A Probabilistic Assessment Methodology for the Evaluation of Geologic Carbon Dioxide Storage

U.S. Geological Survey
Department of the Interior

Outline for Briefing

- Overview and Legislation
- Geologic Model
- Methodology
- Future Steps

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Energy Independence and Security Act 2007

TITLE VII—CARBON CAPTURE AND SEQUESTRATION

Subtitle B—Carbon Capture and Sequestration Assessment and Framework

SEC. 711. CARBON DIOXIDE SEQUESTRATION CAPACITY ASSESSMENT.

(b) METHODOLOGY— …shall develop a methodology for conducting an assessment under subsection (f), taking into consideration—

(1) the geographical extent of all potential sequestration formations in all States;

(2) the capacity of the potential sequestration formations;

(3) the injectivity of the potential sequestration formations;

(4) an estimate of potential volumes of oil and gas recoverable by injection and sequestration of industrial carbon dioxide in potential sequestration formations;

(5) the risk associated with the potential sequestration formations; and

(6) the work done to develop the Carbon Sequestration Atlas of the United States and Canada that was completed by DOE.

(c) COORDINATION—

(1) Federal Coordination

(2) State Coordination

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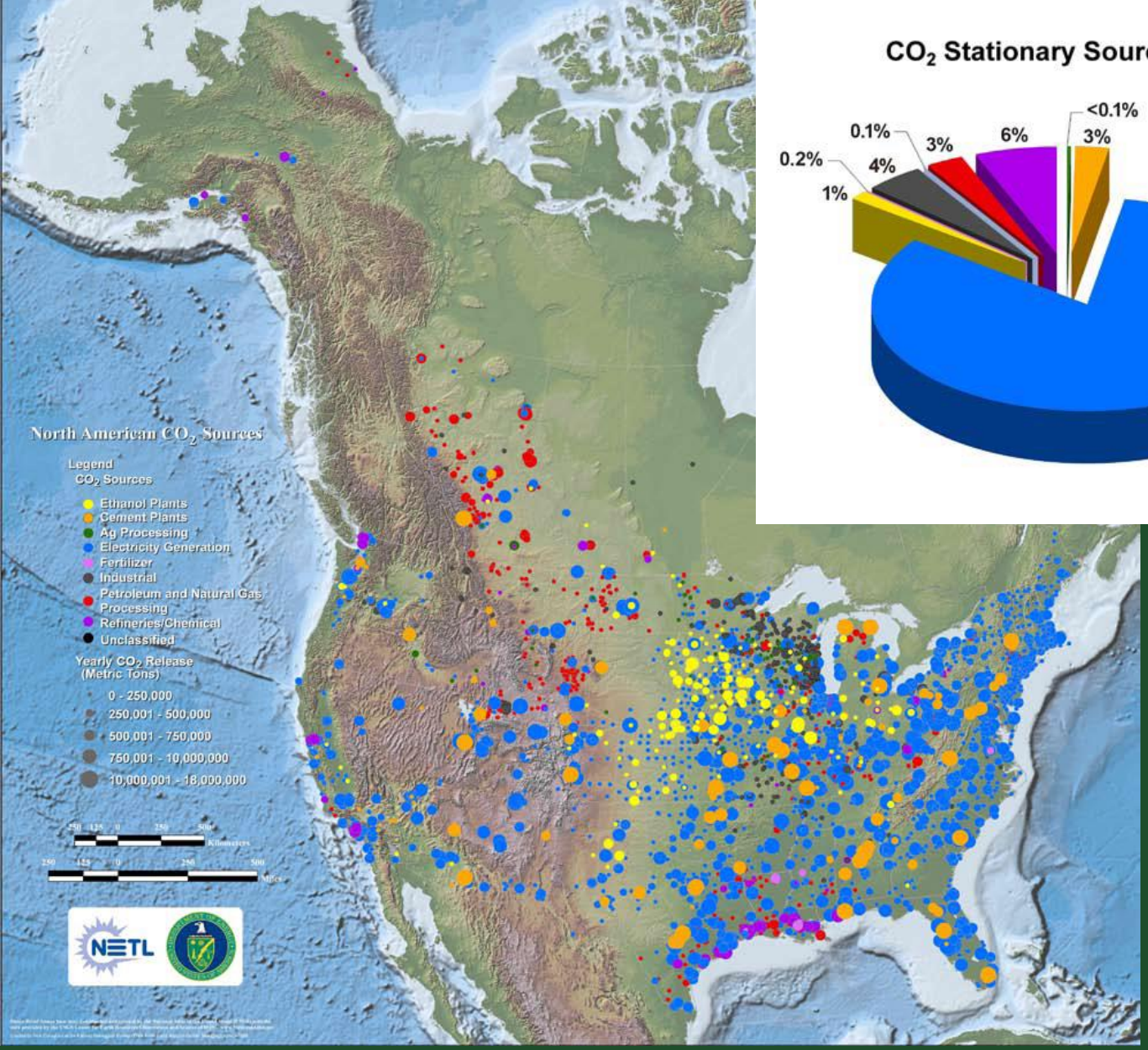

