CO_2 Storage: Reinventing Petroleum Geoscience for New Applications

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Abstract

Carbon Capture and Storage (CCS) is a proven technology for mitigation of climate change. In total, 100s of millions of tons have been injected to date in a combination of saline reservoirs and CO2-EOR projects stretching back to the early 1970s. Growing CCS to the scale needed to mitigate climate change will require more than a 100-fold increase in yearly injection volumes, however. Given decades of experience with subsurface reservoirs, the petroleum industry is well positioned to play a key role. Indeed, the challenge of permanently sequestering a buoyant fluid in geologic reservoirs sounds a lot like petroleum geology in reverse, perhaps with some difference in the details of a different fluid.

While petroleum reservoirs do indeed work for CCS, the differences run deeper than fluid and flow direction. Specifically, there are several key considerations:

- Pressure build-up. Unlike petroleum, which accumulates on geologic time at pressure equilibrium, CCS requires injection at industrial rates. In sealed reservoirs where pore space is already occupied (by brine or hydrocarbons), pressure build-up is inevitable and ultimately limits injection.
- Legacy well risk. Petroleum basins offer attractive advantages for CCS, including existing infrastructure, extensive subsurface data and proven reservoirs and seals. However, they may also have as many as 1 million legacy wells, every one of which is a hole in the geologic seal and few (none?) of which were engineered for CCS or increasing pressure.
- Goal of permanent sequestration. Petroleum accumulations are only attractive if the fluids are producible in economic quantities, which has focused attention on buoyant traps with high-quality reservoirs and seals. For CCS, the goal of permanent sequestration opens the door to using residual trapping, dissolution and mineralization—one man's "waste zone" is another's secure storage.
- Economics and public acceptance. CCS is fundamentally pollution control. It is a low-margin business, akin to trash collection, but capture, transport and wells are expensive. CSS is also new to the general public and there is considerable distrust. These are the critical factors holding CCS back.

In short, carbon storage draws on the same data and subsurface expertise as the petroleum industry but different goals, constraints and boundary conditions create a very different view of what "good" looks like. The Gulf Coast Carbon Center is addressing these challenges, inventing new plays for CO2 storage, developing new tools for resource assessment and educating practitioners, regulators and a public new to CCS.

