Overview of CC^S

U=use

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Gulf Coast Carbon Center

BUREAU OF ECONOMIC GEOLOGY

Prepared for Midwest Governor's Association, September 2011

Gulf Coast Carbon Center (GCCC)

Gulf Coast Carbon Center

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UT- DoGS
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UT- LBJ school
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JSG – EER
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NRG
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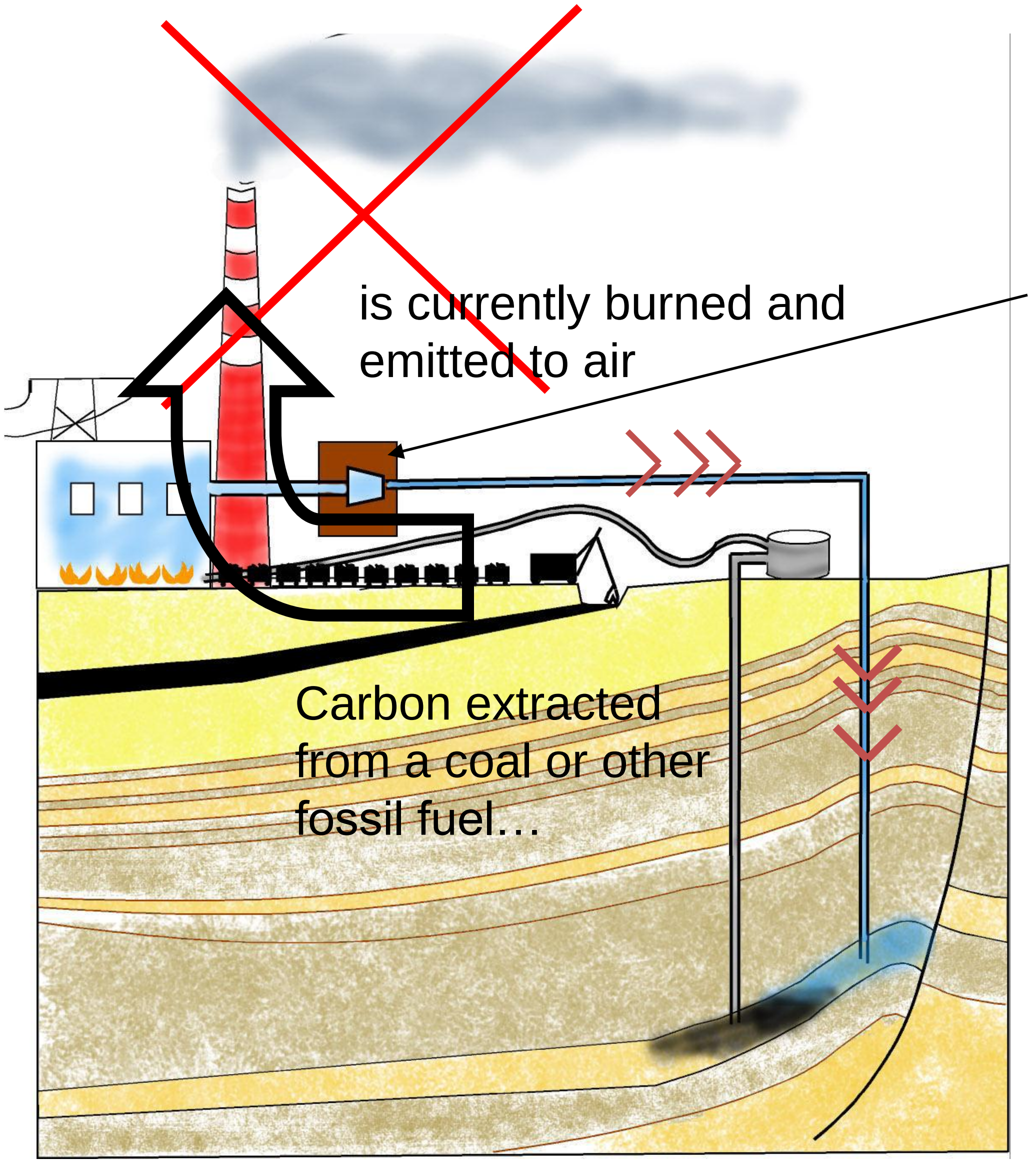
EDF ENVIRONMENTAL DEFENSE FUND Finding the ways that work

STORE sequestration training, outreach, research & education
THE UNIVERSITY OF TEXAS AT AUSTIN JACKSON SCHOOL OF GEOSCIENCES

What is Geologic Sequestration?



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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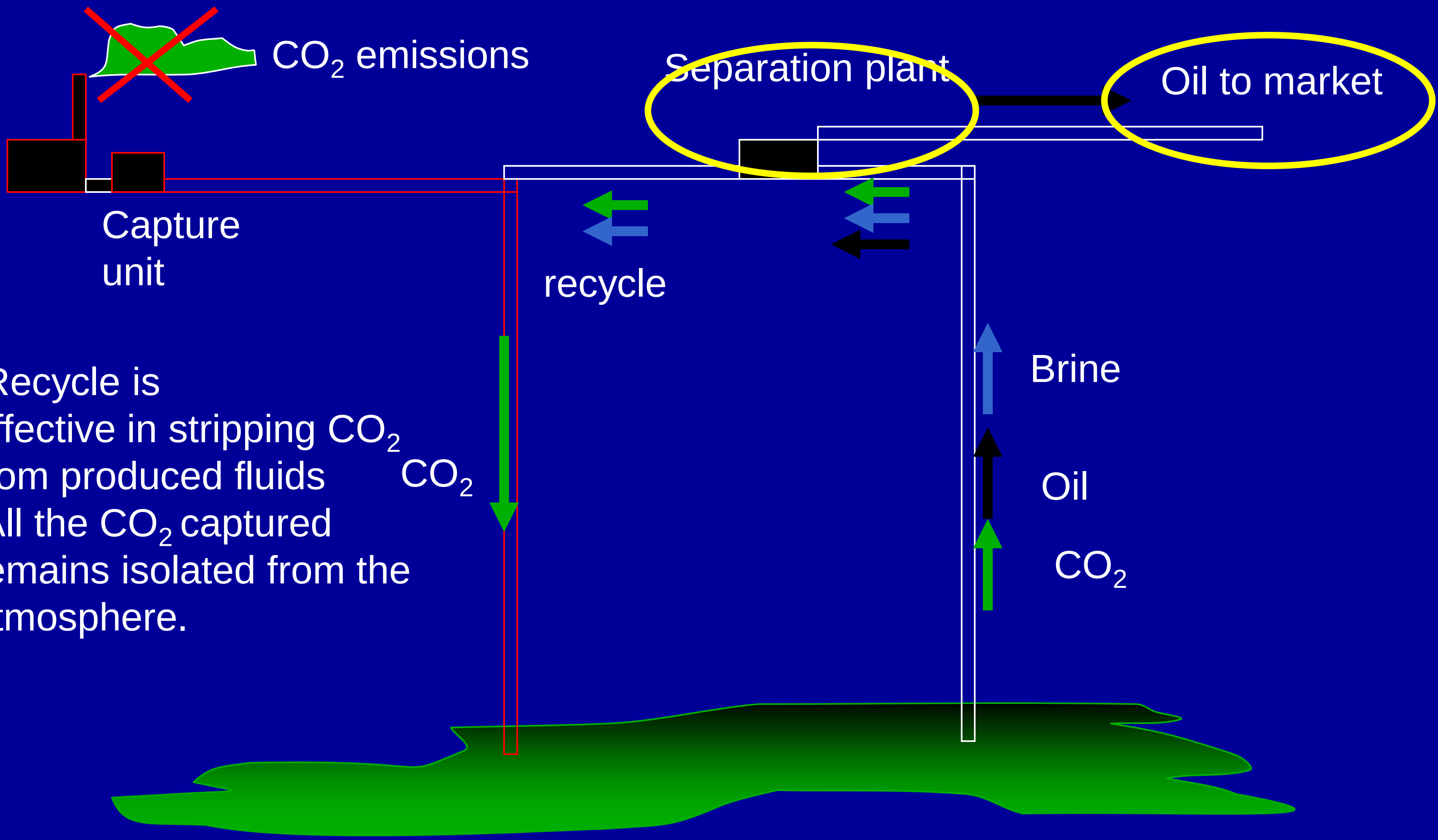
CO_2 use for Enhanced Oil Recovery is Sequestration from Atmosphere



