CO2-EOR as geologic storage: Monitoring for permanence

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CO_2-EOR as Geologic Storage: Monitoring for Permanence

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Agenda

- Who is GCCC?
- What is EOR (in context of CO_2 storage?)
- Multi-step process for storage assurance
  - Review of concepts for storage
  - Documenting storage for CO_2-EOR
- Conclusions

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What is CO_2 EOR?

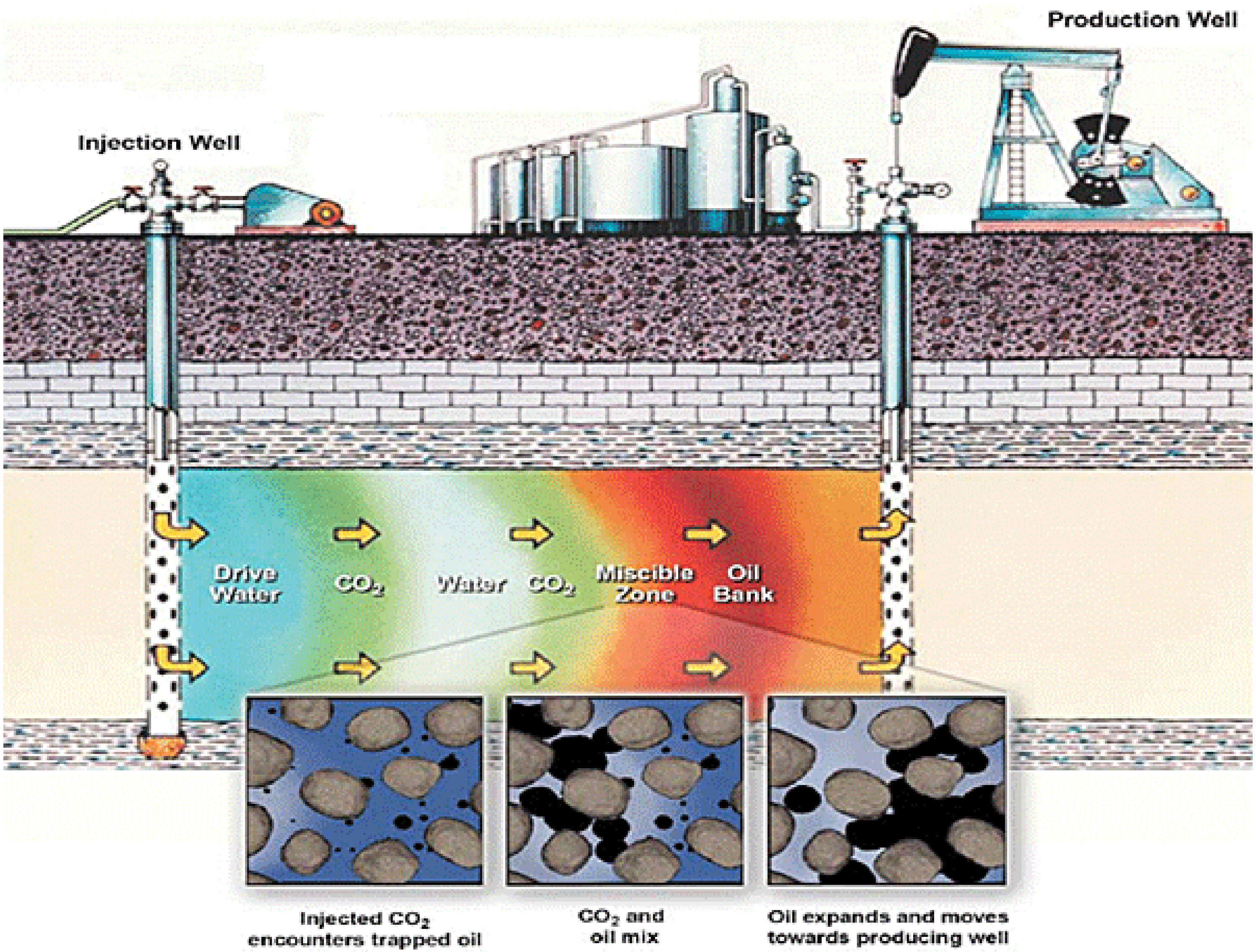
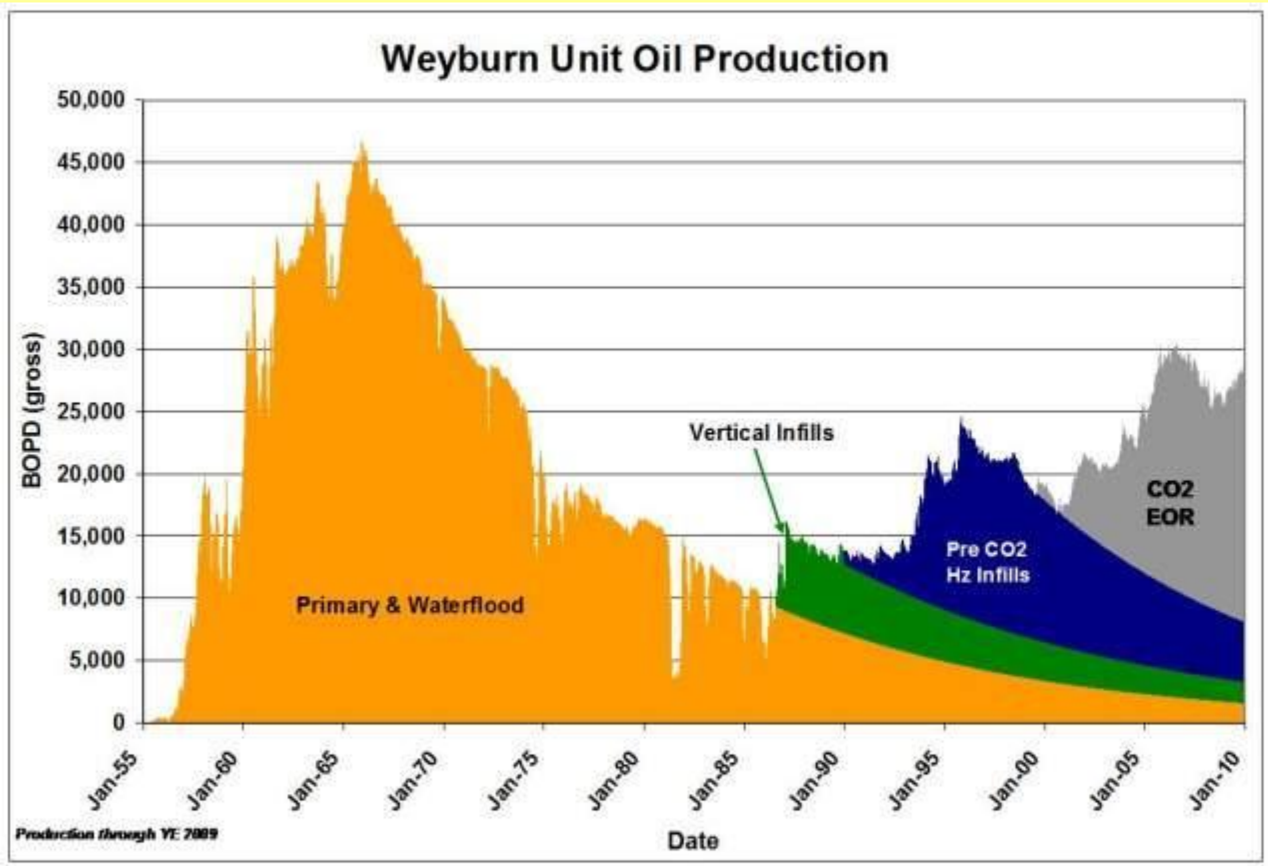