The Role of CCS

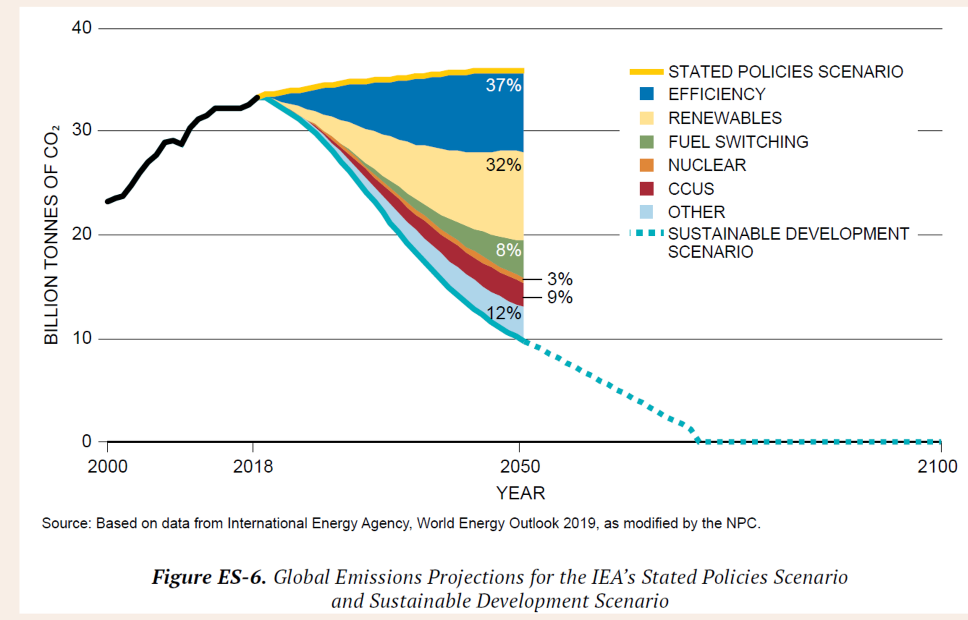
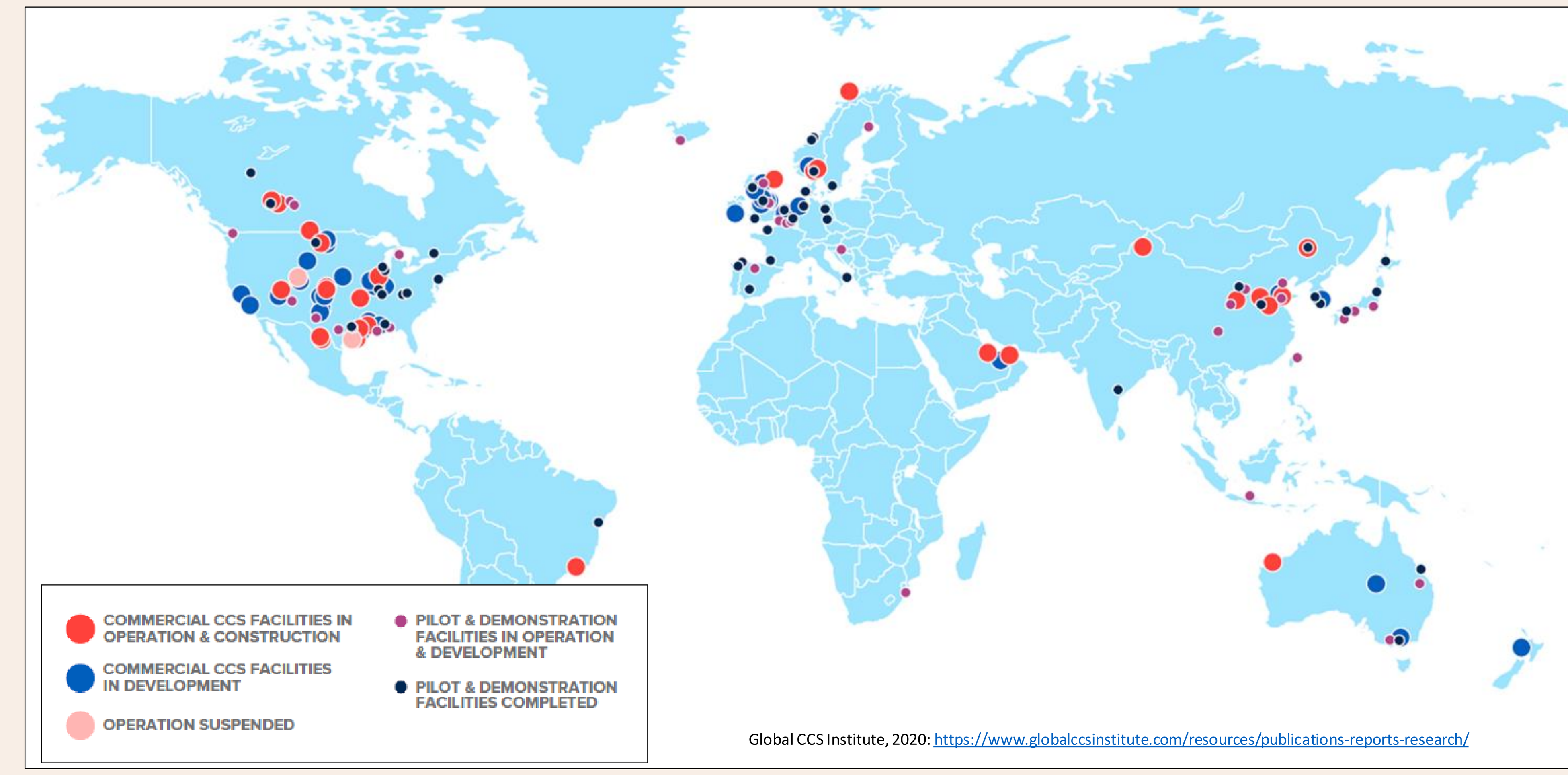