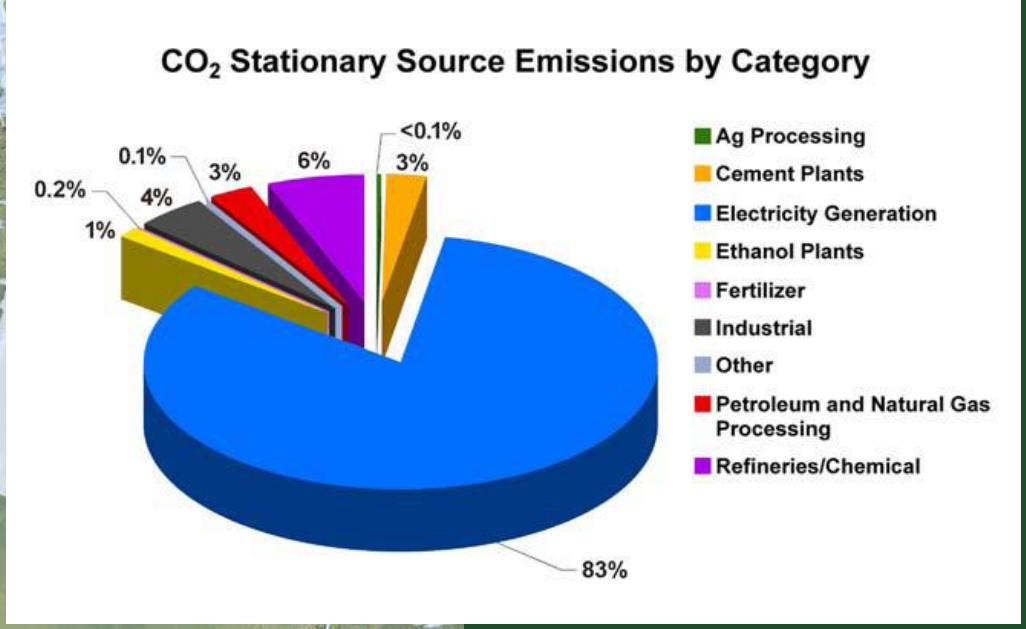

Source: DOE NETL, 2008, Carbon Sequestration Atlas II of the United States and Canada