Image Joe Lindley DOE Bartlesville, OK + additions

Why do CO_2 EOR?



- Domestic oil,
- from brownfield sites,
- At lower risk than exploration

Why not do CO2 EOR?

- No CO_2 supply
- Unfavorable economics
  - Slow ROI*
  - Poor recovery
- No CO_2 expertise

http://en.wikipedia.org/wiki/Weyburn-Midale_Carbon_Dioxide_Project

*Return on Investment

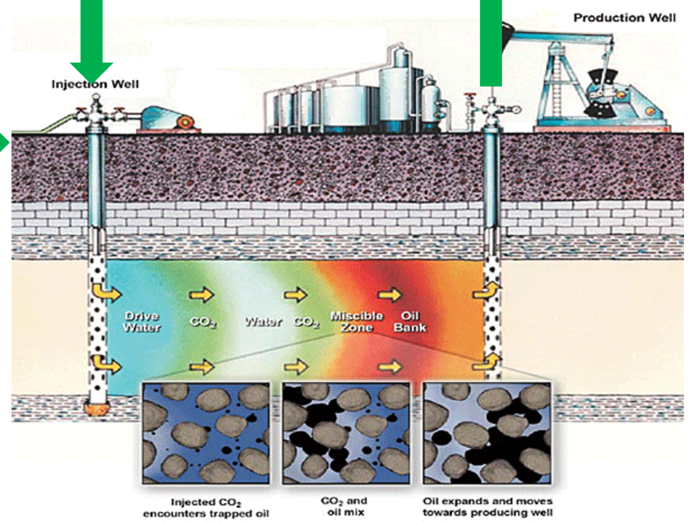
How can CO_2 EOR be part of Geologic Storage?

(four important things missing from orignal picture)

Produced CO_2 is promptly separated from oil, compressed, reinjected. Closed loop. No release.

Large volume sales of CO_2 promote capture

EOR occurs at depth > 1 km, isolated from the atmosphere. Wells designed to isolate



CO_2 is retained in the reservoir :

- In connected pores
- Proven seal
- Capillary trapping
- Dissolved in water and oil

Two types of Geologic Storage

Injection of CO_2 into unused deep saline formations	Use of CO_2 for EOR
• Large volume	• Moderate volume
• Widespread	• Traditionally focused in a few geographic areas
• Sole purpose is storage – Requires funding	• Main purpose is oil recovery – Revenue generation
• Novel – New permitting rules – Cost? – Public acceptance? – Liability	• Mature – Permitting – Known economics – Mature pubic acceptance and liability

EOR as Storage: Questions about Surface Operations

- Does CO_2 recycle count against carbon retention?
  - No, it is a closed cycle
  - Can be audited as part of monitoring
- Does energy use during recycle for separation and compression count against carbon retention?
  - Either part of production, counted with oil, or dealt with via accounting
- Does oil production count against carbon retention?
  - No, it is counted at the point of sale or combustion

Current Regulations on Geologic Storage (incl. subsurface)

