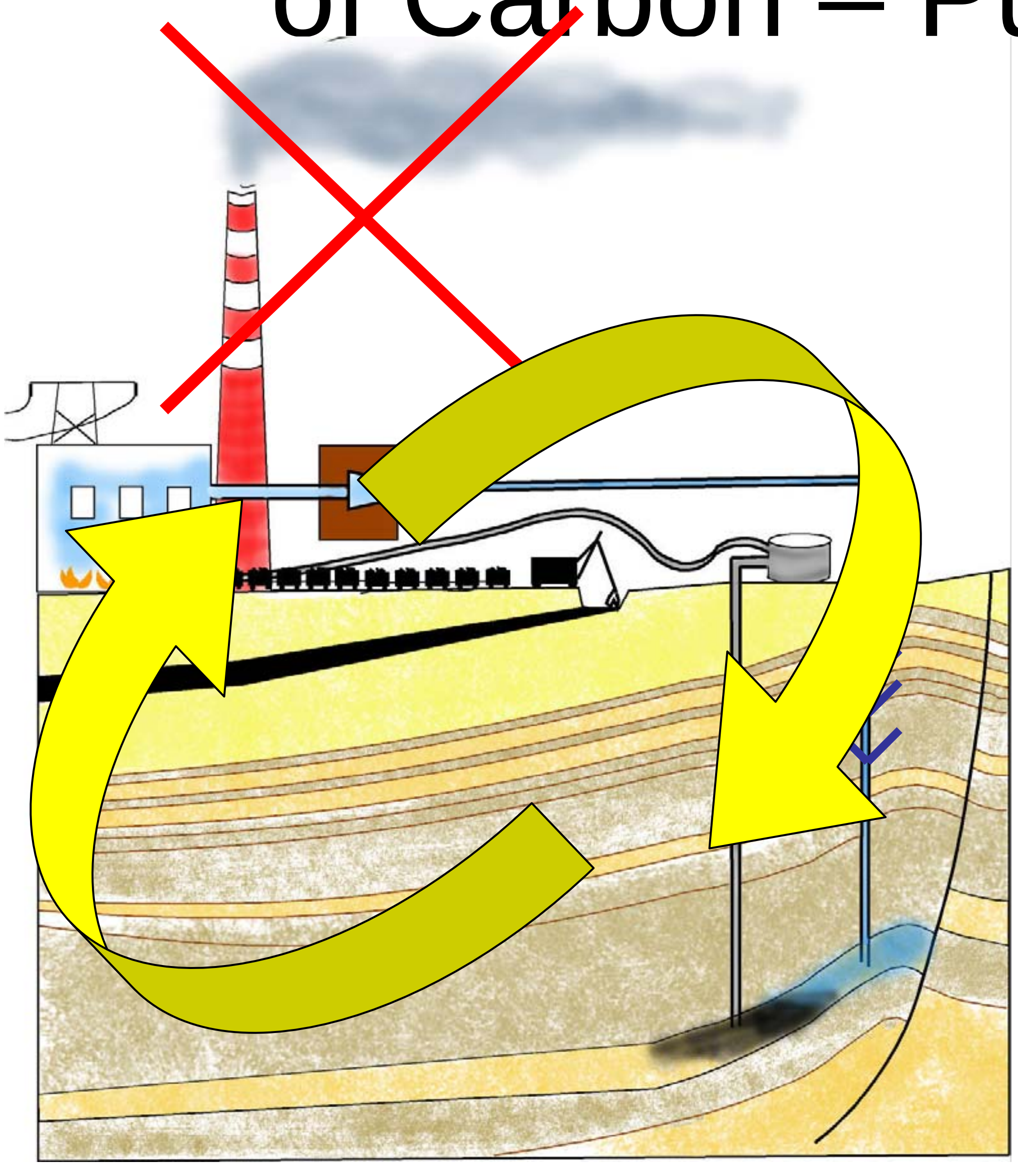
What needs to be done next?

- Prior to injection, CO_2 has to be captured at high concentration and compressed to about 2200 psi
  - Capture is major limit on utilization of geologic storage
- Assurance provided to industry on property rights and permitting
  - Legal precedents for large volume injection into brine in most states are inadequate
- Consensus on Best Practices for monitoring injection and post injection clarified
  - This should be a result of research in coming years – how much monitoring is adequate?

Geologic storage is ready to be used as part of a greenhouse gas emissions reduction program

- Subsurface volumes are adequate to sequester the volumes needed to impact atmospheric concentrations
- Using available technology, adequate storage security can be assured to avoid inducing hazards and to benefit atmospheric concentrations
- The whole system (pipeline, well construction, permitting) is mature enough to proceed forward-some work remaining

Geologic Sequestration of Carbon – Put it back



Carbon extracted from coal or other fossil fuel…

Returned into the earth where it came from