Using EOR as Geologic Storage: Downside and Benefits

Susan Hovorka

Gulf Coast Carbon Center

Bureau of Economic Geology

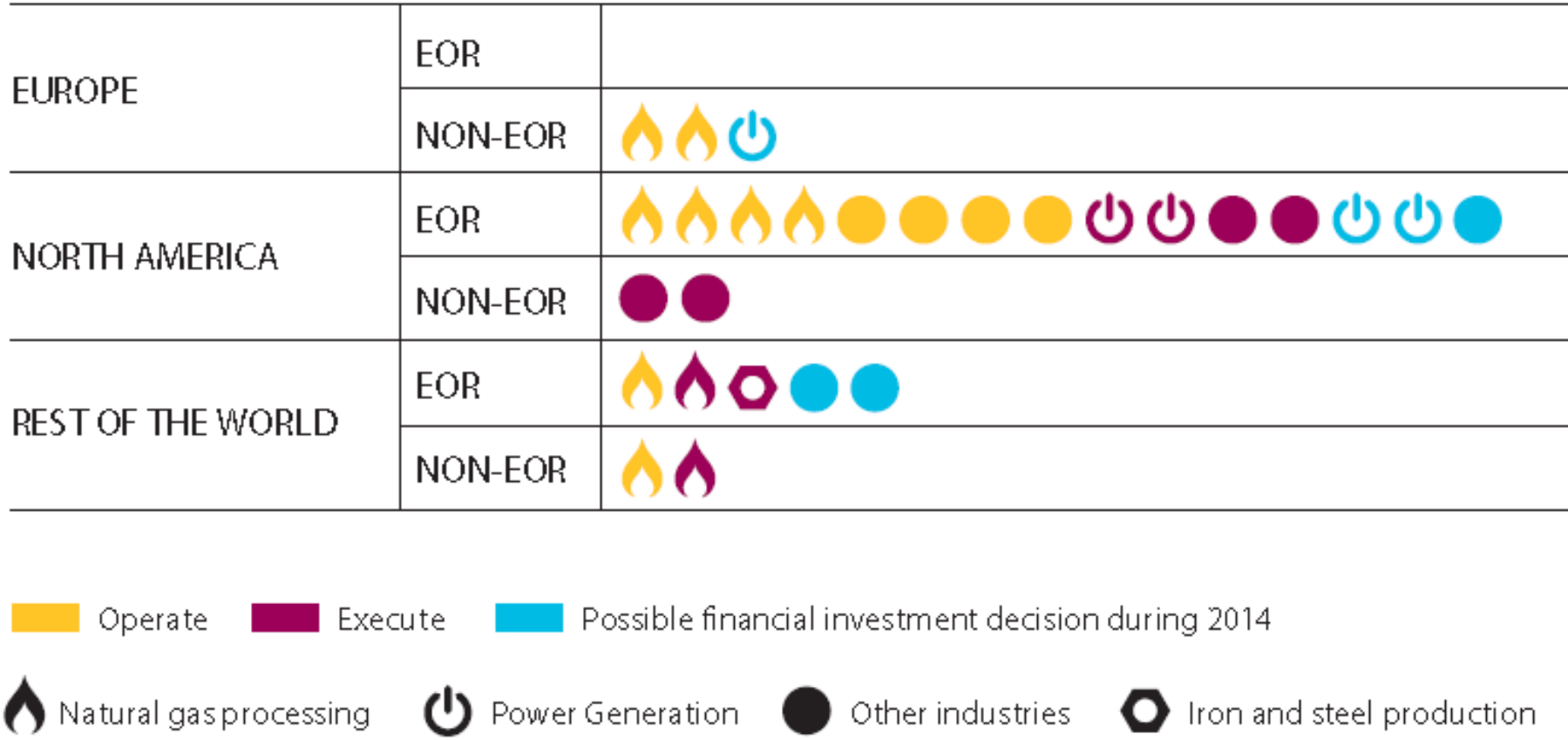
Jackson School of Geoscience

The University of Texas at Austin

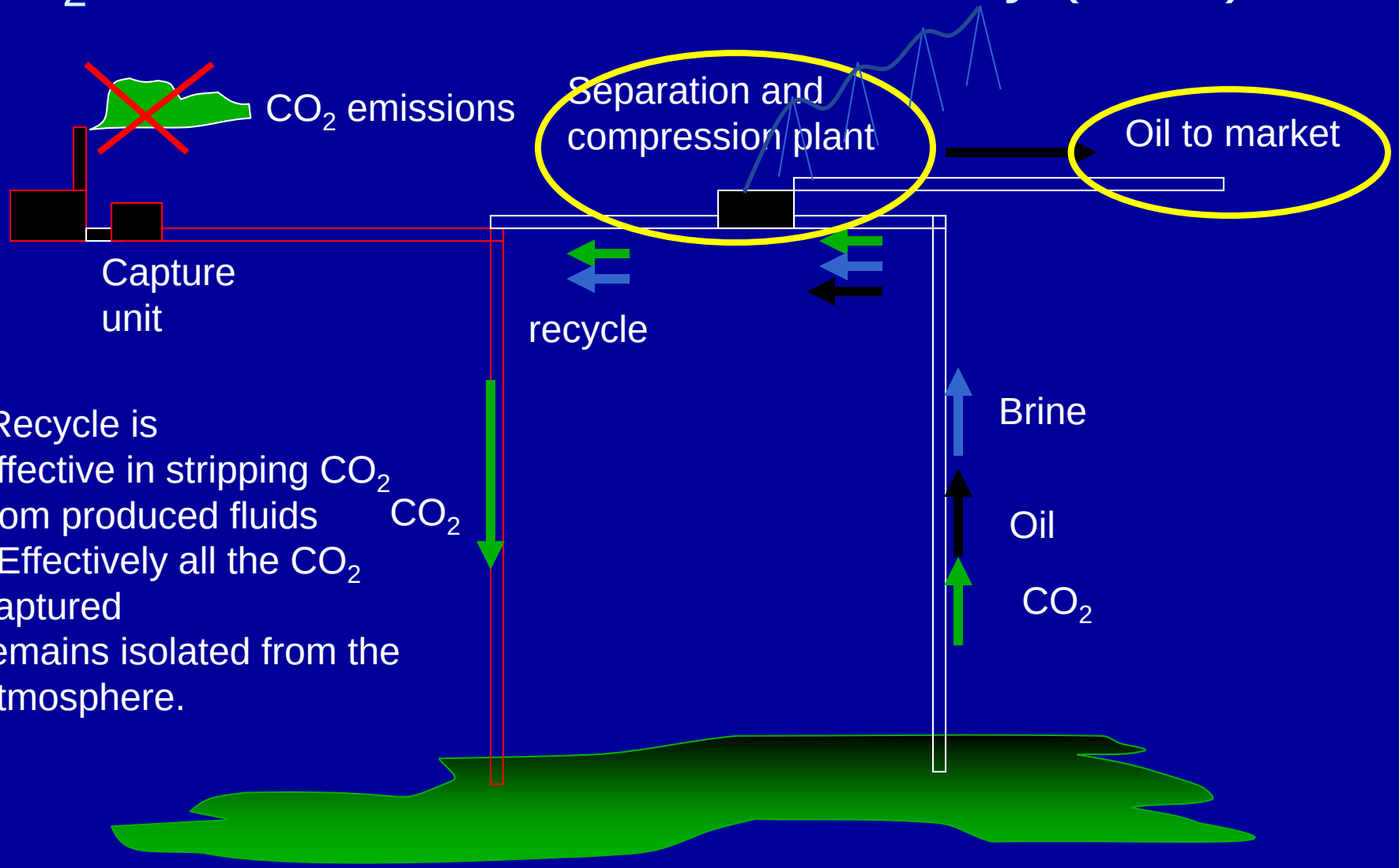
Gulf Coast Carbon Center

www.gulfcoastcarbon.org

EOR is Popular as Storage



CO_2 use for Enhanced Oil Recovery (EOR)



Recycle is effective in stripping CO_2 from produced fluids

Effectively all the CO_2 captured remains isolated from the atmosphere.