Injection of CO_2 into unused deep saline formations	Use of CO_2 for EOR
• Water protection set by EPA UIC* Class VI rules – Rigorous rules set by EPA with extensive monitoring program	• Water protection set by EPA UIC Class II rules, mostly delegated to States – Focus on well integrity
• EPA CAA** program – Required reporting under Subpart UU – Voluntary reporting under Subpart RR with monitoring	• EPA CAA program – Required reporting under subpart UU – Voluntary reporting under subpart RR *with monitoring*
	State rules

* Underground Injection Control

** Clean Air Act

Question about Subsurface Geologic Storage Permanence

- EPA Class VI rules for saline storage require a detailed monitoring program of the plume extent, pressure elevation, USDW* sampling, etc.
- EPA Class II for EOR does not have this type of monitoring
- Does CO_2 injected under Class II need to be monitored under Class VI to be worthy of equal assurance of storage (under CAA Subpart RR)? Or can something else count as monitoring?

* USDW is Underground Sources of Drinking water, EPA protected resource

Groundwater monitoring is not the same as air emissions monitoring

- UIC does not deal with CO_2 emissions to air that do not impact water
  - Direct emissions to air (e.g. through wells)
  - Minimal impact on water (e.g. water already contains fairly high CO_2, or aquifer not reactive)
  - No USDW
  - Slow leakage – cumulative impact on air, no measurable impact on water
- Non-optimum use of EPA's laws

Designing Fit-to-purpose Monitoring Program

- Setting the storage goals
- Characterization plus modeling are primary tools to meet goals
- Inventory of fluid management

  Fluids in - fluids out = storage
- Monitoring to increase confidence
  - Depends on level and type of concern
  - Risk dependent: EOR has different uncertainty profile than saline, therefore requires different approach.

Setting the Project Goals

(driver for monitoring design)

- EPA CAA Subpart RR
  - Annual reporting.
  - What about long term storage assurance
- *or* State Rules
- *or* Credits, tax rebates, BACT, industry best practice, liability….
- *or* Connected to UIC program
- *or* other

Strawman Project Goals

- There is a high probability (statistically stated) that X tons of a total planned injected Z tons will be stored isolated from the atmosphere for more than Y years.
- In addition, the following (enumerated) risks will be avoided or mitigated
  - No triggering felt seismicity
  - No damage to resources
  - No migration into (enumerated) prohibited area.

Conformance

Assurance

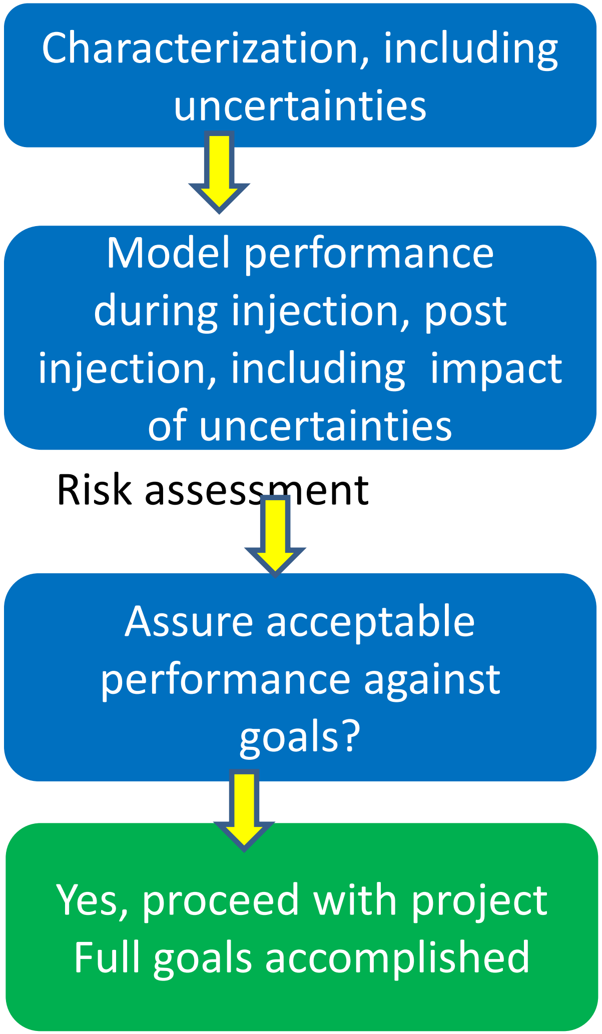
Characterization Provides Assurance of Storage (Saline and EOR)

- Characterization plus modeling
  - Defines the evolution of CO_2 plume over time within the reservoir
  - Defines the ability of the confining system to retain CO_2 in isolation from the atmosphere over the period defined in the storage goals
- Characterization plus modeling also used to evaluate other project goals