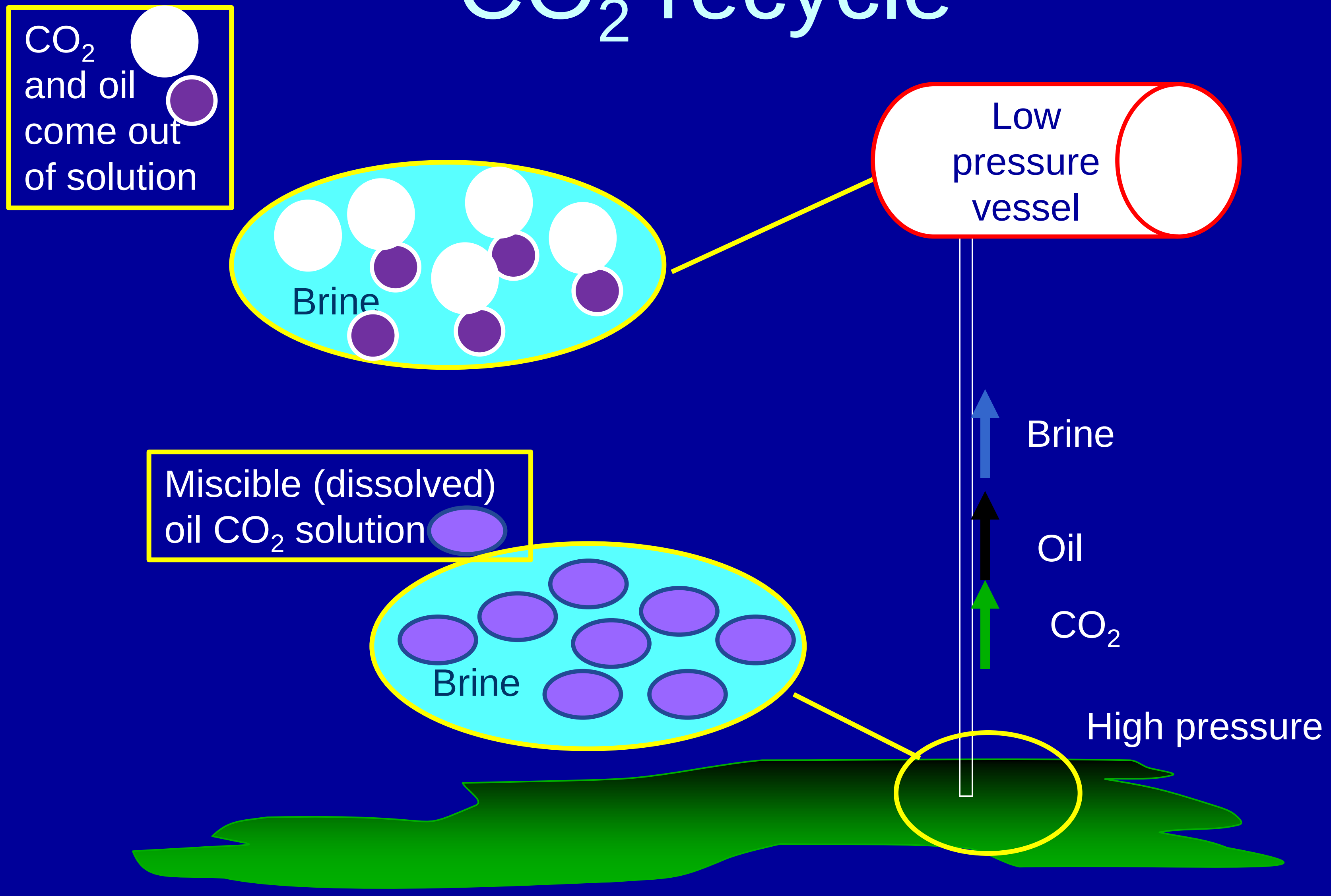
Recycle is effective in stripping CO_2 from produced fluids
All the CO_2 captured remains isolated from the atmosphere.

main doubts – recycle and oil production

Separation and Recycle is Essential to EOR

Denbury Cranfield unit separation plant, Mississippi

CO_2 recycle



CO_2 and oil come out of solution
Brine
Low pressure vessel
Brine
Oil
CO_2
Miscible (dissolved) oil CO_2 solution
Brine
High pressure

How does EOR compare to storage-only?

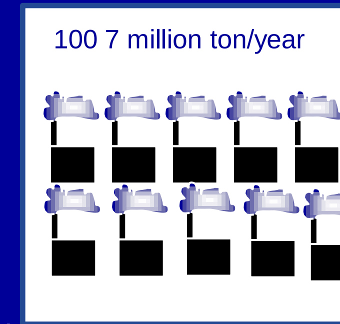
Storage only green field

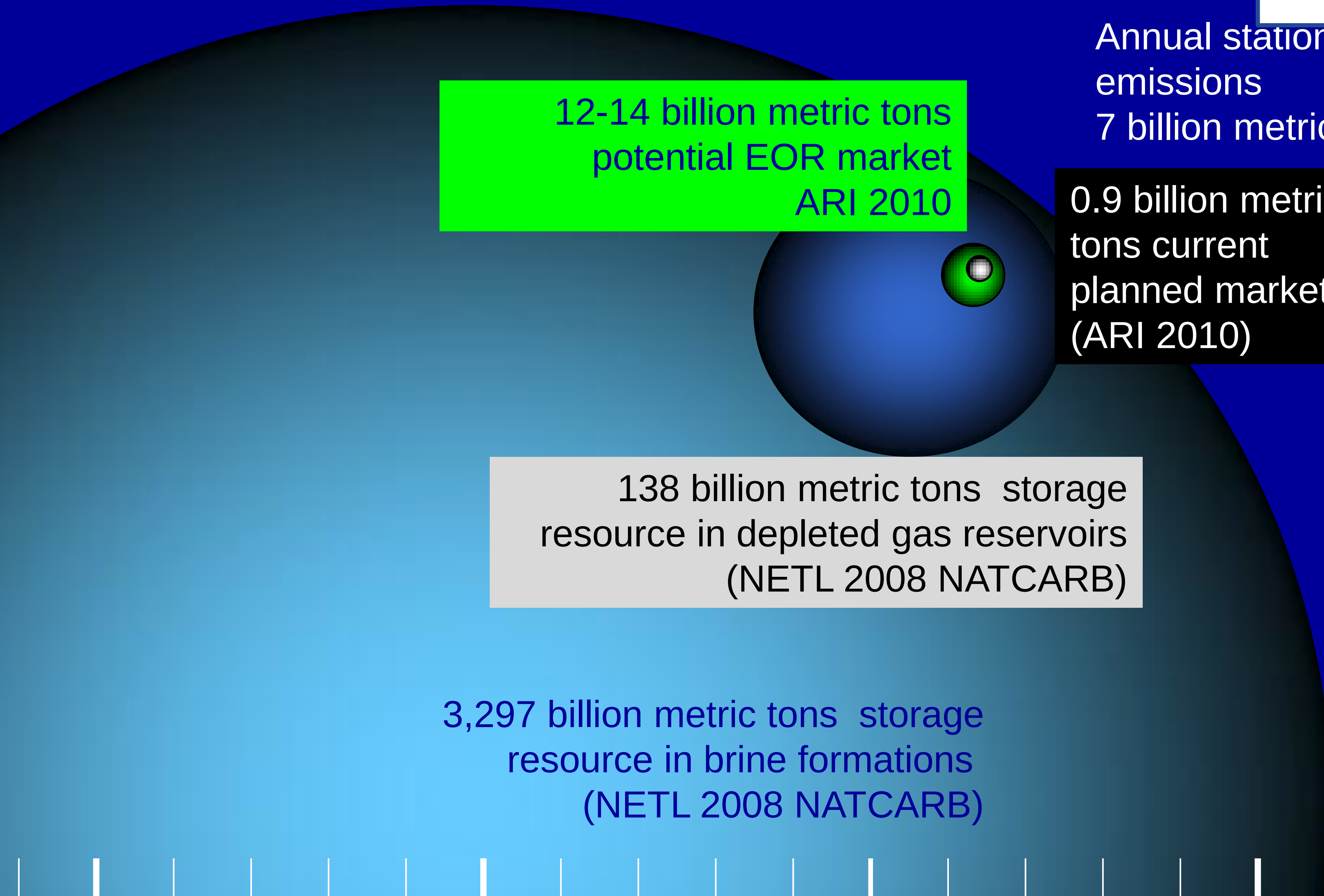
- CO_2 injection
- Large area of pressure increase
- Inferred trapping
- Brine = CO_2 weakly soluble
- Few wells
  - Sparse information
  - Low well failure risk
- All Cost
- Evolving frameworks for permitting and pore space access
- Public acceptance ??

EOR brownfield

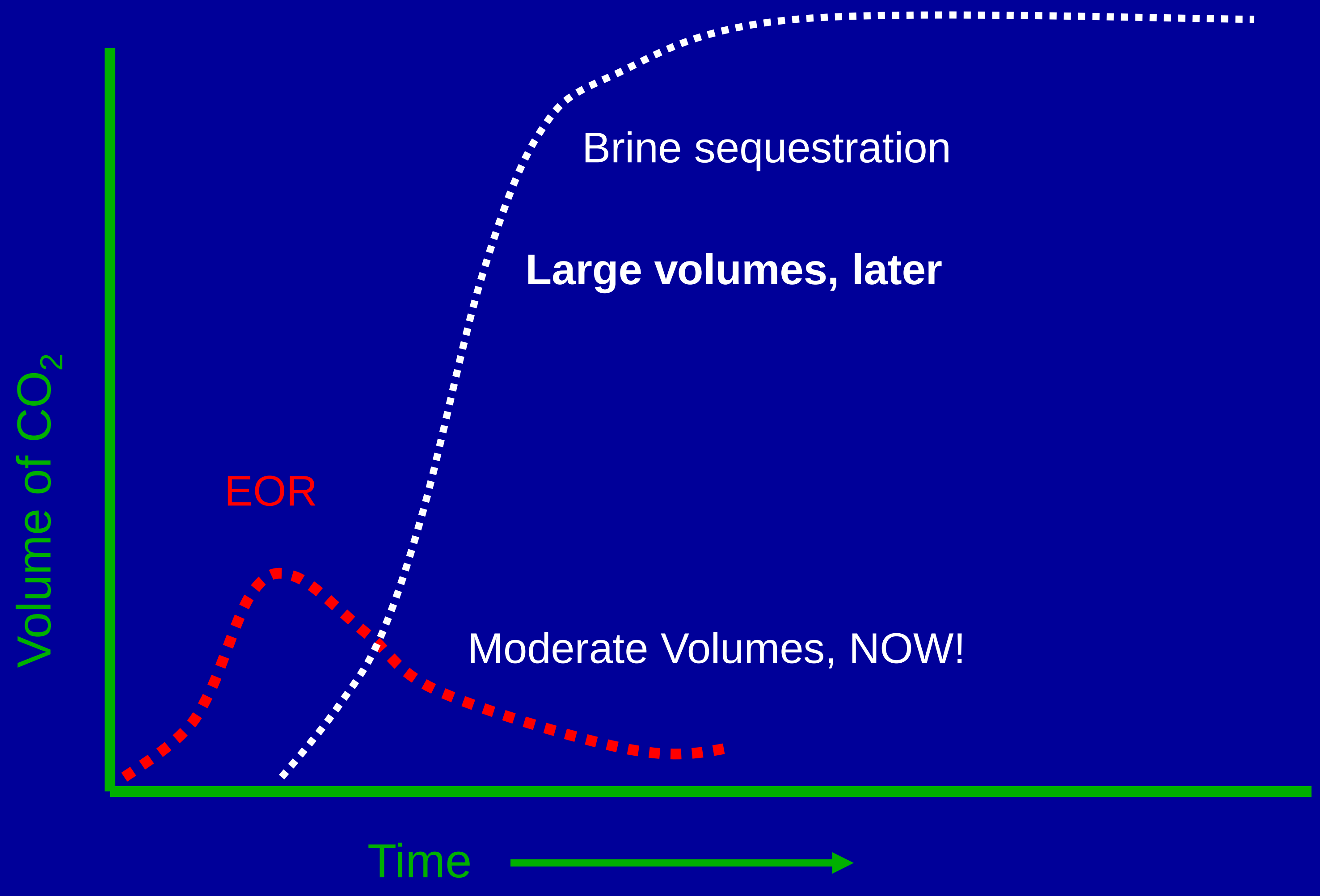
- CO_2 injection + oil and CO_2 production + CO_2 recycle
- Pressure control
- Demonstrated trapping
- Oil + water = CO_2 very soluble
- Many wells
  - Dense information
  - Well management expense
- Cost + revenue
- Historic frameworks for permitting and pore space access
- Public acceptance good