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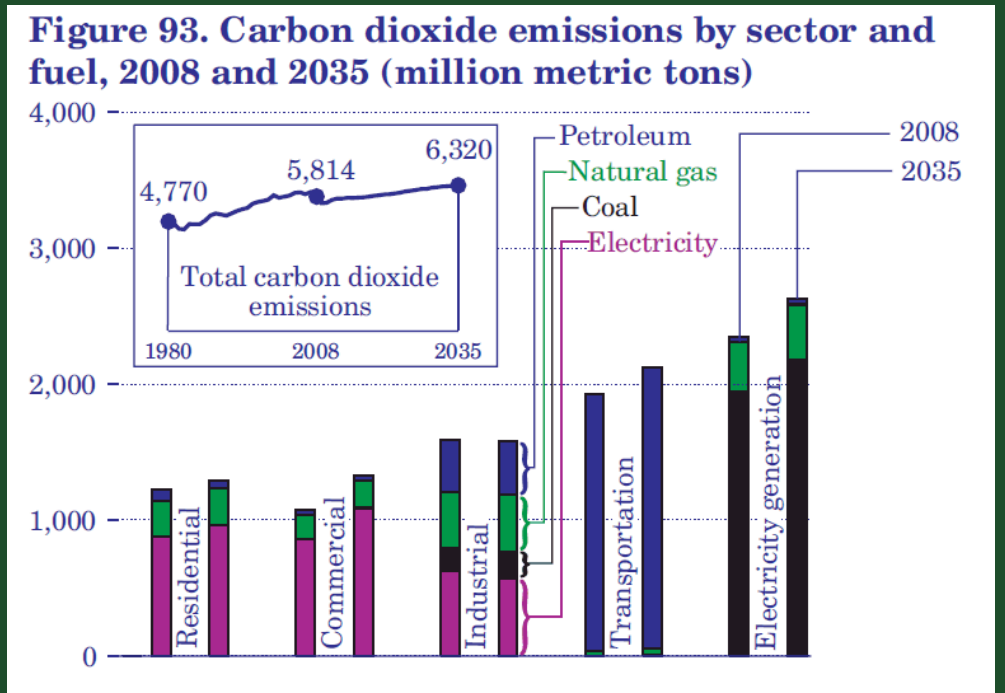
How much needs to be sequestered? Some examples illustrate the range

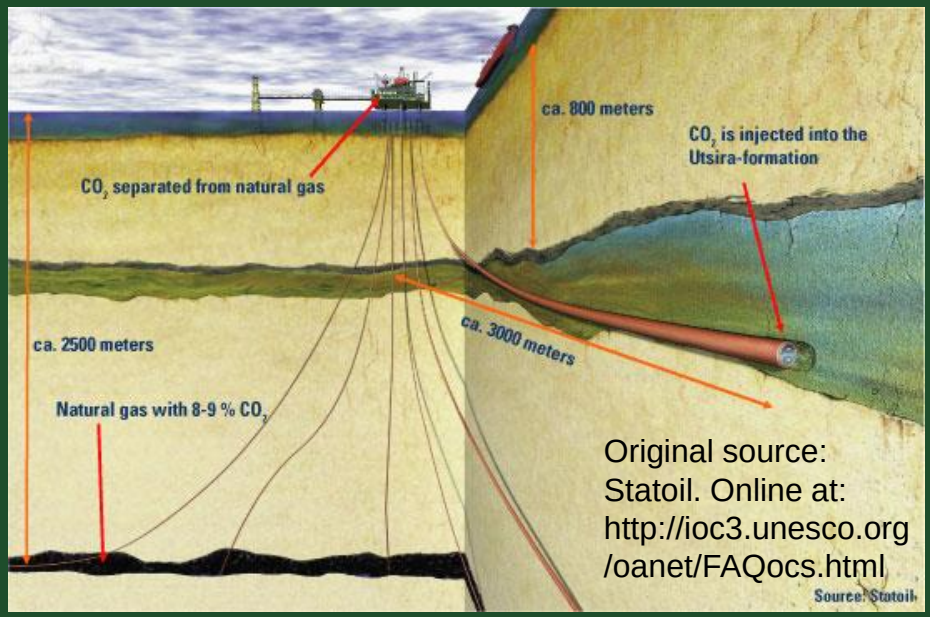
- World: ~ 8 Gt carbon/year or ~ 30 Gt CO_2 /year
- U.S. total all sectors in 2007→ ~ 6 Gt/year CO_2 (Energy Information Administration, 2009)
- Laramie River 2&3 PC plant 1100 MWe → 8.7 Mt/yr CO_2 at 85% capacity factor (Brennan and Burruss, 2006)