Permanence questions – oil production, recycle and well performance

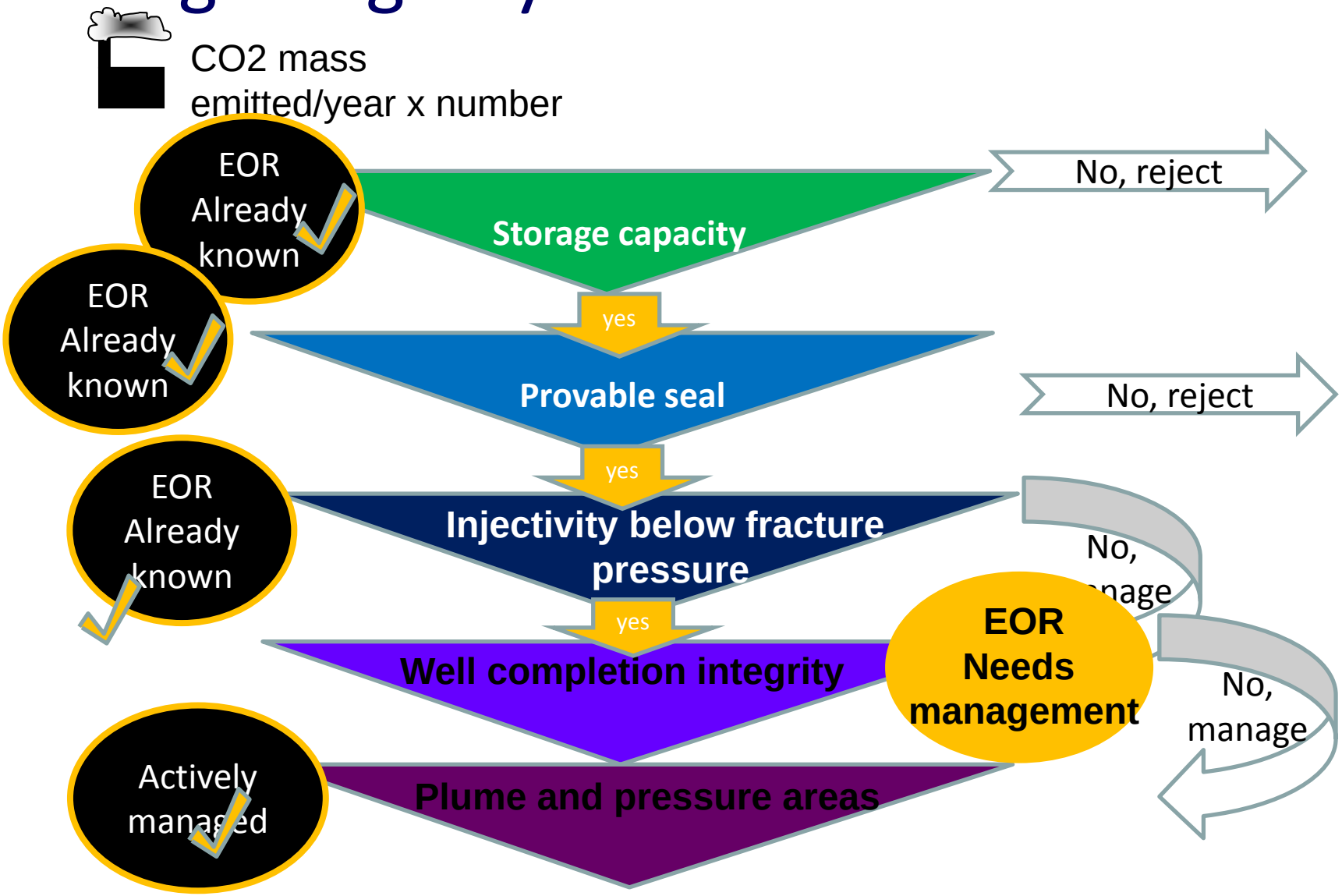
Value of CO_2 Sales to Capture

Facility	Captured	Value $30?T
Air Products	1 MMT	>$30M/year
Boundary Dam	1 MMT	> $30M/year
Kemper County	3.5 MMT	> $105M/year
Leucadia-Lake Charles	4.6 MMT	>$138M/year
Summit	1.5 MMT	>$45M/year

Value of Mature Offtake

- Known permitting
- Pore space ownership and public acceptance
  - Unitization
- Past experience informs risk and liability
  - CO_2 injection for EOR since 1972
  - Dozens of incidents

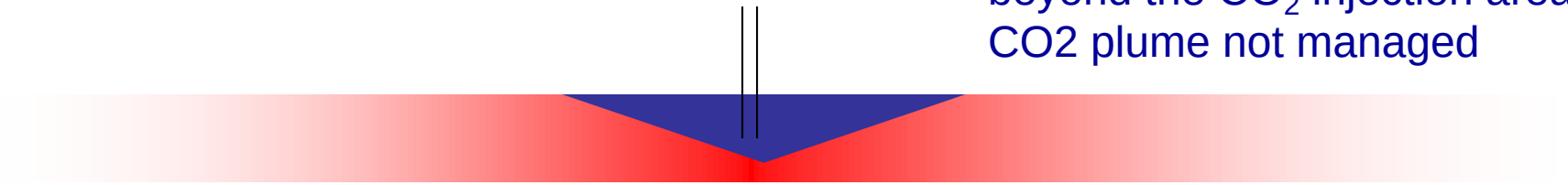
Characterization and monitoring geologic system for retention



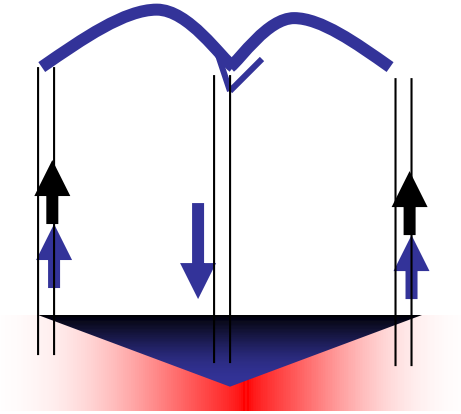
EOR and Sequestration - only have Different Plume and Pressure Footprints

Storage only

CO_2 injection (no production) pressure elevation extends beyond the CO_2 injection area. CO2 plume not managed