Figure ES-6. Global Emissions Projections for the IEA's Stated Policies Scenario and Sustainable Development Scenario

NPC, 2019: Meeting the Dual Challenge

- The role of CCS
- Decarbonize hard-to-mitigate industries (cement, steel, petrochemicals, etc)
- Large-scale production of low-carbon hydrogen
- Low-carbon dispatchable power
- Negative emissions
- Economically meet climate targets
- Strategic risk management: pathways to 2C

Proven Technology, analogous to petroleum geoscience(?)



Global CCS Institute, 2020: https://www.globalccsinstitute.com/resources/publications-reports-research/

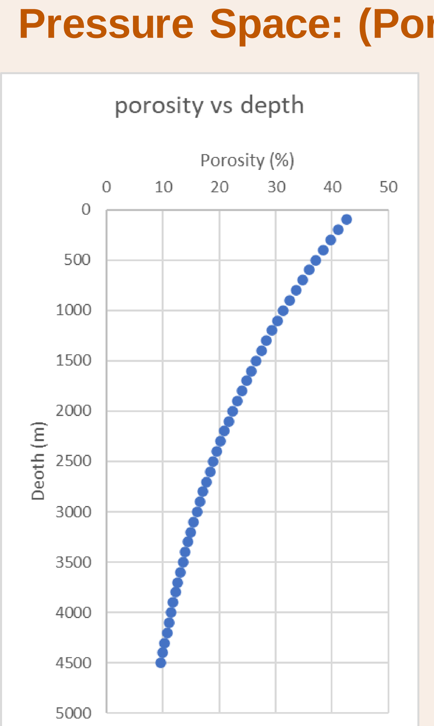
New Storage Concepts: Not your grandfather's petroleum play!

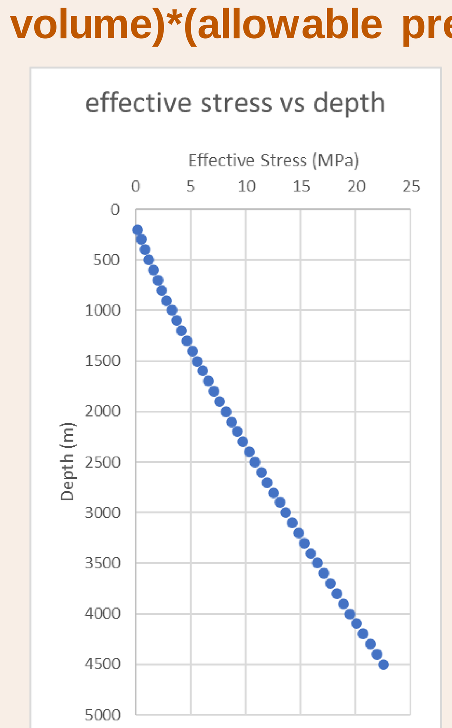
Pressure Space: The key commodity

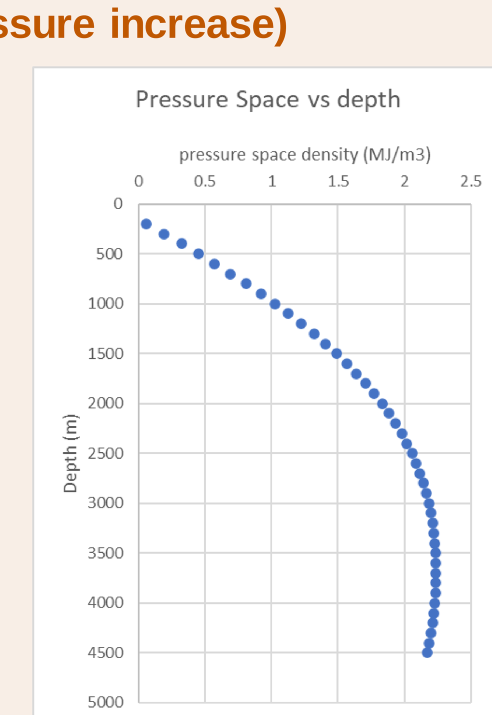
The Problem: Predicting and valuing storage capacity