Can EOR accept the volumes of CO_2 needed to benefit the atmosphere?

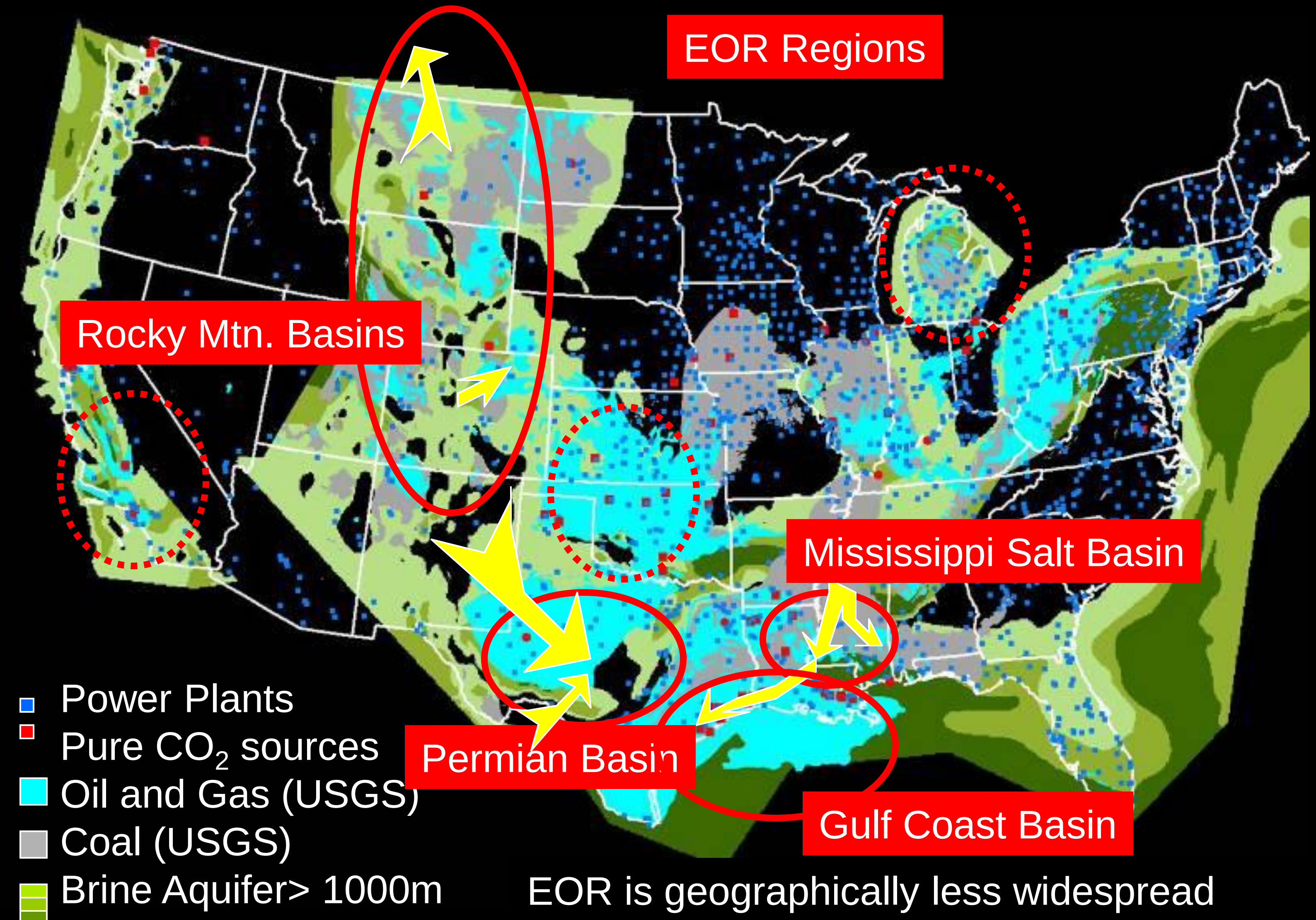




Role of EOR in Sequestration



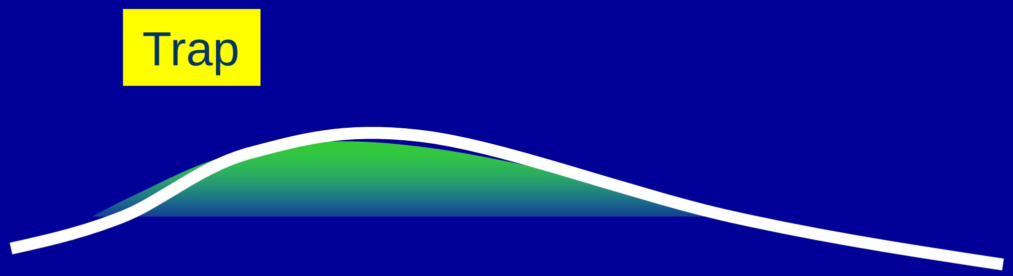
Is EOR available to serve US needs?



Compiled from USGS data

EOR is geographically less widespread compared to brine storage

Injection in a Trap vs. Injecting on Dip



Area occupied by CO_2 is confined, but column height is conserved or very slowly dissolved over time

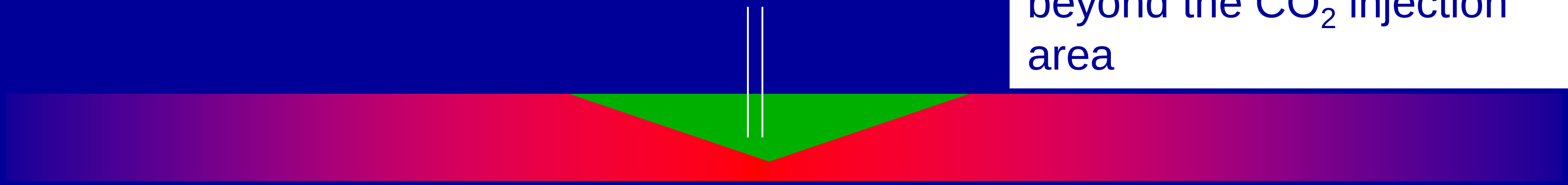
Area occupied by CO_2 is not laterally confined, but column height is quickly reduced and CO2 is trapped by capillary processes and dissolved over time

= Reduced leakage risk

EOR and Sequestration - only have Different Pressure Footprints

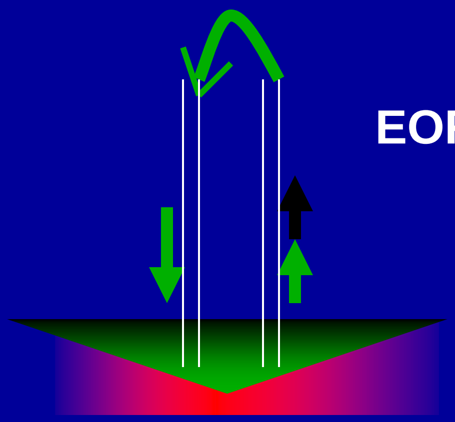
Storage only

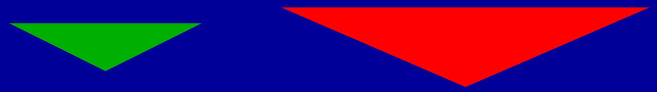
CO_2 injection (no production) pressure elevation extends beyond the CO_2 injection area



CO_2 injection is approximately balanced by oil, CO_2, and brine production so pressure elevation beyond the CO_2 injection area is minimal