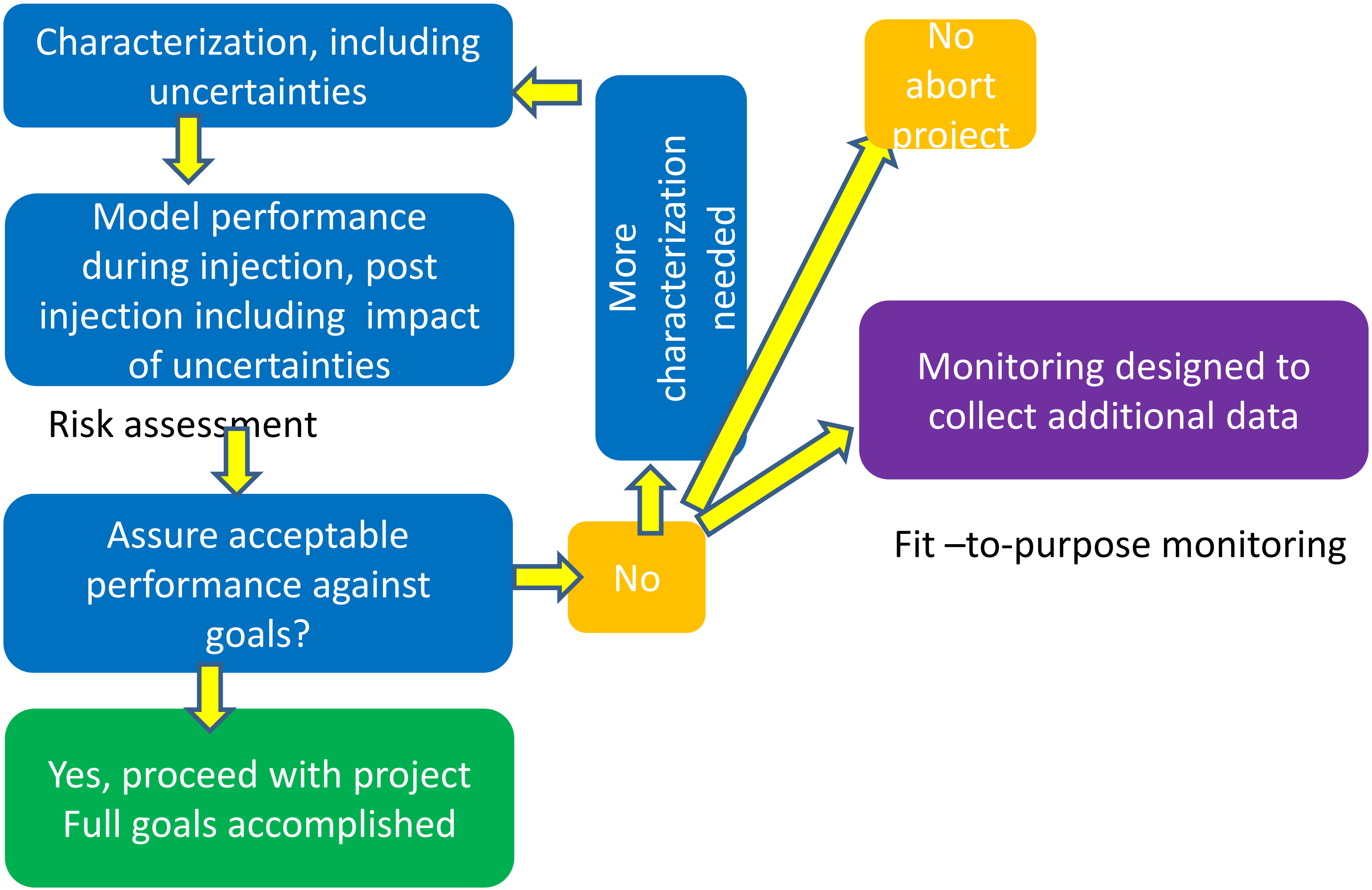
Risks Typical of Different Types of Storage

Risk	Saline	EOR
Reservoir will not accept planned mass of CO_2	Moderate	Low
Confining system will not retain CO_2	Moderate	Low
Plume lateral migration not predictable	Depends on site	Low
Existing wells with engineering inadequate to meet goals	Depends on site	Moderate-high