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



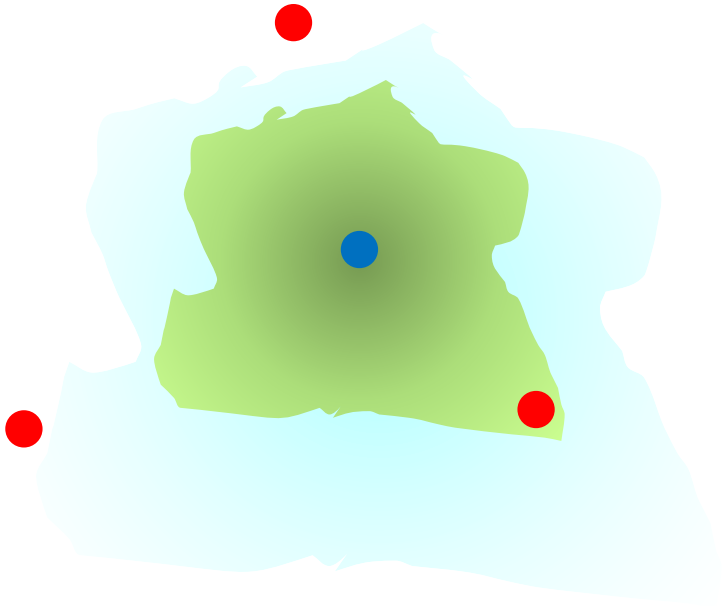
EOR

CO_2

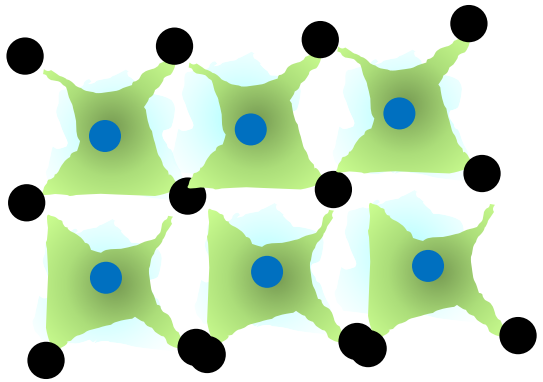
Elevated pressure

Comparing saline injection to EOR pattern flood

Saline injection map



EOR Pattern flood map



Injection well

Monitoring well

Production well

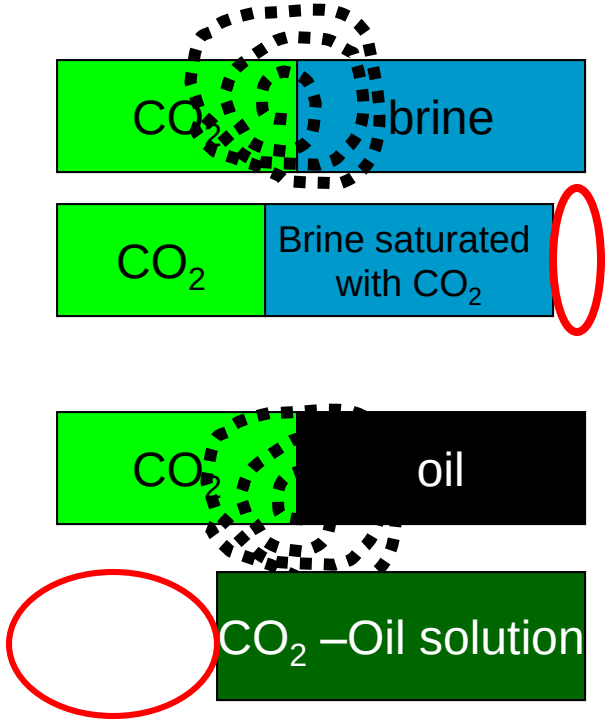
CO_2 plume

Elevated pressure

Benefit 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

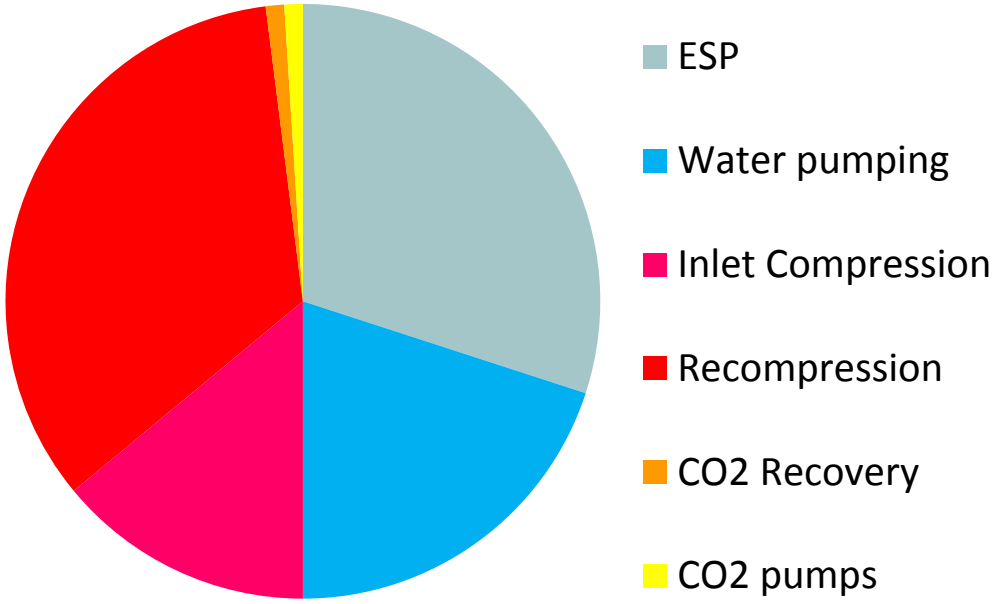


Less space occupied = enhanced security

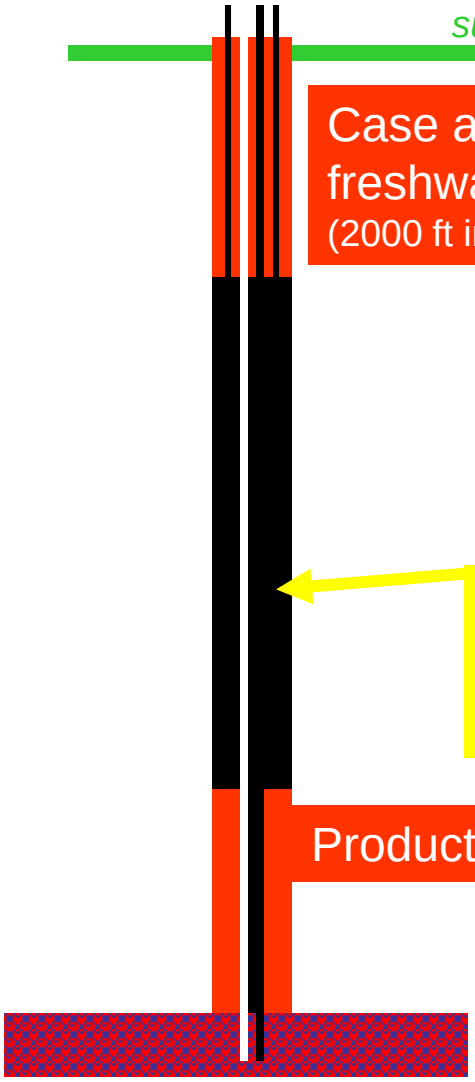
Downside of EOR to storage quality

- Carbon content of produced oil
  - Refining and combustion by end user
  - Ratio of CO_2 stored to oil produced (Jaramillo et al, 2009)
- Compression for recycle and water disposal
- Fugitive emissions
- Well leakage
  - Acute
  - Chronic/long term

CO2 EOR Carbon Balance Chuck Fox KinderMorgan SACROC field



So how good are wells?



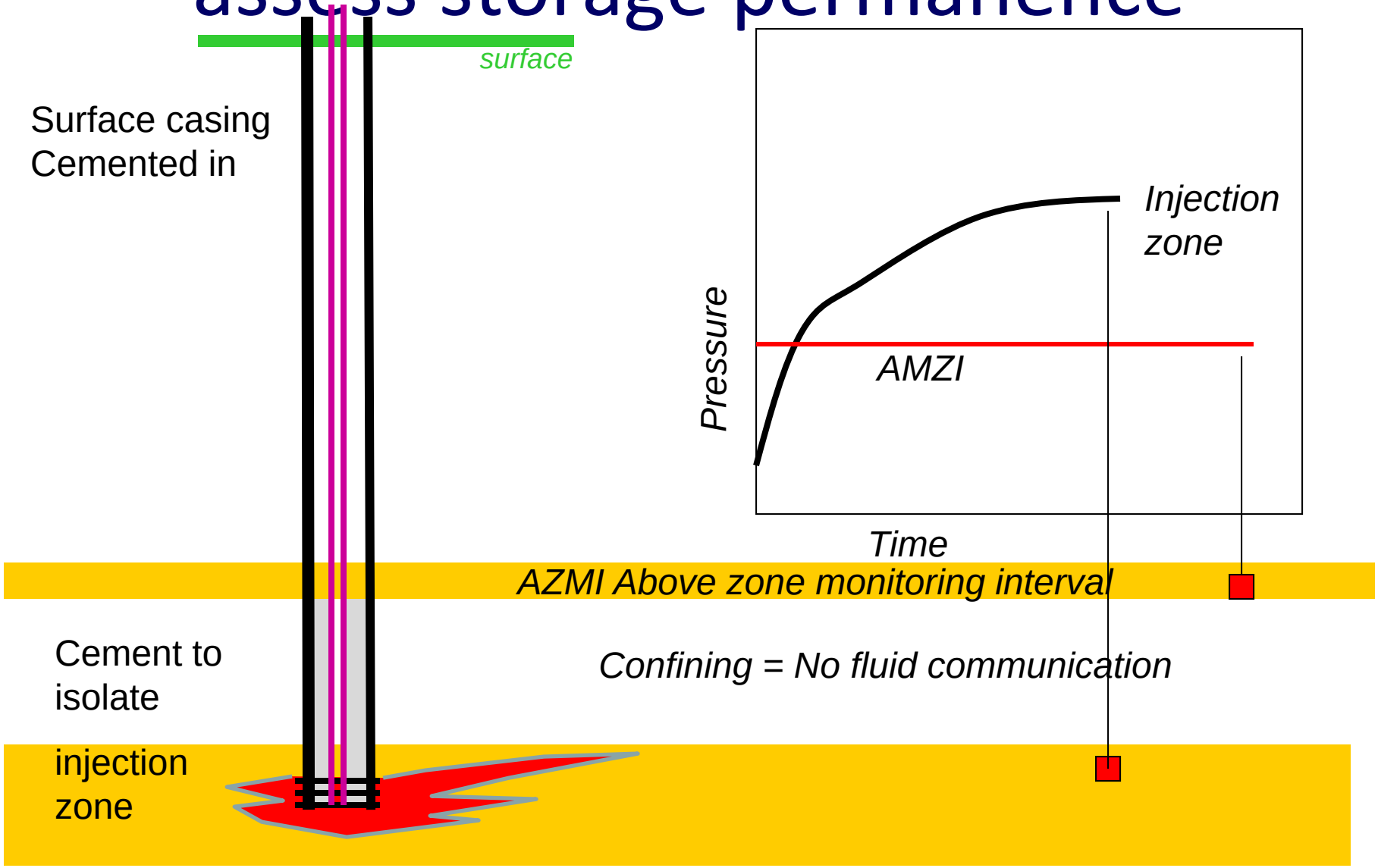
Case and cement to seal off freshwater (USDW)
(2000 ft in Gulf Coast)