EOR

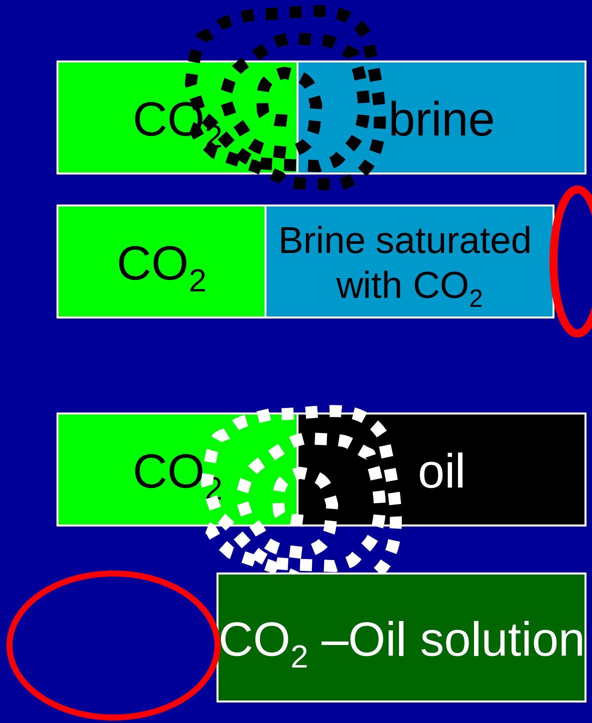




Role of Dissolution in Plume and Pressure Evolution

CO_2 injected into brine:
Minor dissolution: volume displaced 4% less than volume injected

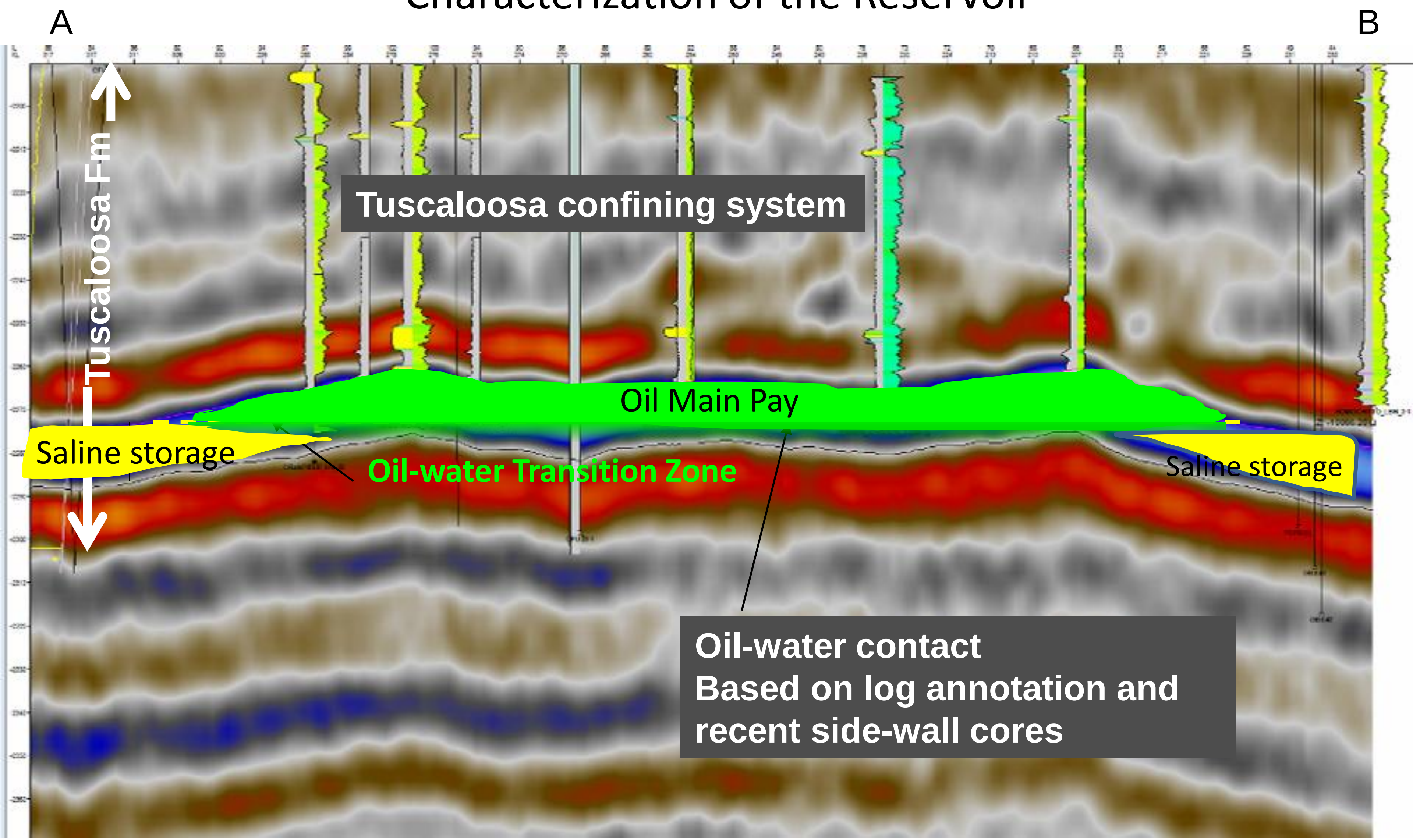
CO_2 injected into oil:
Complete dissolution:
volume displaced
as much as 40% less than volume injected



Less space occupied = enhanced security and lower pressure.

Calculations by Changbing Yang, BEG

Characterization of the Reservoir



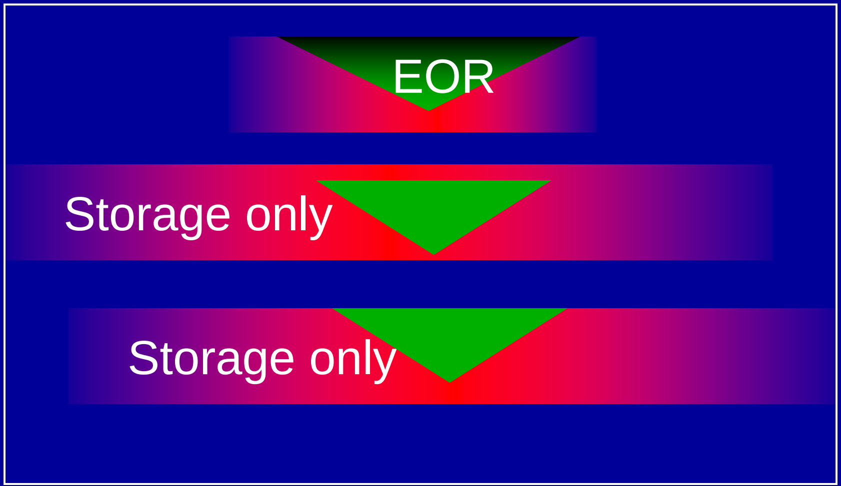
Cost and value of EOR– the hard numbers

- Price of oil
- Cost of EOR operations
  - CO_2 cost
  - Capitol investment – wells, pipelines
  - Operational costs - compression, lifting cost, chemicals

Cost and Value of EOR – fuzzy numbers

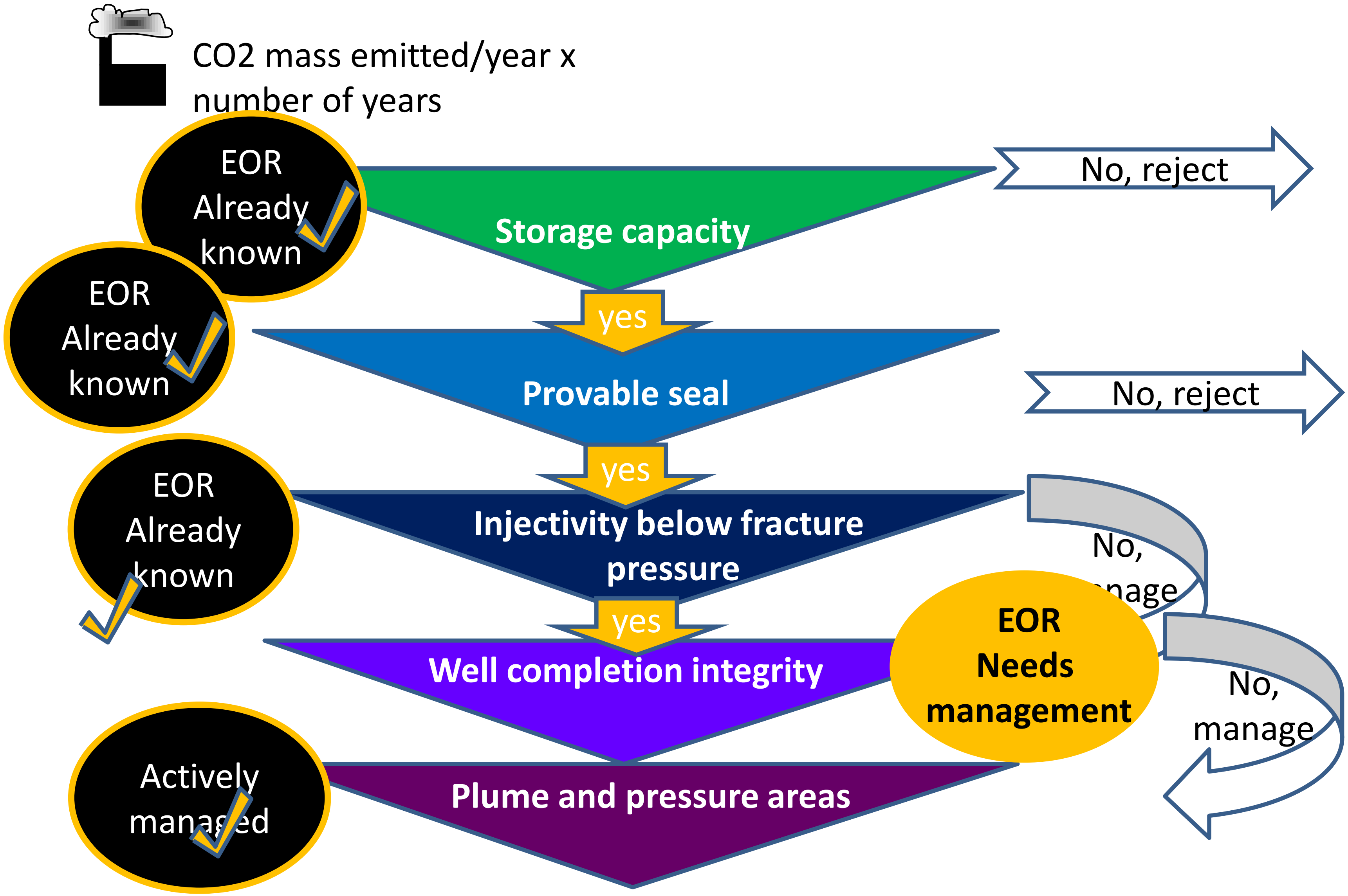
- Declining oil production
  - Cost for communities = jobs
  - Direct link to public acceptance
  - Cost for balance of trade
- Environmental impacts
  - Brownfield production
  - Continued oil production and resultant carbon impact