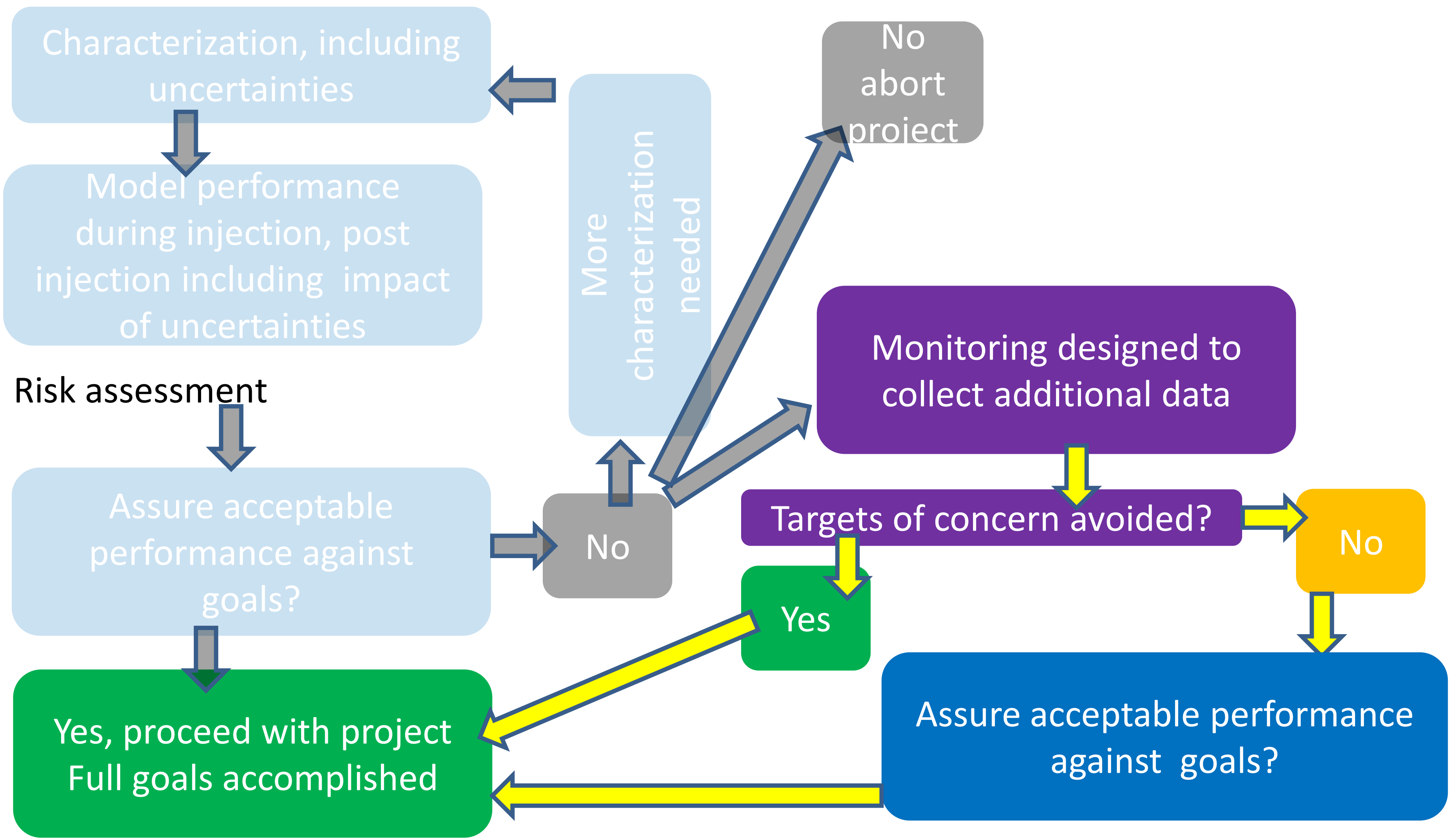
Uncertainties that remain at each stage of the project can be systematically reduced to reach goals (1)



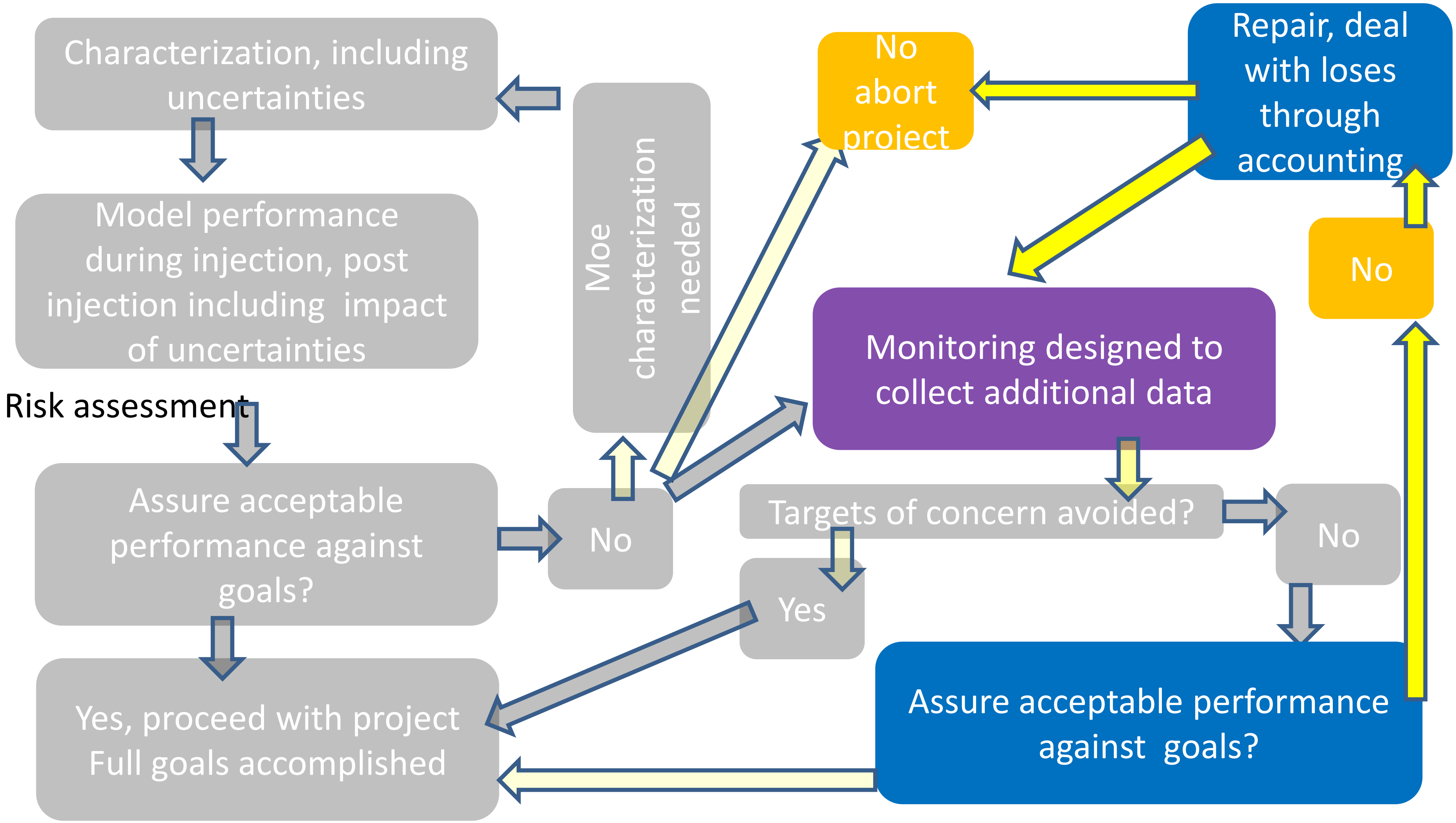
Uncertainties that remain at each stage of the project can be systematically reduced to reach goals (2)