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

Production casing and cement above production zone

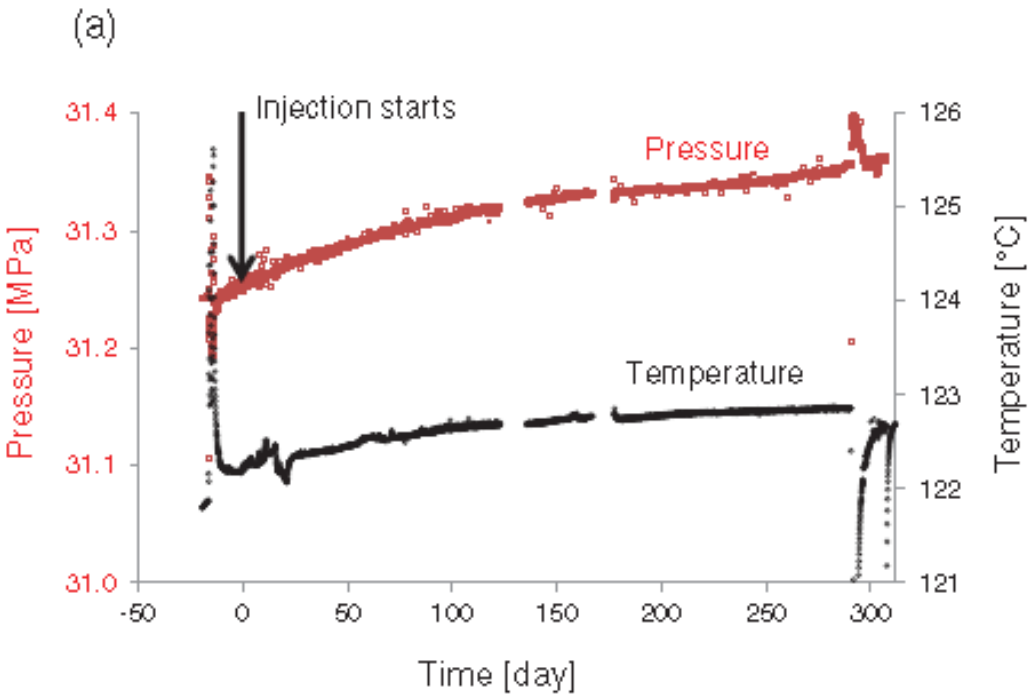
Oil reservoir,
add CO_2 for tertiary production of hydrocarbon resource

Using above AZMI pressure to assess storage permanence



Quantifying well leakage

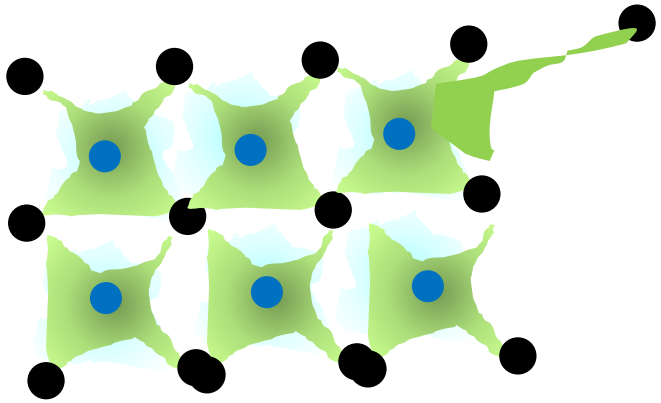
- Analog studies: Sustained casing pressure,
  - Huerta, 2009
  - Watson and Bach
- AZMI at Cranfield
- Hastings
- P-site



AZMI pressure change as injection pressure increases 31-38 MPA
Kim and others, 2013