Rolling from EOR to Storage Only via Stacked Storage



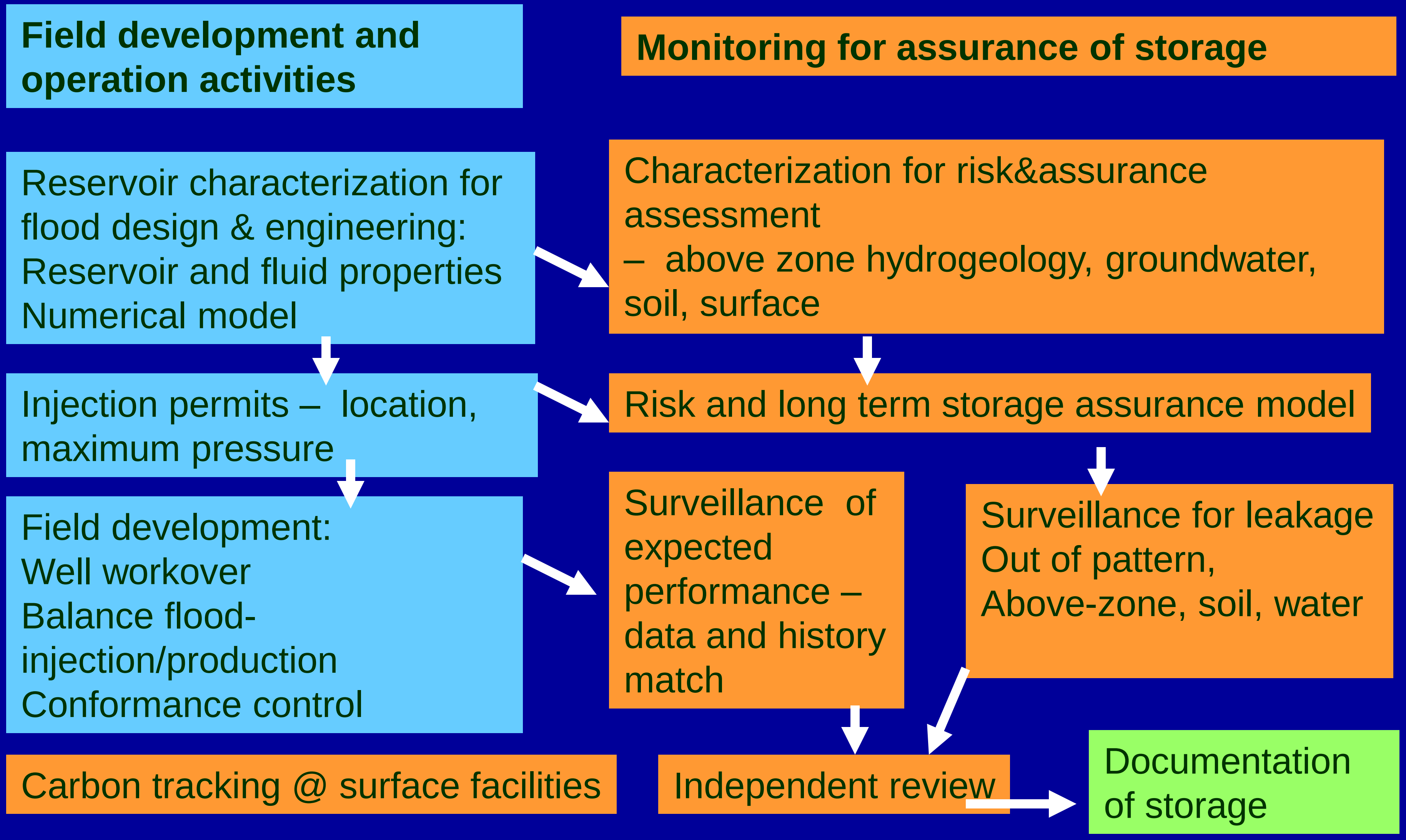
- By developing multiple injection zones beneath the EOR zone, the footprint of the CO_2 and pressure plume can be minimized and storage volume maximized

Characterization and monitoring for retention



Assuring Permanence via Monitoring during CO_2 EOR

Field Operation Activities Linked to Storage Monitoring



Motivation for Monitoring Programs

- **Historic Motivation**
  - Groundwater and surface water protection
  - Historic damages = salinization

- **Current motivations**
  - Benefit to the atmosphere

- Follow the $ -Who pays gap between cost of capture and purchase price of CO_2? - now taxpayer -- ultimately electricity rate payer
- Liability (real issue?)

- Public concerns/values/standards

EOR Provides Experience in Handling CO_2

The Track Record CO_2 Enhanced Oil Recovery In the US

over 13,000 EOR wells

over 3600 miles of CO_2 pipelines

over 600 million tons/year of CO_2 transported

Cumulatively approximately 1.2 billion metric tons of CO_2 injected

Ian Duncan, 2011

Transition From… To

Research Monitoring

Tests-

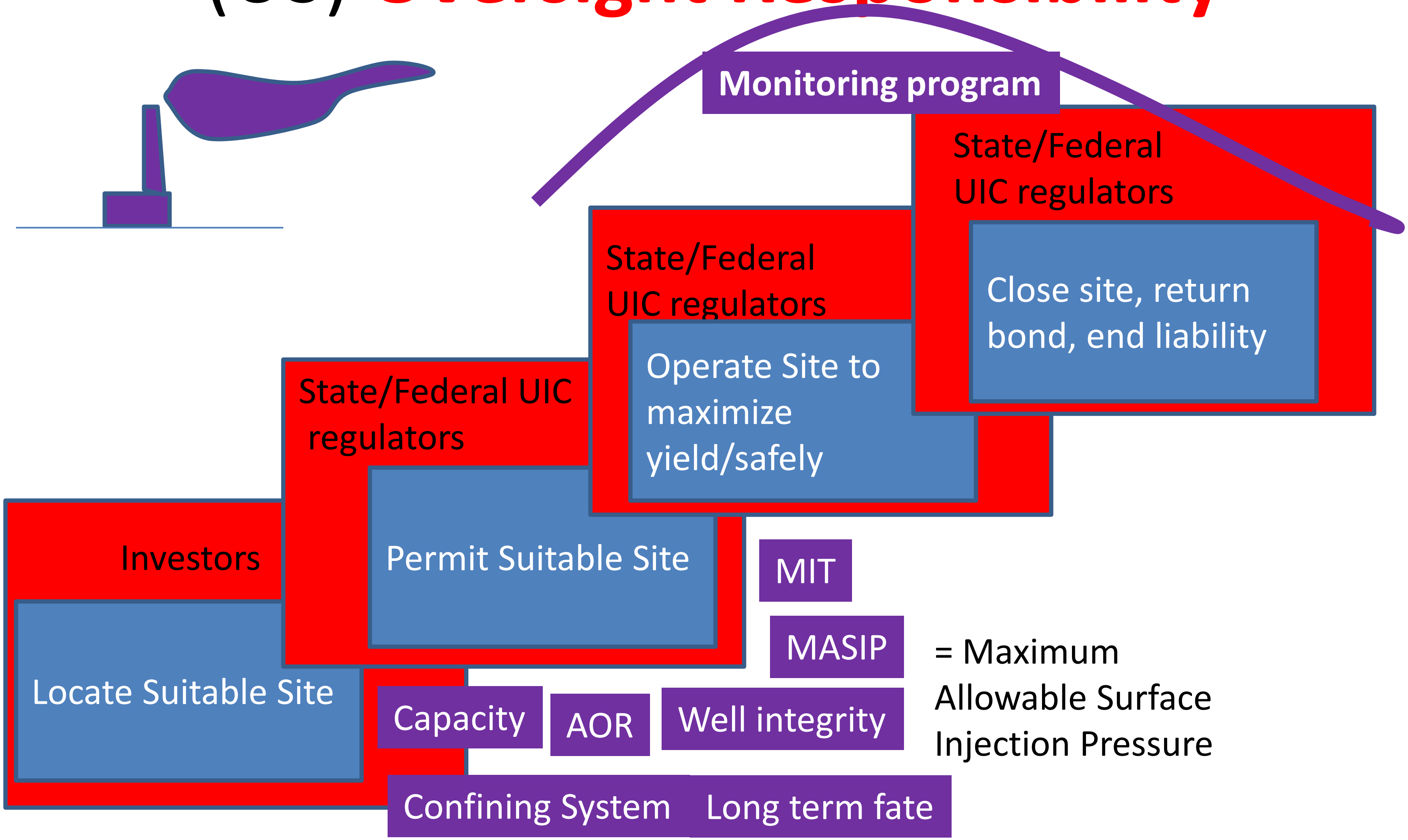
- Hypotheses about the nature of the perturbation created
  - compare response modeled to the response observed via monitoring.
- Performance and sensitivity of monitoring tools
  - sensitivity to the perturbation
  - conditions under which tool is useful,
  - reliability under field conditions.