USGS EIA, Annual Energy Outlook

Carbon Capture and Storage

- Capture:
  - Flue gas is 5 -15 % CO_2, must be separated for storage
  - Compressed to a liquid for pipeline transport



Original source: Statoil. Online at: http://ioc3.unesco.org/oanet/FAQocs.html

- Geological storage:
  - The USGS assessment will focus on CO_2 injected at depths of 3,000 to 13,000 ft
  - CO_2 is buoyant and displaces existing water, oil, or gas
  - Storage formation must be sealed to retain buoyant CO_2
  - USGS assessment methodology addresses buoyant and residual trapping

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USGS Methodology

- Geologically-based, statistically-sound hypotheses for quantities of resource
- Comprehensive & consistent treatment (compatible/comparable to assessments in other areas)
- Transparent – methodology, assumptions
- Probabilistic – range of values to reflect uncertainty
- Not project site specific, estimates are regional (but geological models are developed for each region)
- External expert input

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To create a methodology for storage resources:

- Define the geologic resource
  - Pore space accessible for storage (injection and retention) of CO_2
- Define the geologic setting
  - Storage formation (net porous thickness)
  - Seal formation
- Define the geologic model for the storage resource
- Identify resource (trapping processes)
  - Buoyant Trapping (high storage efficiency)
  - Residual Trapping (low storage efficiency)
- Use statistical method to estimate storage resource

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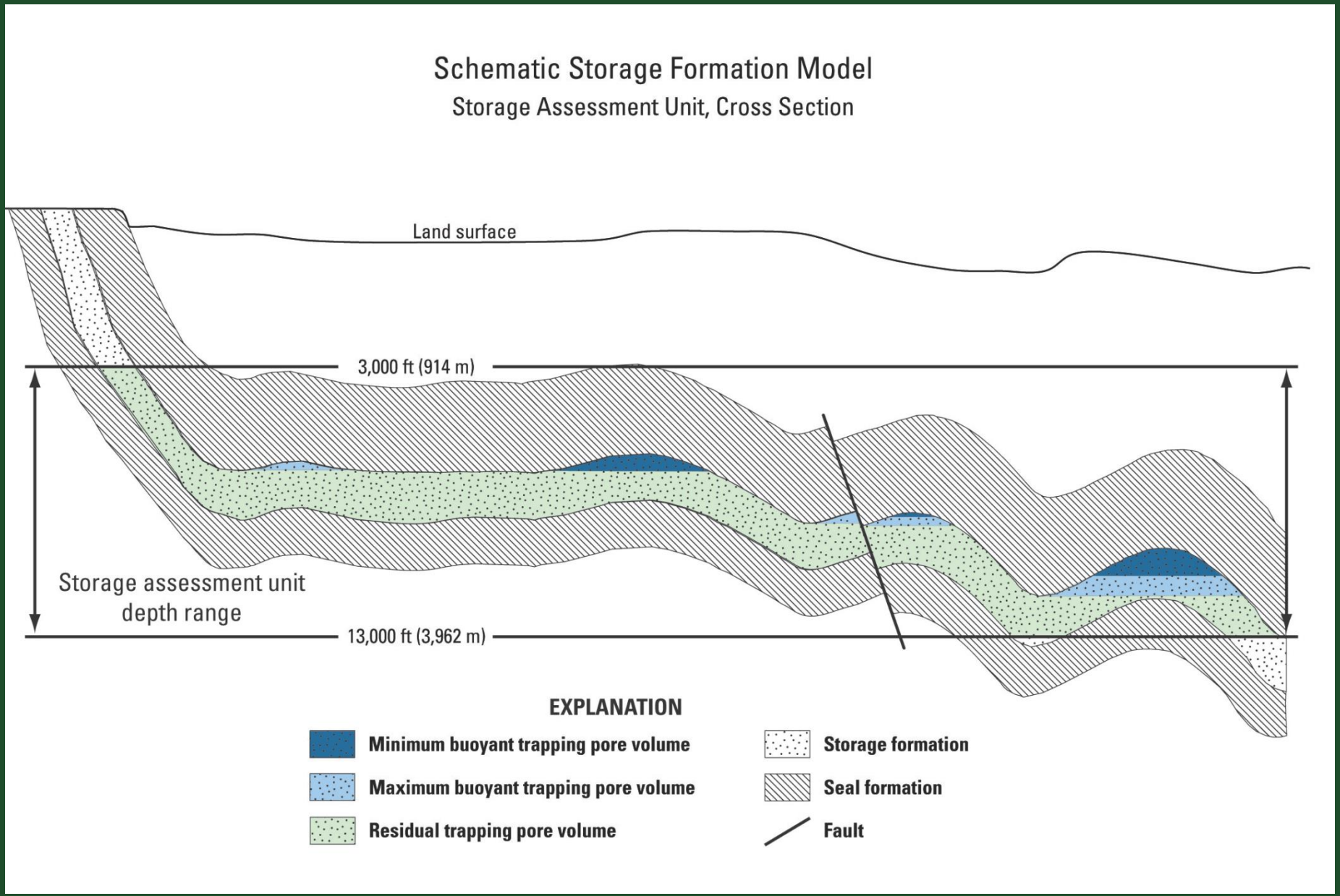