Main well risk – unintended production

EOR Pattern flood map



Injection well

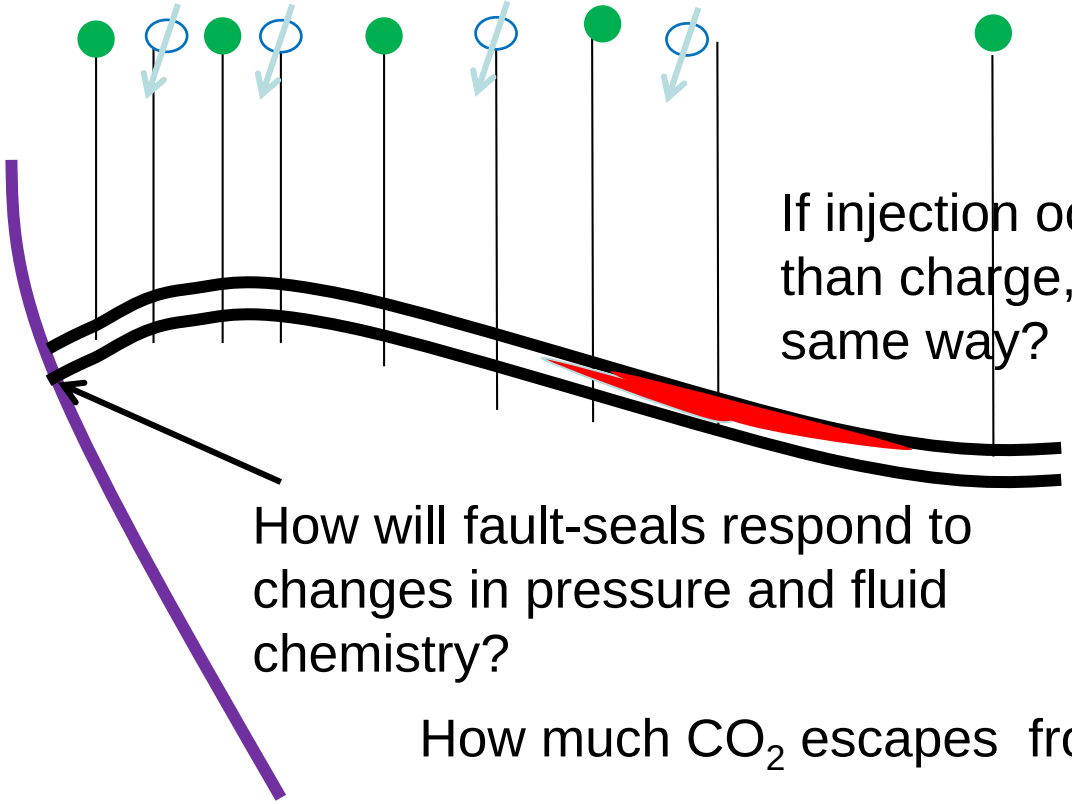
Production well

CO_2 plume

Elevated pressure

Pay attention to the data that disturbs our entrenched beliefs

Traps and seals that held oil will hold CO_2



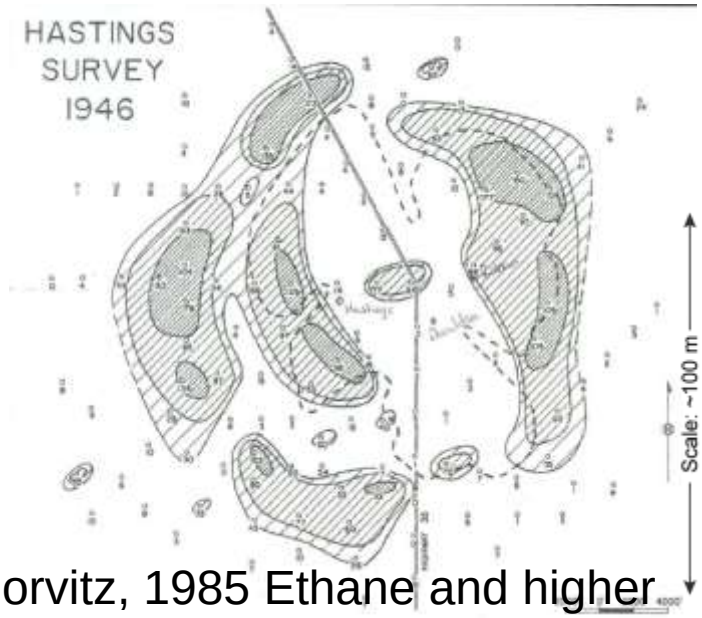
If injection occurs much more rapidly than charge, will it fill the trap the same way?

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

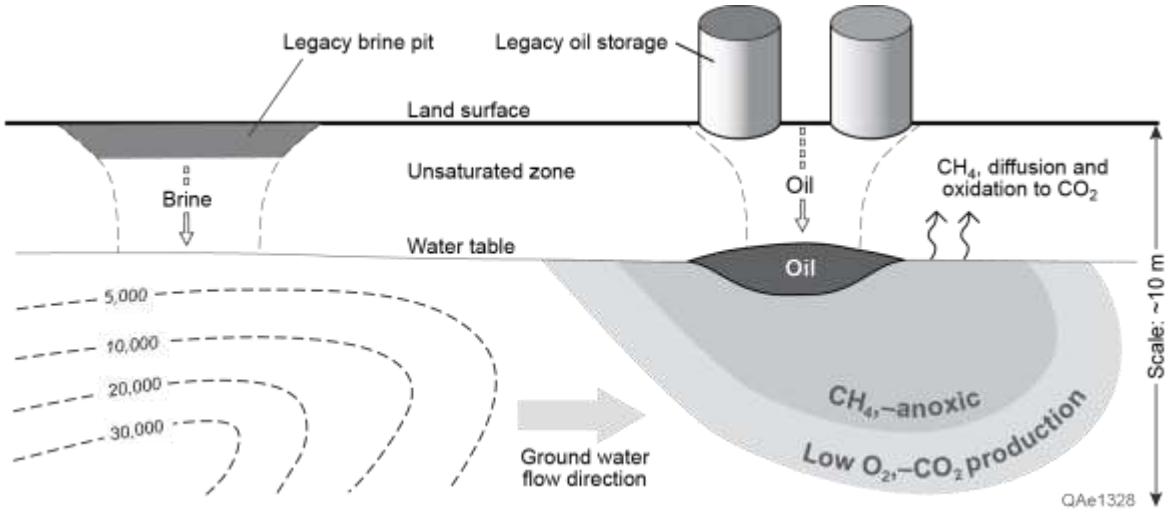
How much CO_2 escapes from pattern floods?

Limits of monitoring EOR

- Geologic microseepage – high and dynamic carbon content throughout geologic column
- Perturbed near surface
- Perturbed subsurface, past, present, future

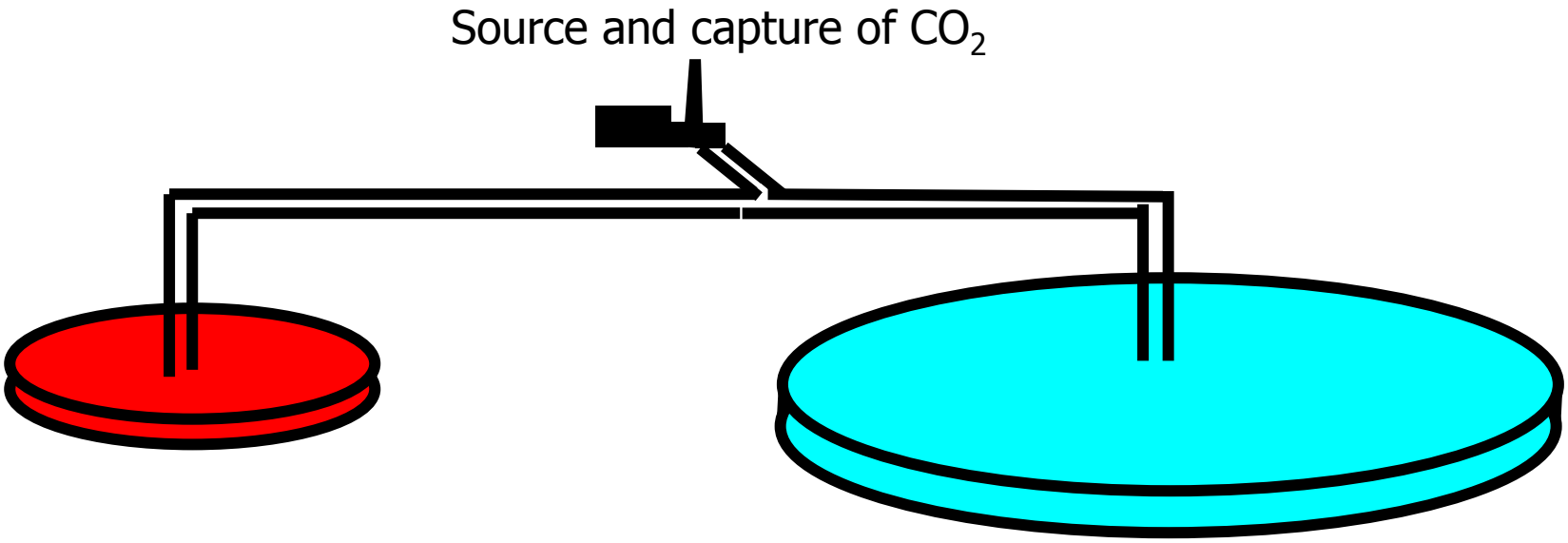


Horvitz, 1985 Ethane and higher hydrocarbons at 12 ft



Wolaver et al, 2013

Traditional conceptual dichotomy between use for EOR for storage in brine: CCUS or CCS



CO_2 use for enhanced oil production to offset development cost and speed implementation

CO^2 Storage in brine formation

EOR can accept only part of total stationary source emissions

Annual stationary source emissions
7 billion metric tons

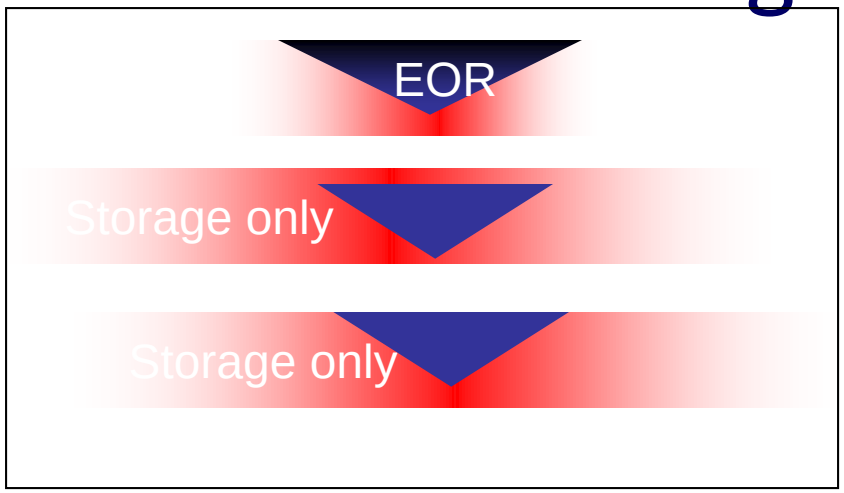
12-14 billion metric tons potential EOR market ARI 2010