Uncertainties that remain at each stage of the project can be systematically reduced to reach goals (3)



Uncertainties that remain at each stage of the project can be systematically reduced to reach goals (4)



For saline and EOR to be equally worthy of counting as storage…

the monitoring program must be different

What needs to be done at typical EOR site to meet storage goals?

- Characterization based on reservoir data and production history
- Proven confining system
- Model prediction of CO_2 use
- Assessment of well condition, rehabilitate for EOR use
- Inventory of fluid management
  - Injection and withdrawal accounting

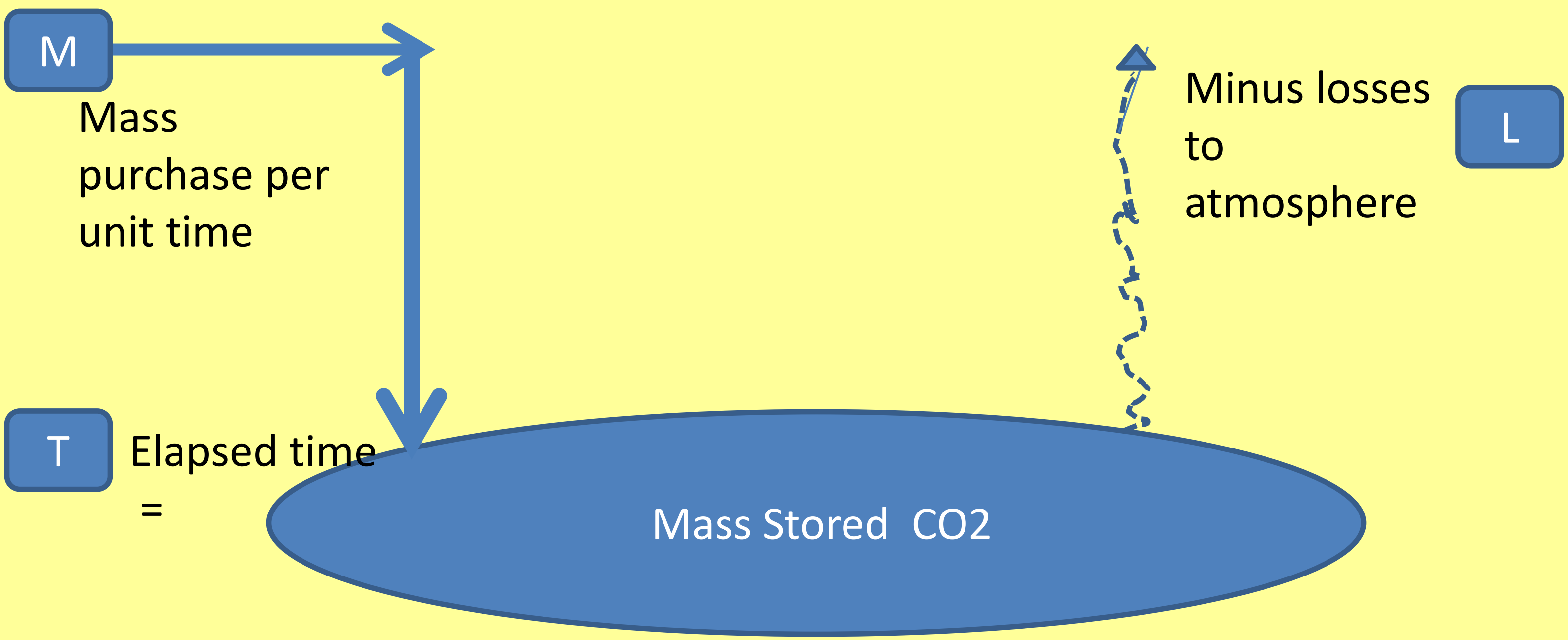
Harmonized with commercial activities

- Storage risk assessment
  - Issues related to obtaining storage goals
    - Short and long duration