- Hydrocarbon experience suggests assessing capacity as a function of pore space and saturation but hydrocarbons accumulate slowly, at pressure equilibrium
- But CCS requires injection at industrial rates into pore space that is already full
  - **Sweep efficiency is highly uneven and saturation is notoriously unpredictable**
  - **Pressure rise is inevitable and the key limitation**
- **Pore volume is only part of the answer.**

Pressure Space: (Pore volume)*(allowable pressure increase)







So what?

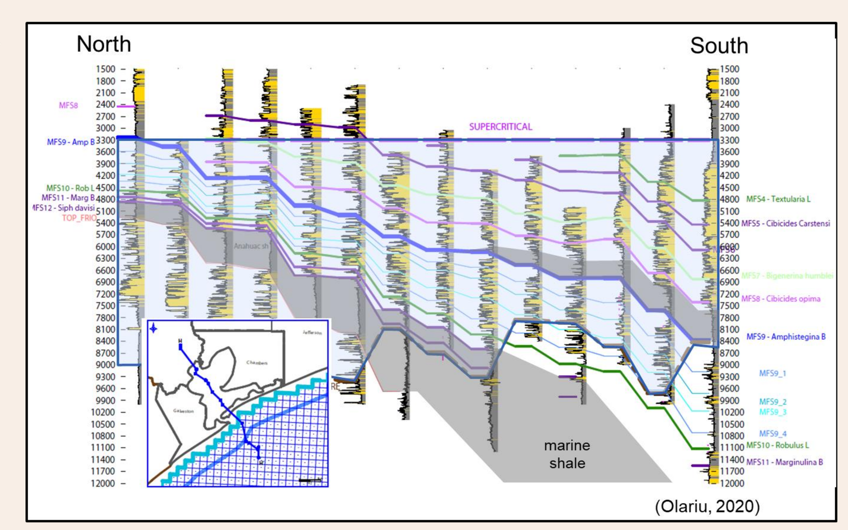
Basis for realistic, quick-look capacity estimation at regional scale

- Allows developers to screen for potential sites and identify subsurface boundaries
- Allows landowners and regulators to quantify and value storage resources

Composite Confining Systems: "Seal" not required

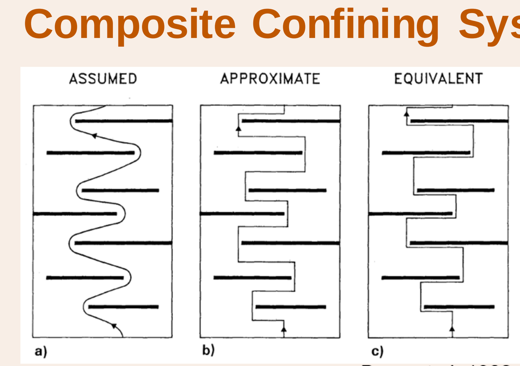
The Problem: Transport is expensive and classic "seals" may be scarce

- Petroleum experience proves the capacity of geologic seals
- But classic seals are scarce and the focus on them is based on needing to produce
- **CCS is not petroleum!**
  - **Goal is sequestration—injected fluids need not remain mobile, concentrated or recoverable (storage is most secure if they are not!)**
  - Low-margin business--local storage is desirable