Commercial Monitoring

Confirms -

- predictions of containment based on site characterization at the time of permitting are correct
- Confidence to continue injection is gained
  - monitoring observations that are *reasonably close* to model predictions
  - any non-compliance explained.
  - no unacceptable consequences result from injection
- Monitoring frequency could be diminished through the life of the project
  - eventually stopped, allowing the project to be closed.

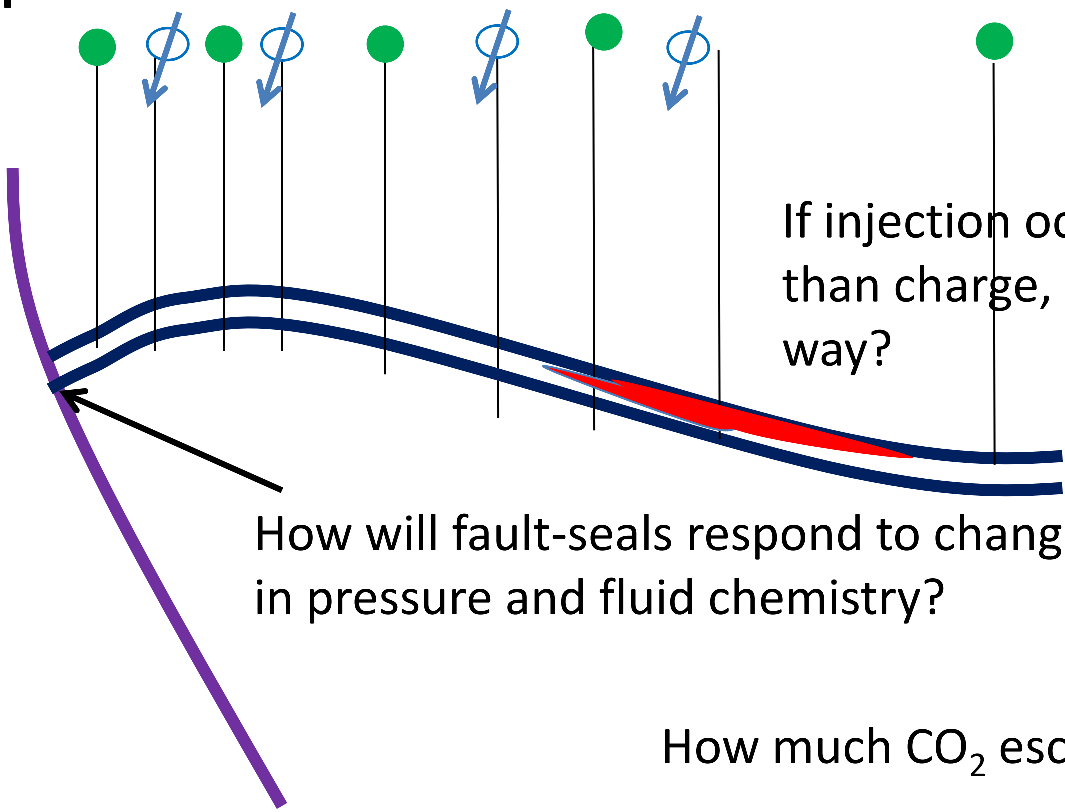
CCS Project Dynamics: Proponent Goals and (US) Oversight Responsibility



Pay attention to the data that disturbs our entrenched beliefs

Jonah Lehrer “How we decide”

Traps and seals that held oil will hold CO_2

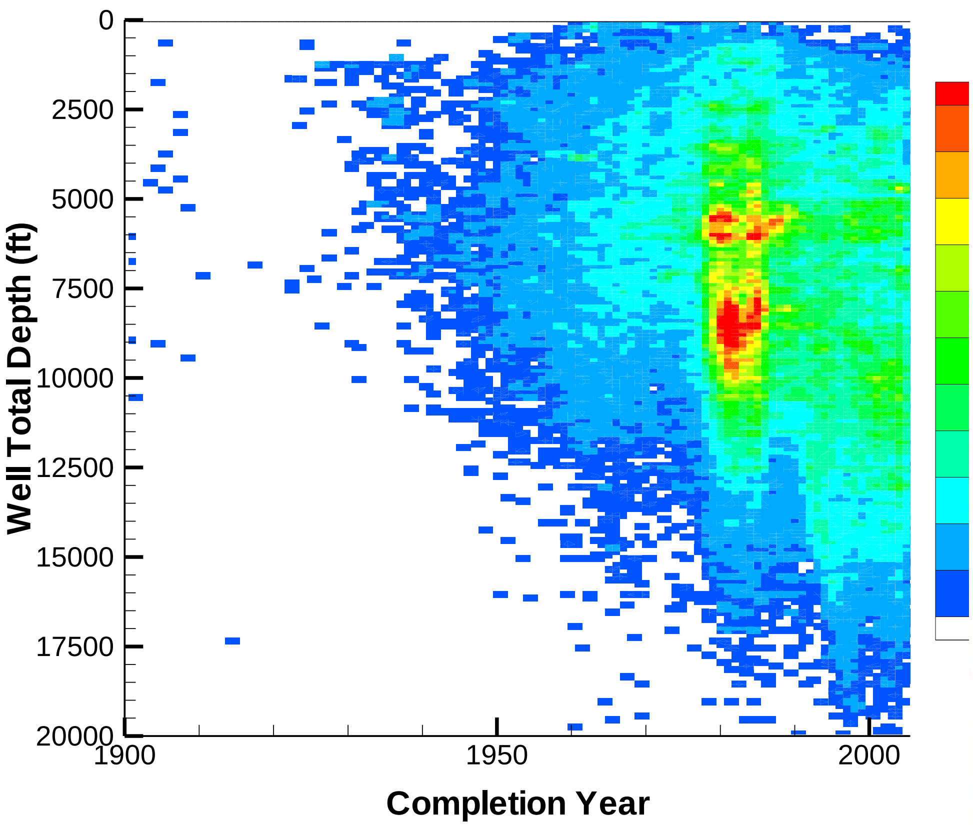


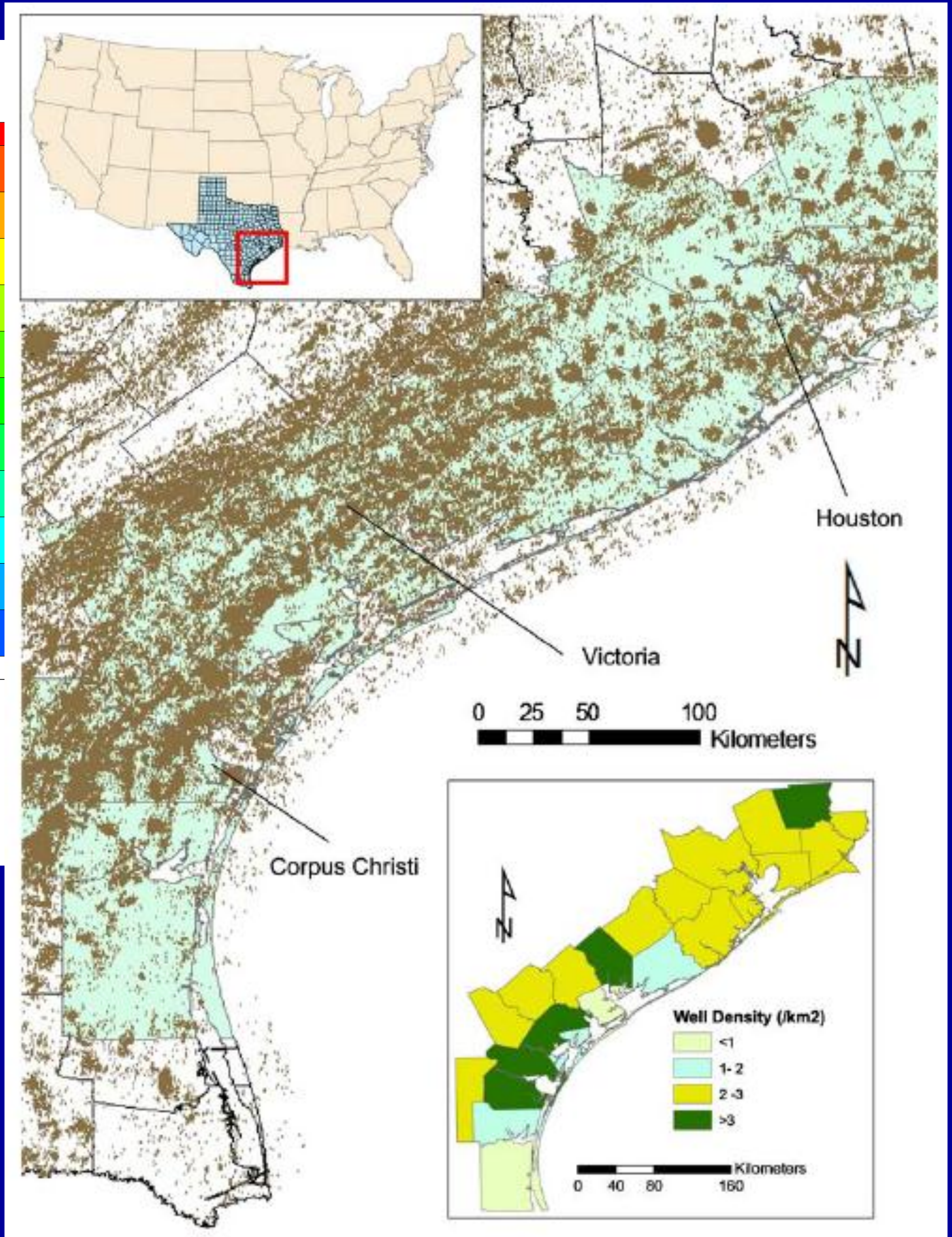
If injection occurs much more rapidly than charge, will it fill the trap the same way?