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Salinity of water in storage formation must be > 10,000 ppm TDS per EPA regulations

Basics of USGS CO_2 Storage Formation Assessment Methodology

- Estimate pore volume of Storage Formation
- All pore space within Storage Formation is available for storage
- Storage will be via either buoyant or residual trapping
- Buoyant and residual trapping have very different storage efficiencies and risks

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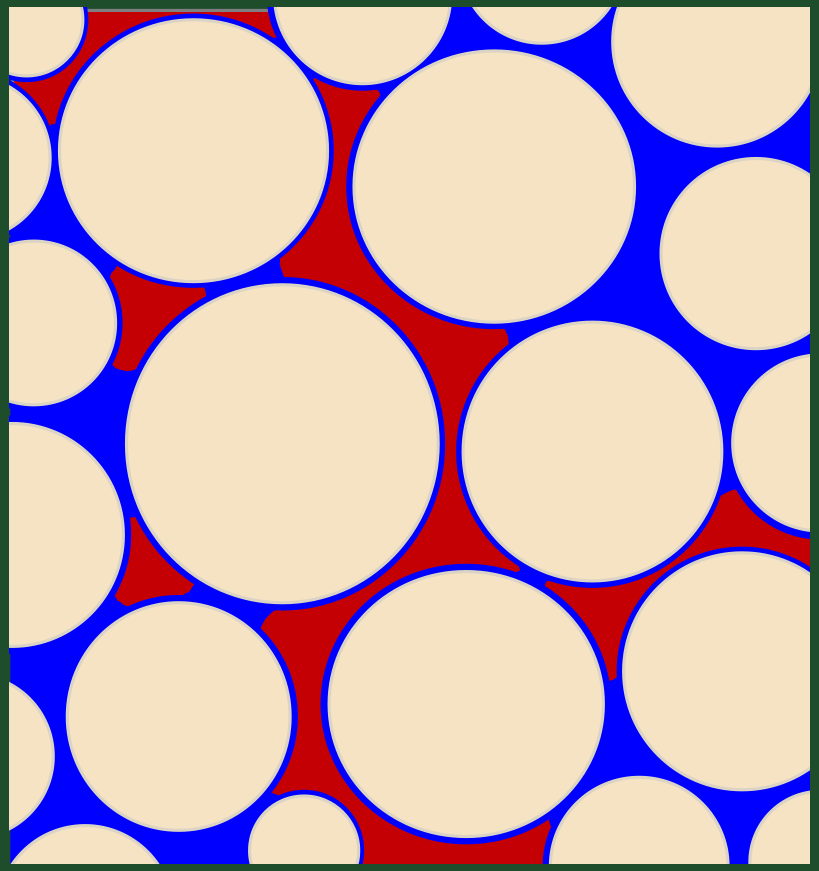
CO_2 Trapping Types