0.9 billion metric tons current planned market (ARI 2010)

138 billion metric tons storage resource in depleted gas reservoirs (NETL 2008 NATCARB

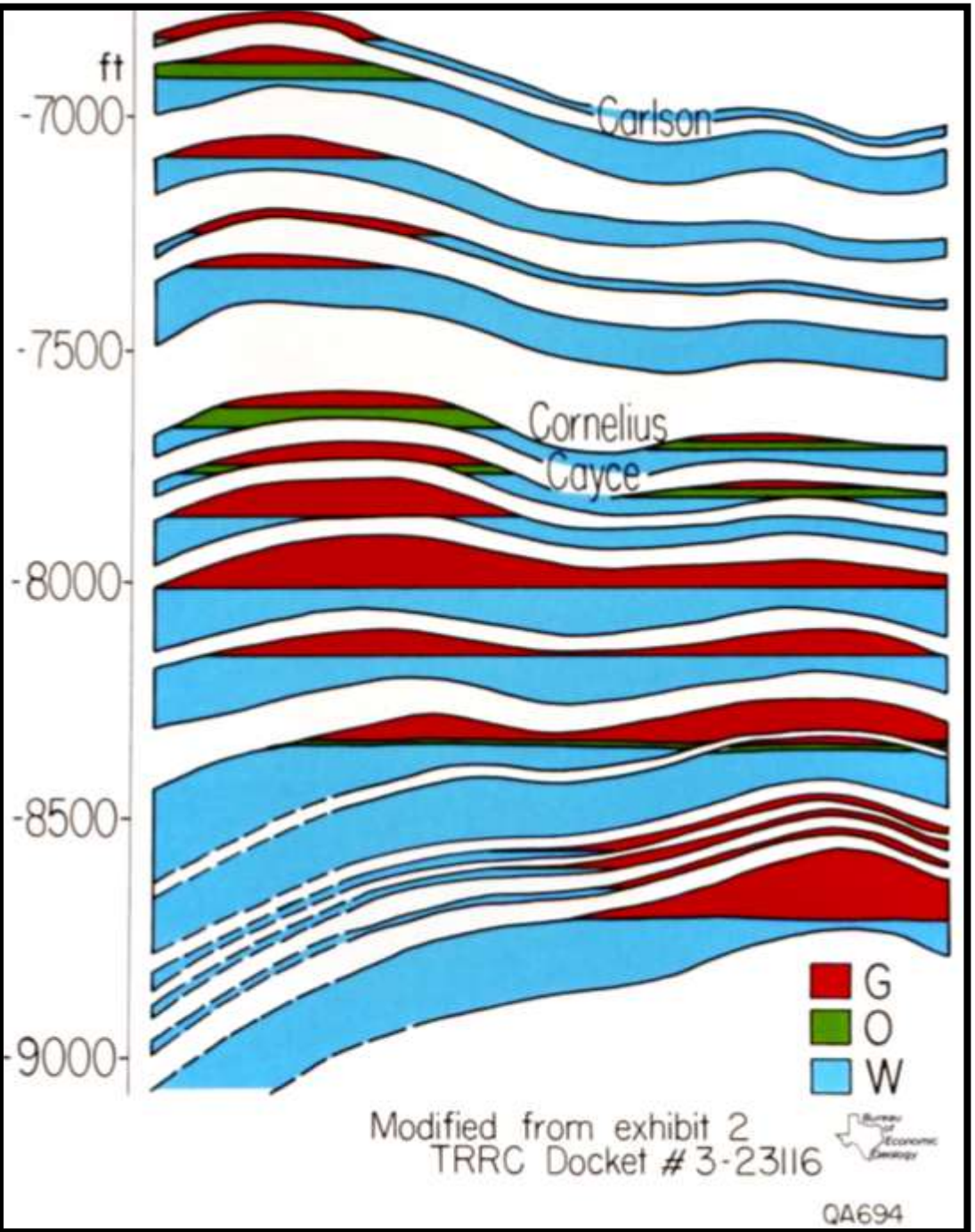
3,297 billion metric tons storage resource in brine formations (NETL 2008 NATCARB)

Rolling from EOR to Saline Storage via Stacked Storage

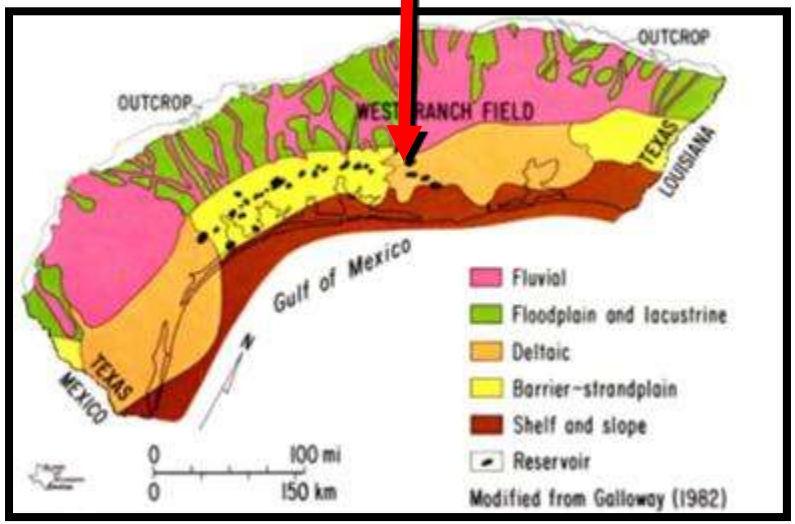


- By developing multiple injection zones beneath the EOR zone, the footprint of the CO_2 and pressure plume can be minimized and storage volume maximized

Stacked Frio Reservoirs: Rollover Anticlines



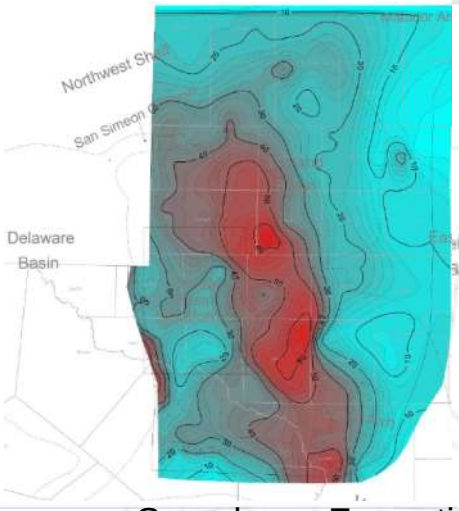
Markham North-
Bay City North field



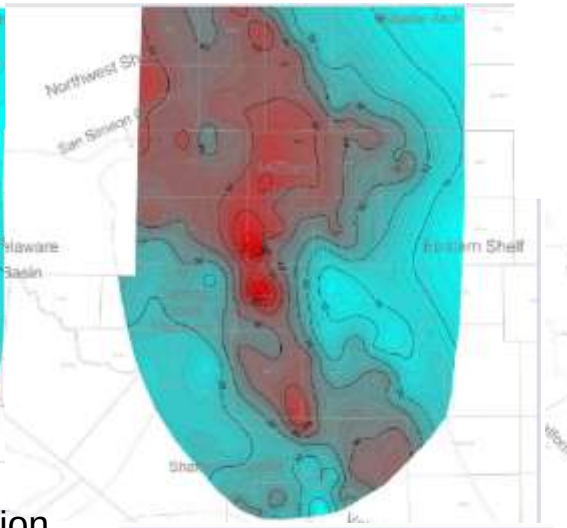
Modified from Tyler and Ambrose (1986)