How will fault-seals respond to changes in pressure and fluid chemistry?

How much CO_2 escapes from pattern floods?

The Issue of Wells



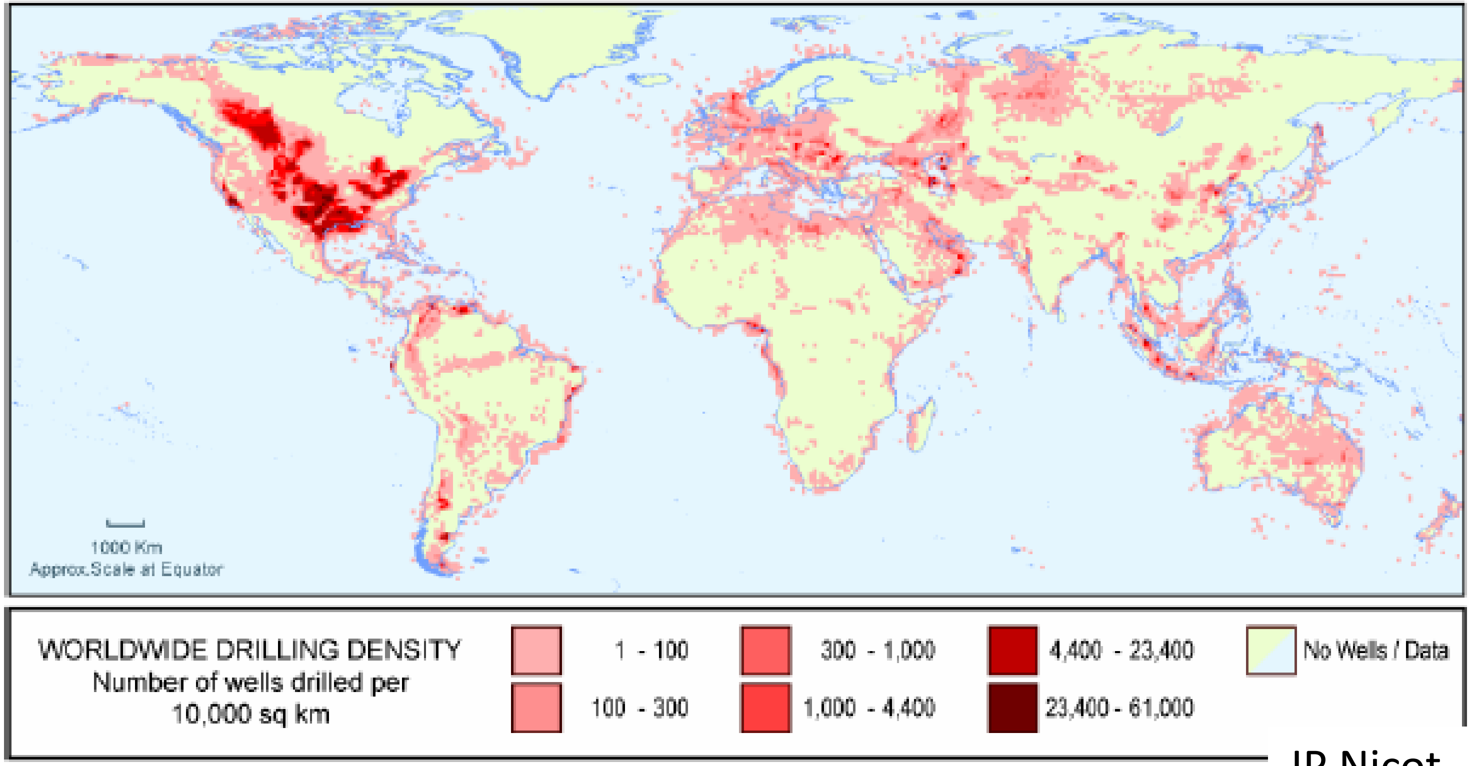


Texas Gulf Coast data only

JP Nicot, BEG

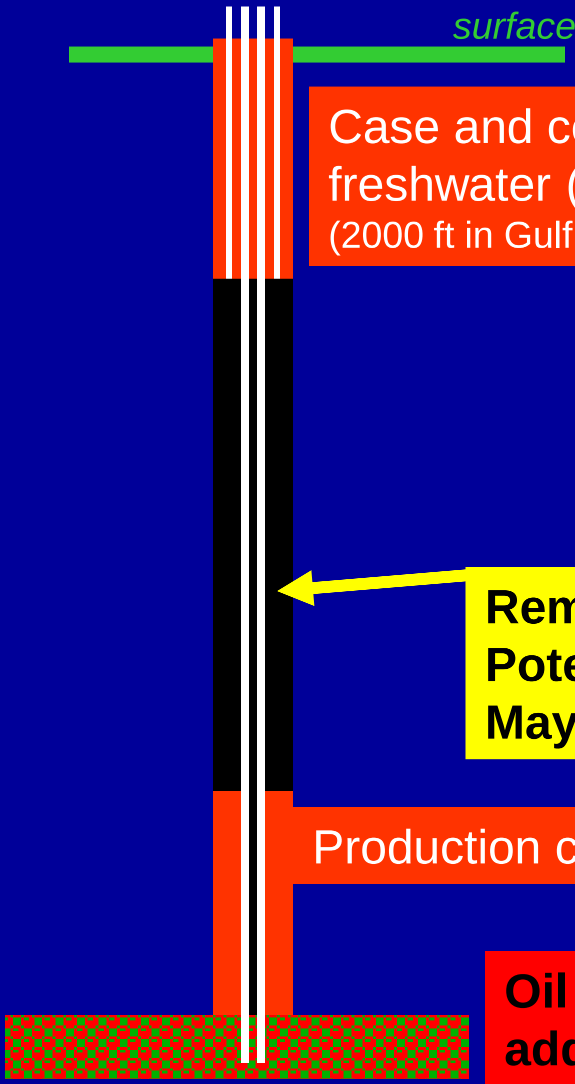
Well Density

Texas:	1.6 well/km^2
Texas Gulf Coast:	2.4 well/km^2
Alberta Basin:	0.5 well/km^2
Most O&G provinces:	<<1 well/km^2



JP Nicot

So how good are wells?



Case and cement to seal off freshwater (USDW)
(2000 ft in Gulf Coast)

Remaining open annulus between rock and casing=
Potential leakage path for CO_2 or displaced brine
May be healed by creep of sloughing

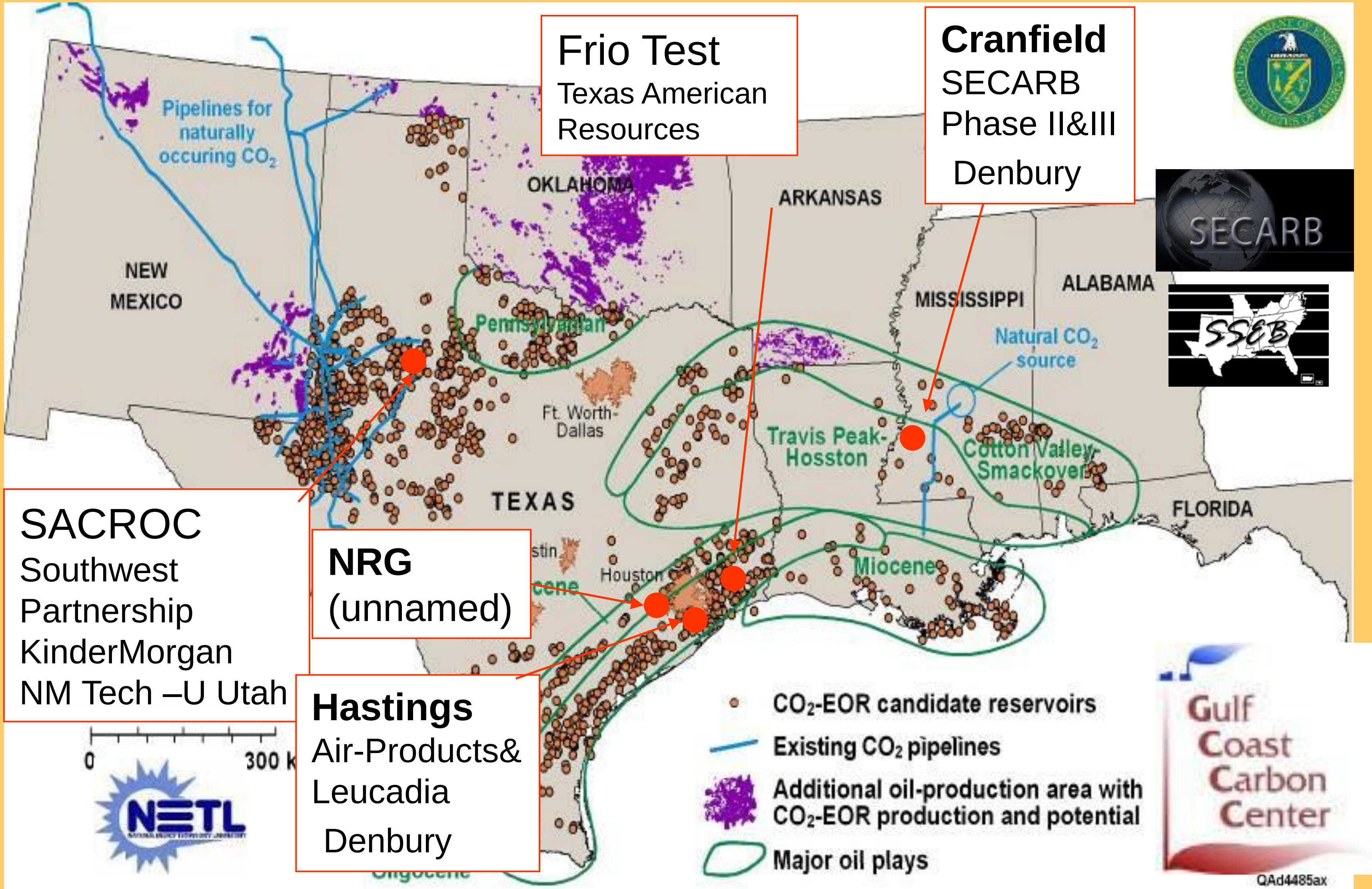
Production casing and cement above production zone