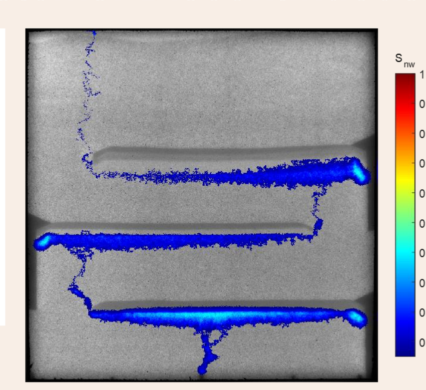


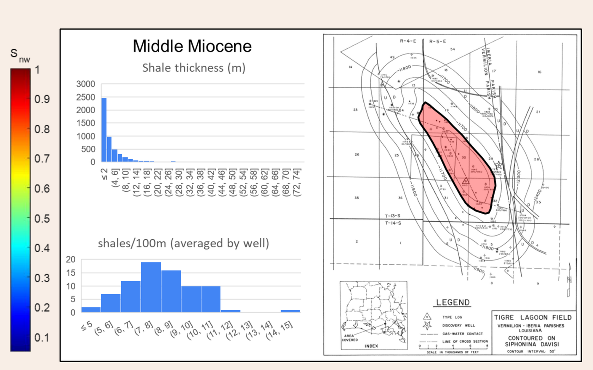
(Olariu, 2020)

Composite Confining Systems: Discontinuous barriers that arrest flow



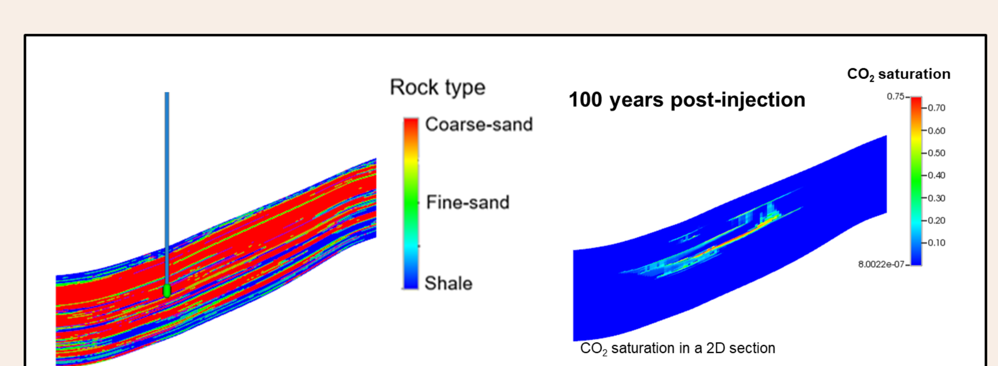
Begg et al, 1982





So what?

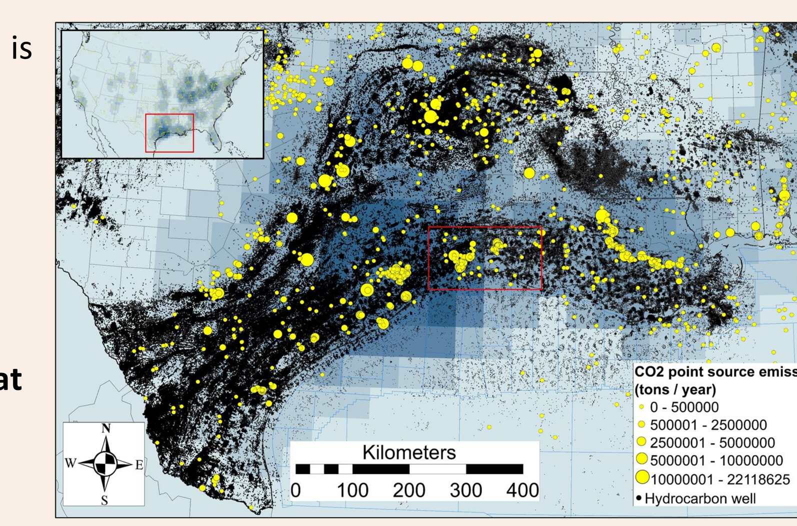
- Composite systems effectively engineer "migration loss"
- **CO2 is dispersed and immobilized—effectively irretrievable, minimizing long-term risk**
- Candidate layered systems are widely availably, broadening the prospective geography