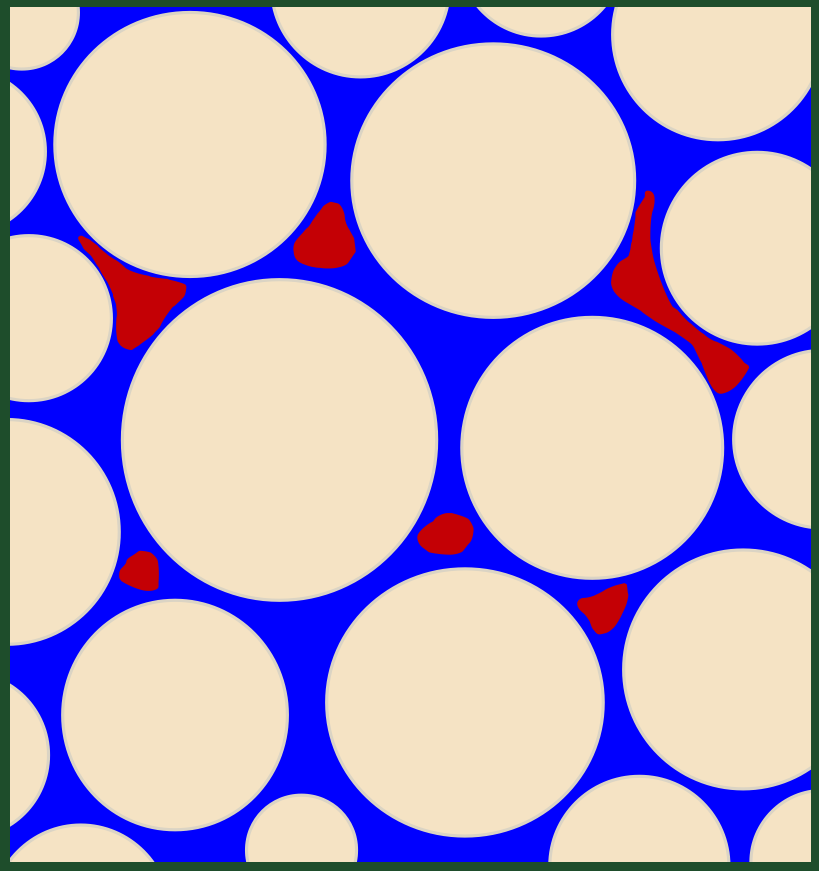
Buoyant Trapping

CO_2 fills pore space, held in place by top and lateral seals



Residual Trapping

CO_2 droplets left behind by mobile plume, trapped by surface tension



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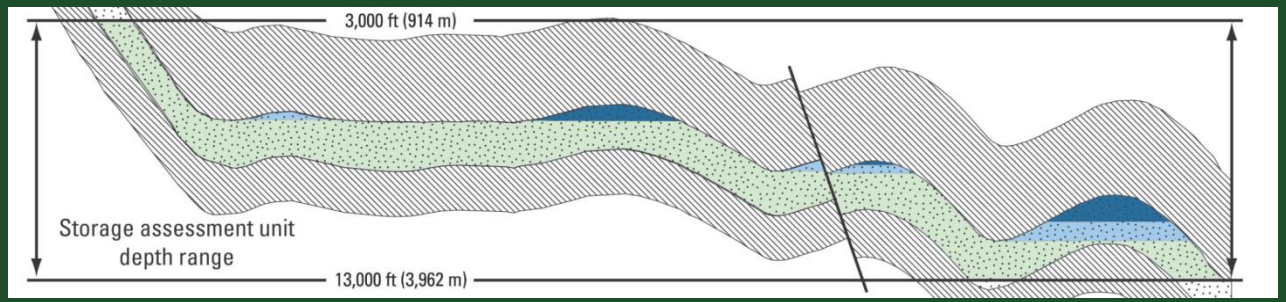
Beige = sand grains, Blue = water, Red = CO_2