Permian Basin: "Type locality" of EOR, has large Saline Storage Capacity

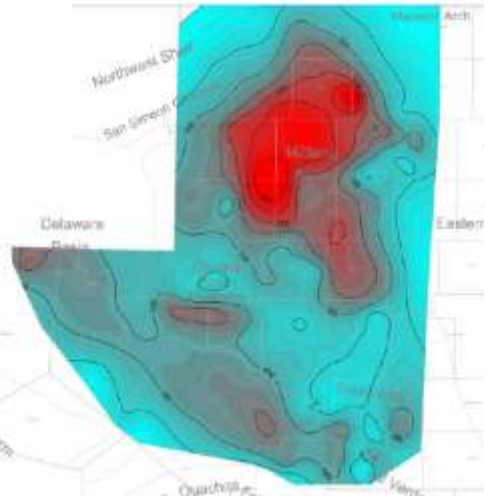
Yates Formation



Queen Formation



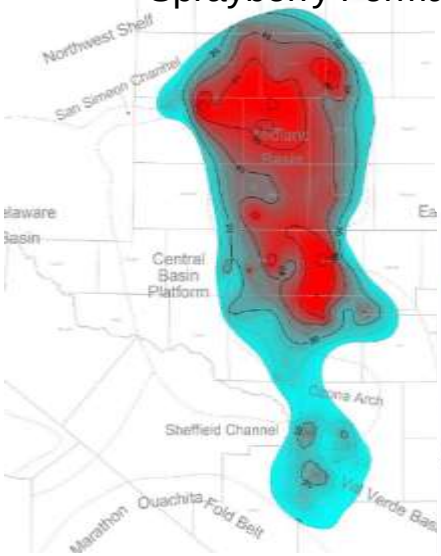
San Andres Formation



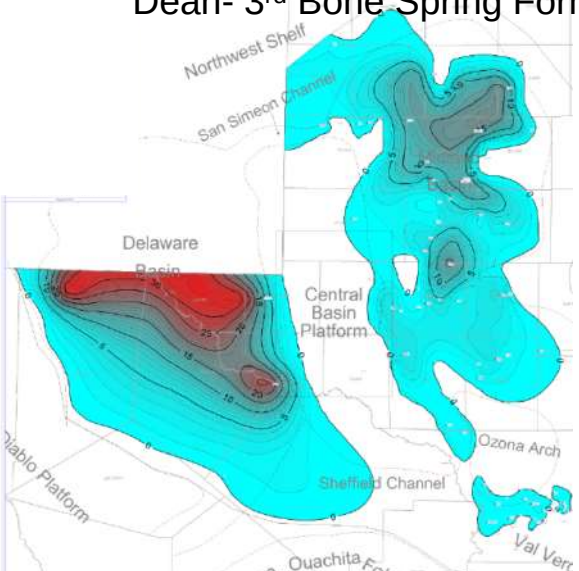
low — High

Capacity in porosity times thickness, (units variable)