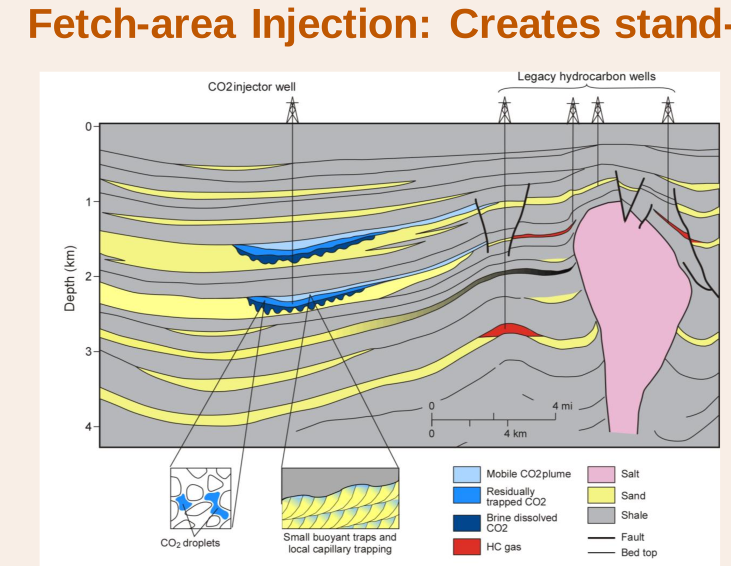
Fetch-Area Injection: Finding running room

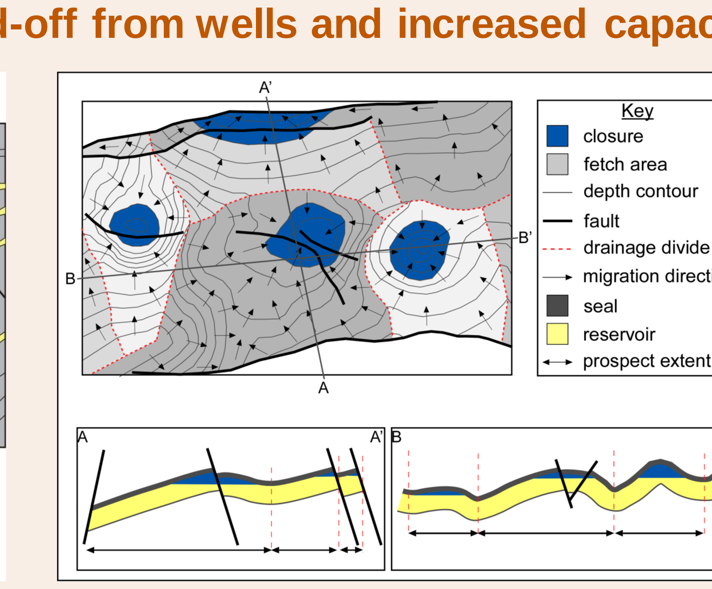
The Problem: Every legacy well is a hole in the confining system

- CCS is a low-margin business and transport is expensive. Local storage minimizes cost
- The Gulf of Mexico has 1.1M legacy wells
  - Each is a hole in the confining system
  - Not engineered for CCS
- **Permitting injection requires defining an Area of Review (elevated pressure) and reviewing/remediating all wells within that area**
  - Gets expensive fast!



Fetch-area Injection: Creates stand-off from wells and increased capacity





So what?

- **Creates space for pressure dissipation between injectors and legacy wells, reducing project cost**
  - **Gives scope to remove most wells from the AoR**
  - **Increases geography under consideration and therefore flexibility in project siting**
- **Maintains coherent and predictable CO2 flow**
- **Offers the chance for residual trapping, reducing long-term risk**

Bottom Line: CCS is not simply petroleum geology—different goals, constraints and boundary conditions create a very different view of "good"