Specific to storage

Inventory of fluid management all projects

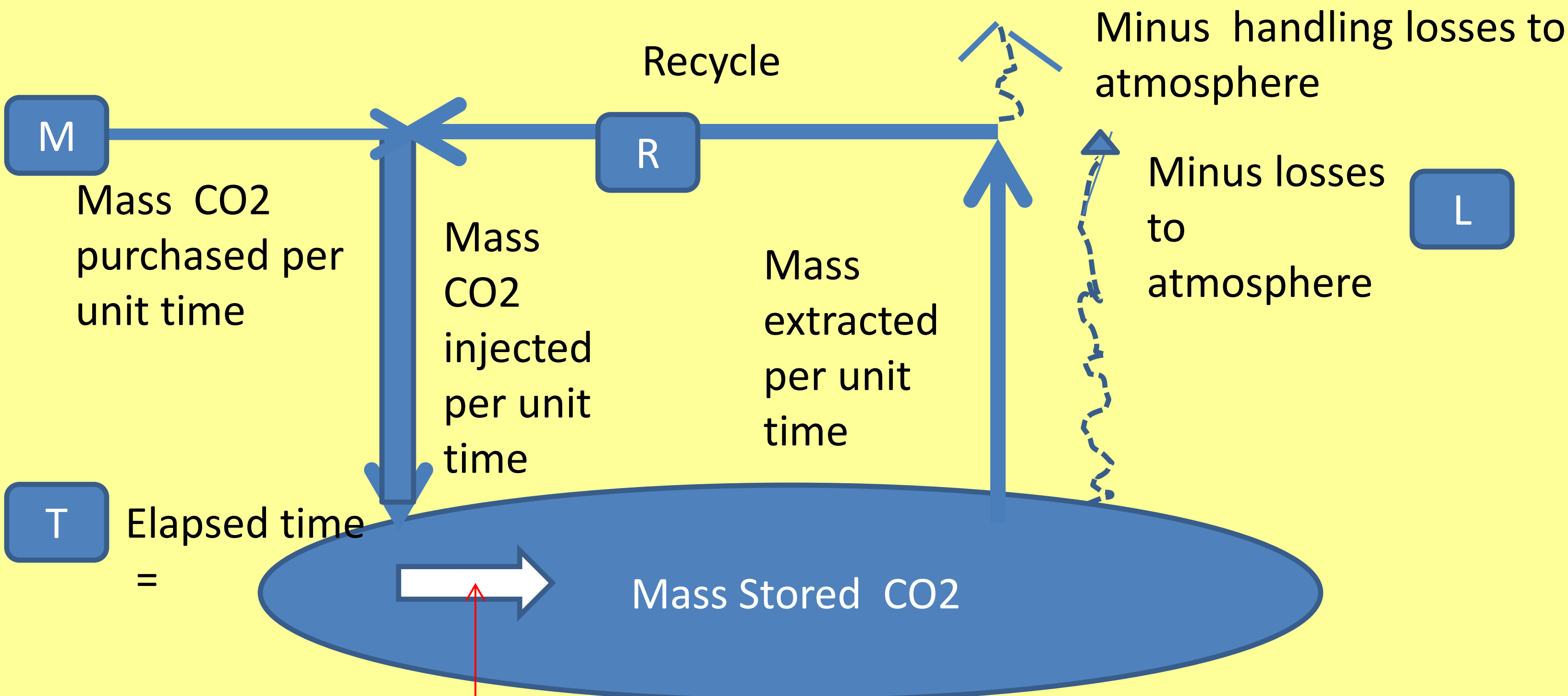
- The accounting is simple



This number, the mass CO_2 stored , is important to GHG accounting

Inventory of fluid management for EOR

- Confusion in conceptualization



This number, the CO_2 moving though the reservoir is important to oil production

Well failure:
Burst pipe or continual drip?

- Well failure can be fast or slow
- Rapid release “blow-out” can be dramatic, with noise and clouds of condensed steam from cooling the air.
- Slow release however may be more damaging to storage, as the small rate may not be detected, and last a long time
- Tools are available to diagnose and repair wells
  - Largest problem are wells that have been plugged and abandoned (or lost and forgotten).

EOR-Specific Storage Differences:

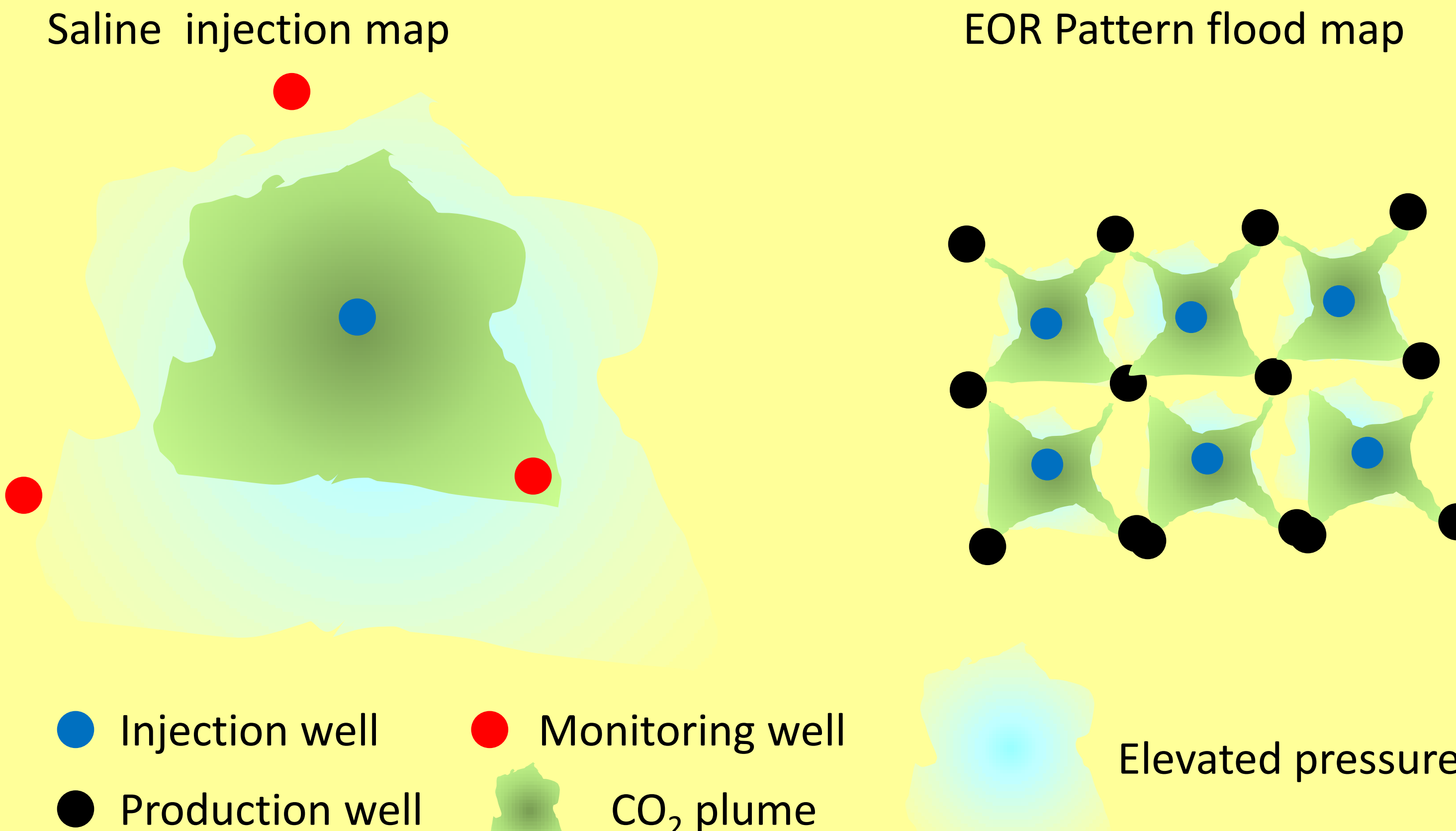
Some problematic uncertainties in saline setting are well known in EOR setting (low or no additional monitoring needed)