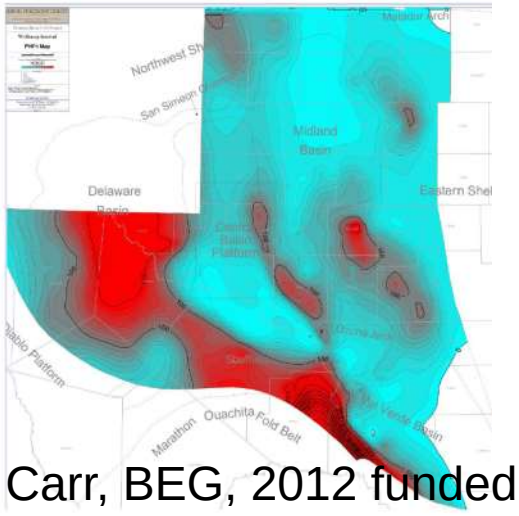
Sprayberry Formation



Dean- 3rd Bone Spring Formation



Wolfcamp – Lime

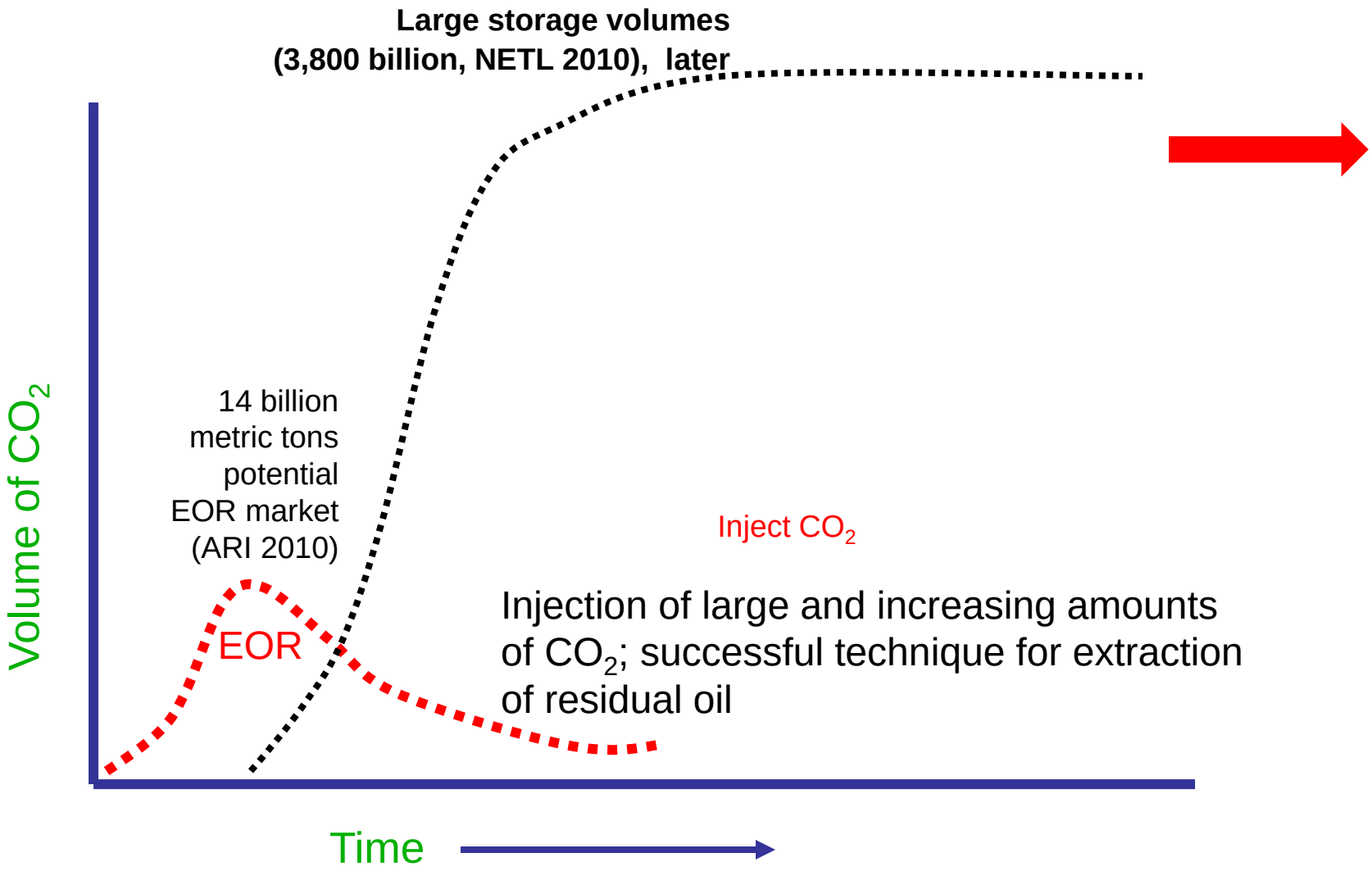


D. Carr, BEG, 2012 funded by USGS

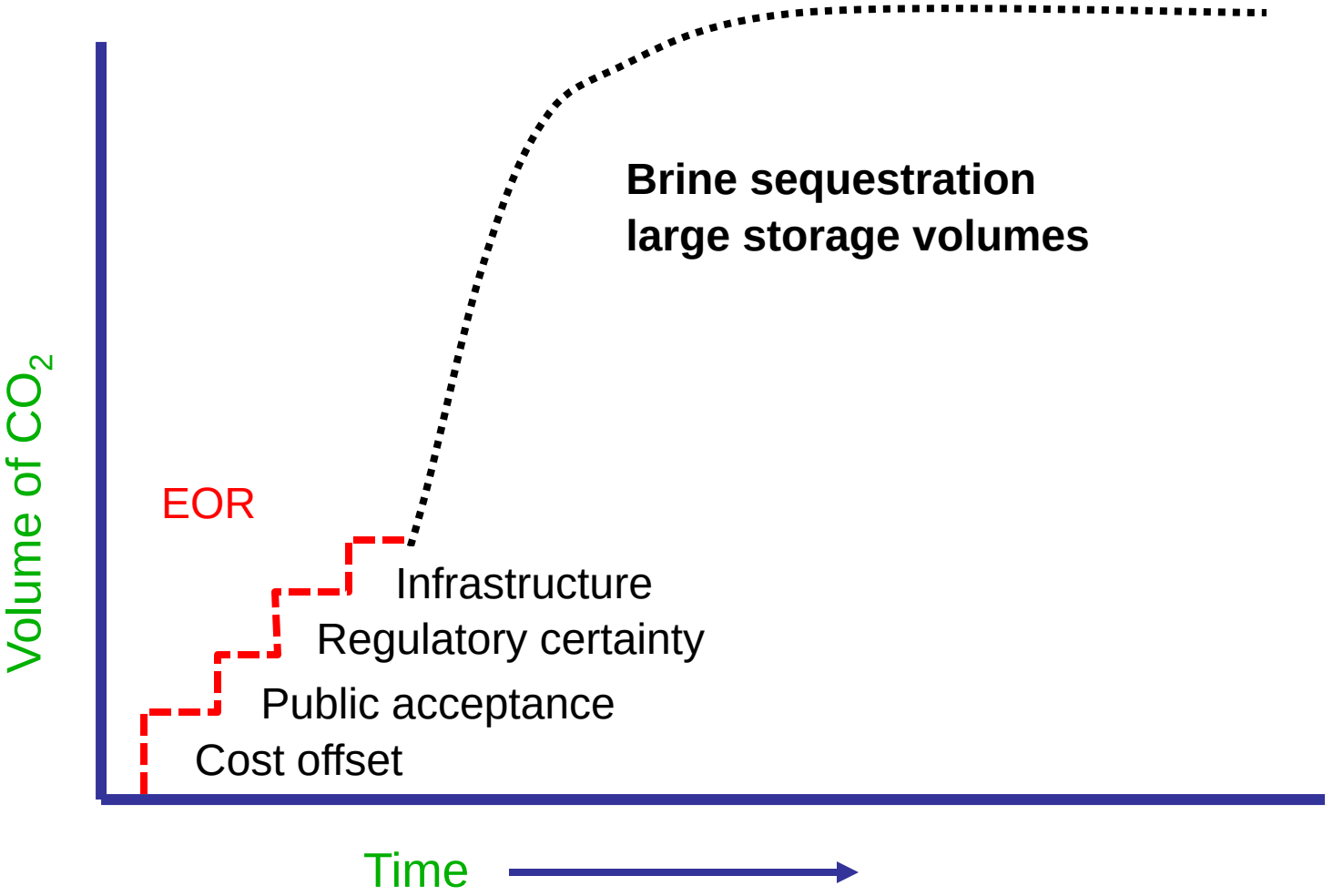
Advantages of Stacked Storage

- Limit plume and increased pressure footprint
- Characterization of multiple injection zones = reduced cost
- Co-monitoring multiple injection zones
  - Use of shallower zones for surveillance of deeper zones
  - Near-surface monitoring of same footprint
- Brownfield
  - Reduced environmental impact, same infrastructure
  - Increased public acceptance
- Revenue during initial (most expensive) stages

Role of Use (CO_2EOR) in Storage



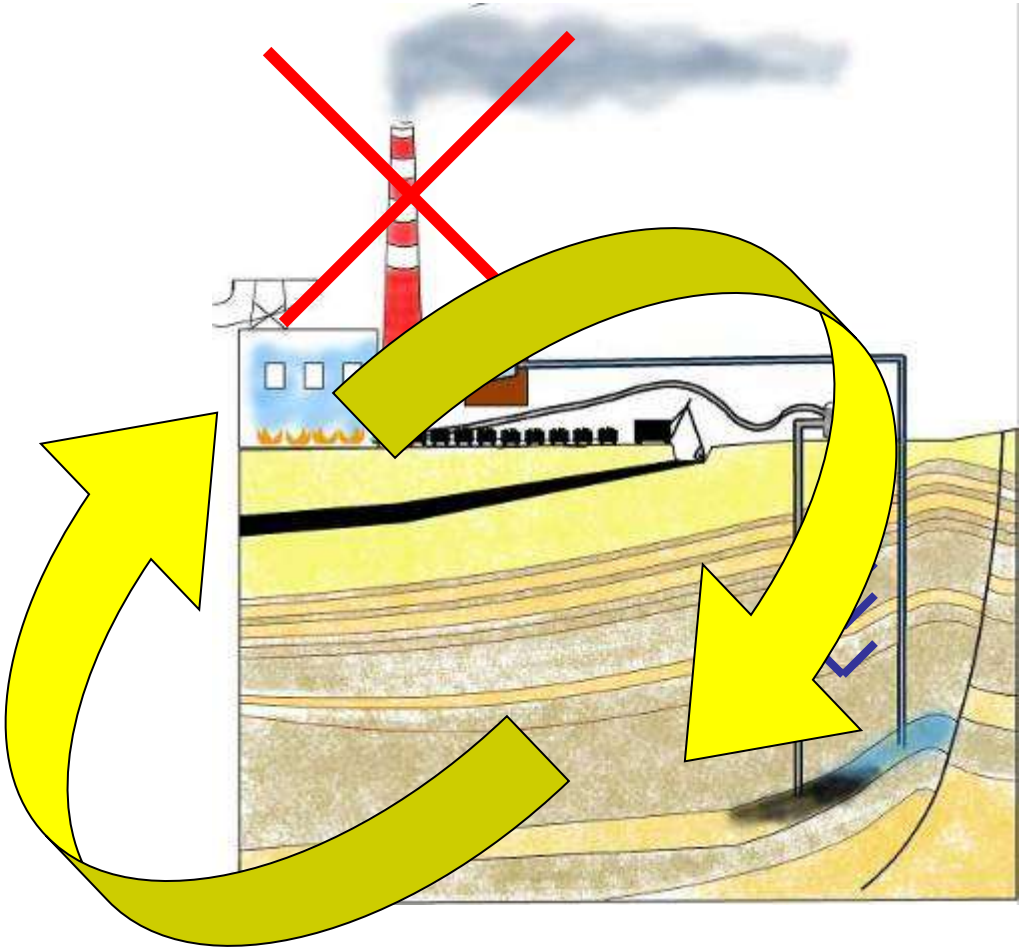
Updated Role of Use (EOR) in Storage



Conclusions

- Use of CO_2 for CO2-EOR is a happening and is a logical first step toward large scale CCS
- Incentivizes capture
  - Supports capture technology development financially and logistically
- Effective storage via EOR
  - Higher confidence than saline – geologically and operationally
  - Supports public acceptance
  - Supports development of monitoring and storage validation techniques – already 40 years of history
- Transition from EOR to very large volume saline storage is possible

Geologic Sequestration of Carbon – Put it back



Carbon extracted from coal or other fossil fuel…

Returned into the earth where it came from

Gulf Coast Carbon Center

Gulf Coast Carbon Center (GCCC)

IA sponsors

BG GROUP

bp

Chevron

China Petroleum Company (Taiwan)

ExxonMobil

KCRC
(재)한국이산화탄소포집및처리연구개발센터
Korea Carbon Capture & Sequestration R&D Center

NRG

Schlumberger Carbon Services

EDF ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

Aramco Services Company

www.gulfcoastcarbon.org

GCCC Training & Outreach

STORE

Collaborators

NETL

LBNL
LLNL
ORNL
SNL
Mississippi State U
U of Mississippi
SECARB
UT-PGE
UT Chem-E
CFSES- BES
UT- CIEEP
UT- DoGS
BEG- CEE
JSG – EER
Univ. Edinburgh
Univ. Durham
RITE
CCP -BP
CO2-CRC
AWWA

Personnel

Scott Tinker, Director BEG
Michael Young, Assoc. Dir. BEG
Sue Hovorka, Director GCCC
Dave Carr
Seyyed Hosseini
Toti Larson
Jiemin Lu
Tip Meckel
Patrick Mickler
J. P. Nicot
Vanessa Nuñez-Lopez
Hilary Olson
Katherine Romanak
Rebecca Smyth
Alex Sun
Ramón Treviño
Brad Wolaver
Changbing Yang
Mehdi Zeidouni
students and post-docs