Oil reservoir,
add CO_2 for tertiary production of hydrocarbon resource

What is known and not known about cement performance

- CO_2 + water = weak acid, in the lab in open cells consumes cement in months
- CO_2 EOR has been conducted with standard well completions for decades
- Several "dissected" multi-decade old CO_2 wells, cement appears OK
- What will happen over hundreds of years?
- Research by Carbon Capture Project, Princeton, Schlumberger etc.

GCCC Field Tests for Monitoring and Verification Technologies - DOE-NETL and Industry Hosts



POST COMBUSTION CAPTURE OF CO2

Post-Combustion CO2 Capture Systems

- The separation of CO2 from the flue gases produced after burning coal in air
- The CO2 separation from flue gas at low concentration and pressure
- The most common separation method used are Amines (chemical solvents)

Ian Duncan

ISSUES WITH POST COMBUSTION CAPTURE OF CO_2

- Very large volumes of flue gas must be processed
- CO_2 separation by Amines uses 25 to 30% of plant energy
- Compression CO_2 required because low pressure processes
- New electric plants must be built to maintain power generation

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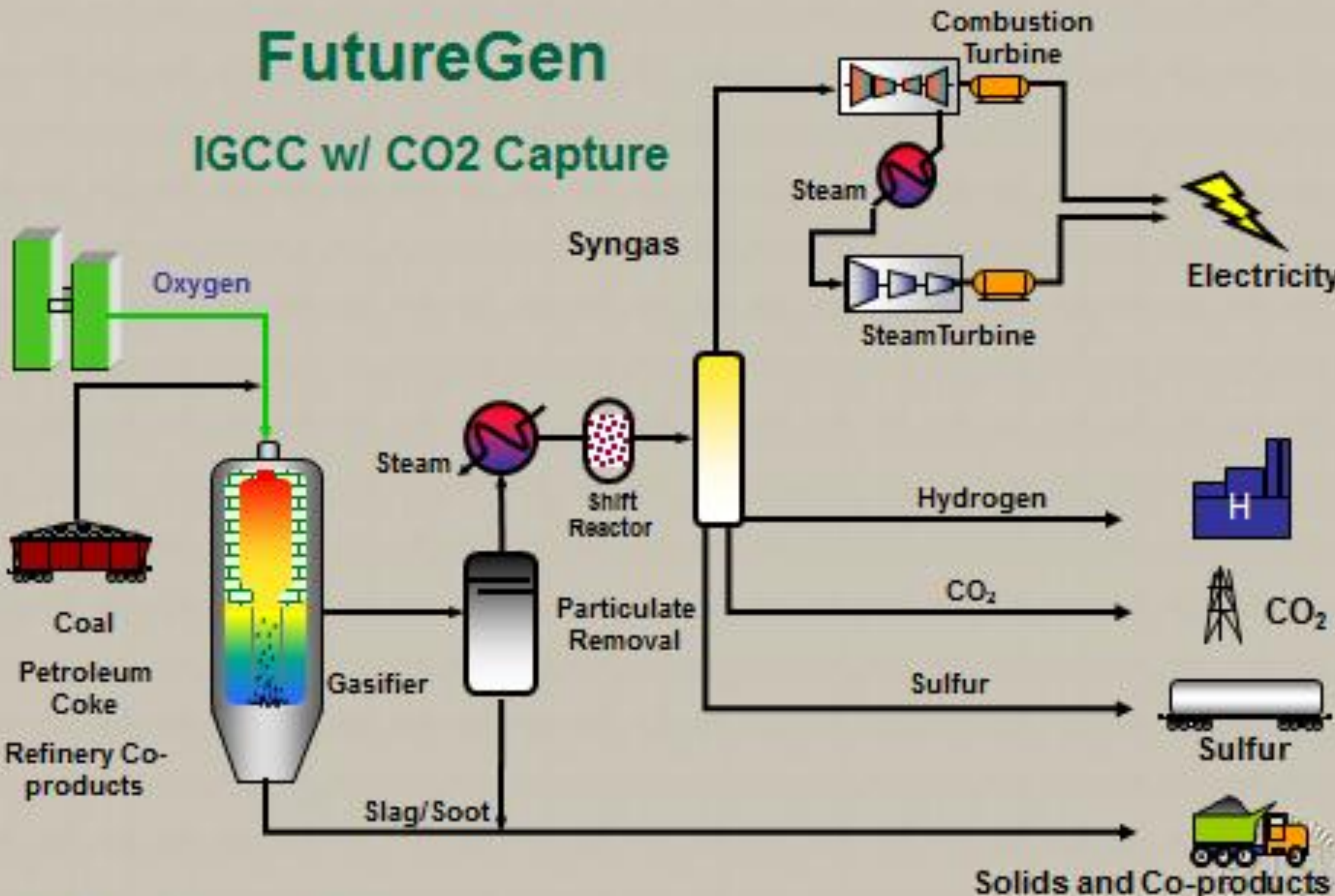
PRE COMBUSTION CAPTURE CO2

Gasification of Coal

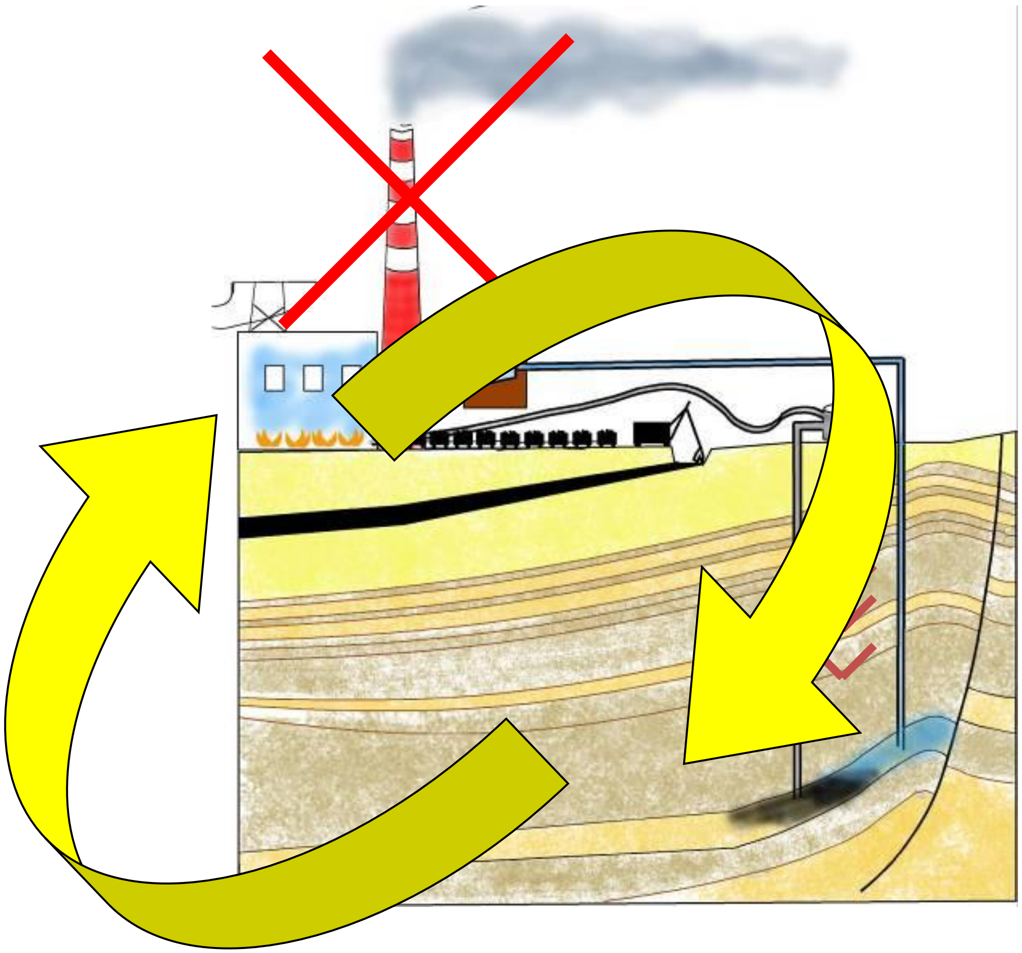
FutureGen

IGCC w/ CO2 Capture



Modified from Eastman Chemical

Geologic Sequestration of Carbon – Put it back



Carbon extracted from coal or other fossil fuel…

Returned into the earth where it came from