- Capacity and injectivity (defined by production history)
- Confining system quality (defined by trapping)
- Long-term lateral migration (defined by hydrocarbon geometry)
- Pressure and fluid flow (actively managed)

EOR-specific Storage Risks

- Wells (old and numerous)
  - Well known issue
  - Significance to storage goals needs evaluation
  - Out-of-pattern migration
  - CO_2 produced by wells not connected to pattern
  - CO_2 migration lateraly out of structure
- Damage to top or fault seal because of past or future pressure (or fluid) change
  - hypothetical

Comparing saline injection to EOR pattern flood



EOR specific monitoring

- Strengths – many well penetrations, abundant data
- Weakness – complex fluids, complex history may obscure leakage signal

Where we put monitoring

- Injection zone – pressure signal, average across injectors and producers
- Injection zone uncertainties: spill point, possible out-of-pattern migration (fit to purpose)
- Above confining zone: array of pressure measurements, optimized in laterally continuous, thin, well connected transmissive zones.
- Detailed near-surface characterization to assess ambient variability, processes, and determine what CO_2 impact would look like.

Conclusions

- Sales of CO_2 for EOR can provide a valuable “kick start” for CCS
  - Market
  - Low risk profile
  - Intrinsically high quality storage
- Some policy decisions might limit value of EOR to CCS
  - Oil production
  - Regulatory miss-matches with needs
    - Too strict – loose business case
    - Too lax – loose atmosphere case

Conclusions
"just right assurance"

- Clear statement of project goals

Document achievement of long-term atmospheric goals with CCS

Enforce a specified storage efficiency

Credit volume documented as stored

Incentivize capture

Step at a time

- Assessment of methods and barriers to achieving goals
  - Systematic fit-to-purpose process by which achieving project goals can be documented.
  - Fit-to-purpose means that monitoring needs for EOR will be different from saline

Reading list

- Texas Administrative Code, Title 16, Part 1, Chapter 5, subchapter C, Certification of geologic storage of anthropogenic carbon dioxide (CO_2) incidental to enhanced recovery of oil, gas, or geothermal resources,
- U.S. CFR, 1983. Code of Federal Regulations, 40 CFR 146.23. Part 146—Underground Injection Control Program: Criteria and Standards. Subpart C—Criteria and Standards Applicable to Class II Wells. 146.23 Operating, Monitoring, and Reporting Requirements. 31404.
- U.S. CFR, 2010a. Code of Federal Regulations, 40 CFR Parts 72, 78, and 98. Mandatory Reporting of Greenhouse Gases: Injection and Geologic Sequestration of Carbon Dioxide., 75060-75089.
- U.S. CFR, 2010b. Code of Federal Regulations, 40 CFR Parts 124, 144, 145, 146, and 147. Federal Requirements under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells. Final Rule. EPA Docket: EPA–HQ–OW–2008–0390 FRL–9232–7, 77230-77303.

Reading list (continued)

- Wolaver, B. D., Hovorka, S. D., Smyth R. C., 2013. CO2 sequestration at greensites and brownsites: Contrasting characterization, risk assessment and monitoring, International Journal of Greenhouse Gas Control 19 (2013) 49–62
- Hill, Bruce, Hovorka, S. D., and Meltzer, Steve, 2013, Geologic carbon storage though enhanced oil recovery, Energy Procedia 37, p 6808 – 6830
- Lake, L. W., 1989, Enhanced oil recovery; Prentice-Hill, Inc, Engelwood Cliffs NJ, 550 p.