Buoyant Storage

- The buoyant storage resource is based on petroleum reservoir-sized enclosures that will trap CO_2
- To estimate the buoyant storage resource, we can use:
  - Petroleum production data to identify the known enclosures
  - USGS National Oil and Gas Assessment results to identify the undiscovered enclosures
  - Data gathered during CO_2 assessment research to estimate the non-petroleum filled enclosures
- Storage efficiency estimates: 10% min, 30% mode, 60% max (Bennion and Bachu, 2005, 2008; Burton and others, 2008)



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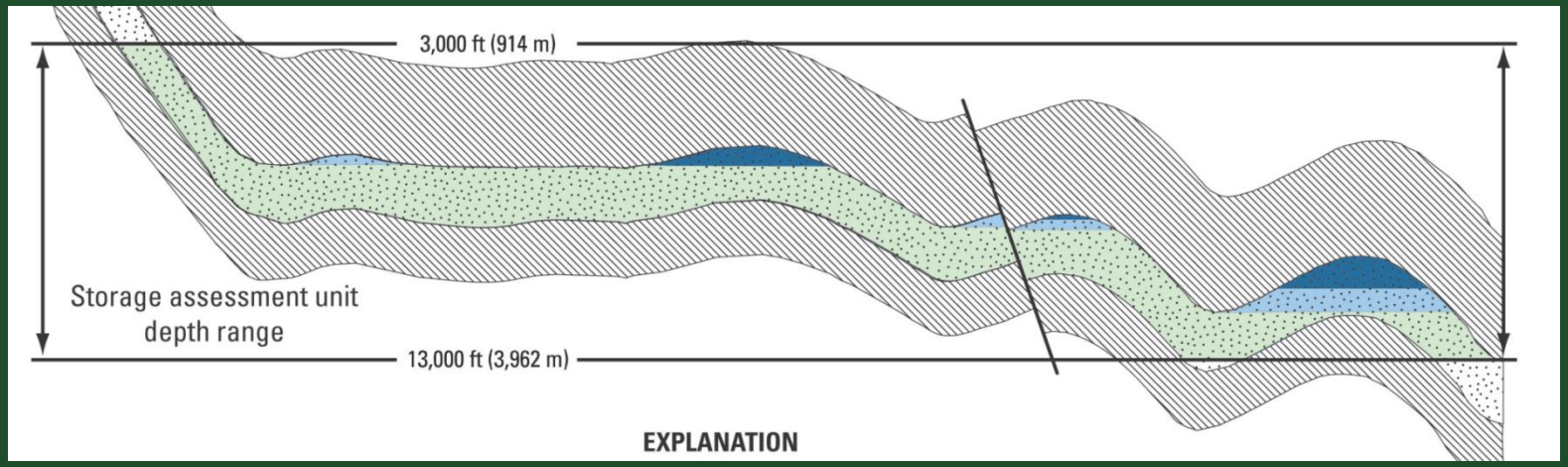
Residual Storage

- The remainder of the pore space within the Storage Formation that is not available for buoyant storage is available for residual storage
- The residual storage includes residual trapped CO_2 and all buoyant trapping in enclosures that are less than petroleum reservoir-sized
- The residual storage resource is divided into three classes based on variations in the permeability of the storage formation



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Residual Storage Resource Classes

- Class 1, High Permeability (> ~1 Darcy)
  - No injectivity problems
  - CO_2 will flow easily and has the potential to bypass much of the residual trapping, which leads to lower storage efficiencies
- Class 2, Medium Permeability (< ~1 Darcy, > ~1 millidarcy)
  - Little to no injectivity problems
  - Highest potential for residual trapping, due to lower flow rates
- Class 3, Low Permeability (< ~1 millidarcy)
  - Significant injectivity problems
  - If CO_2 can be injected, high residual trapping potential. But likely CO_2 will not be injected into these rocks

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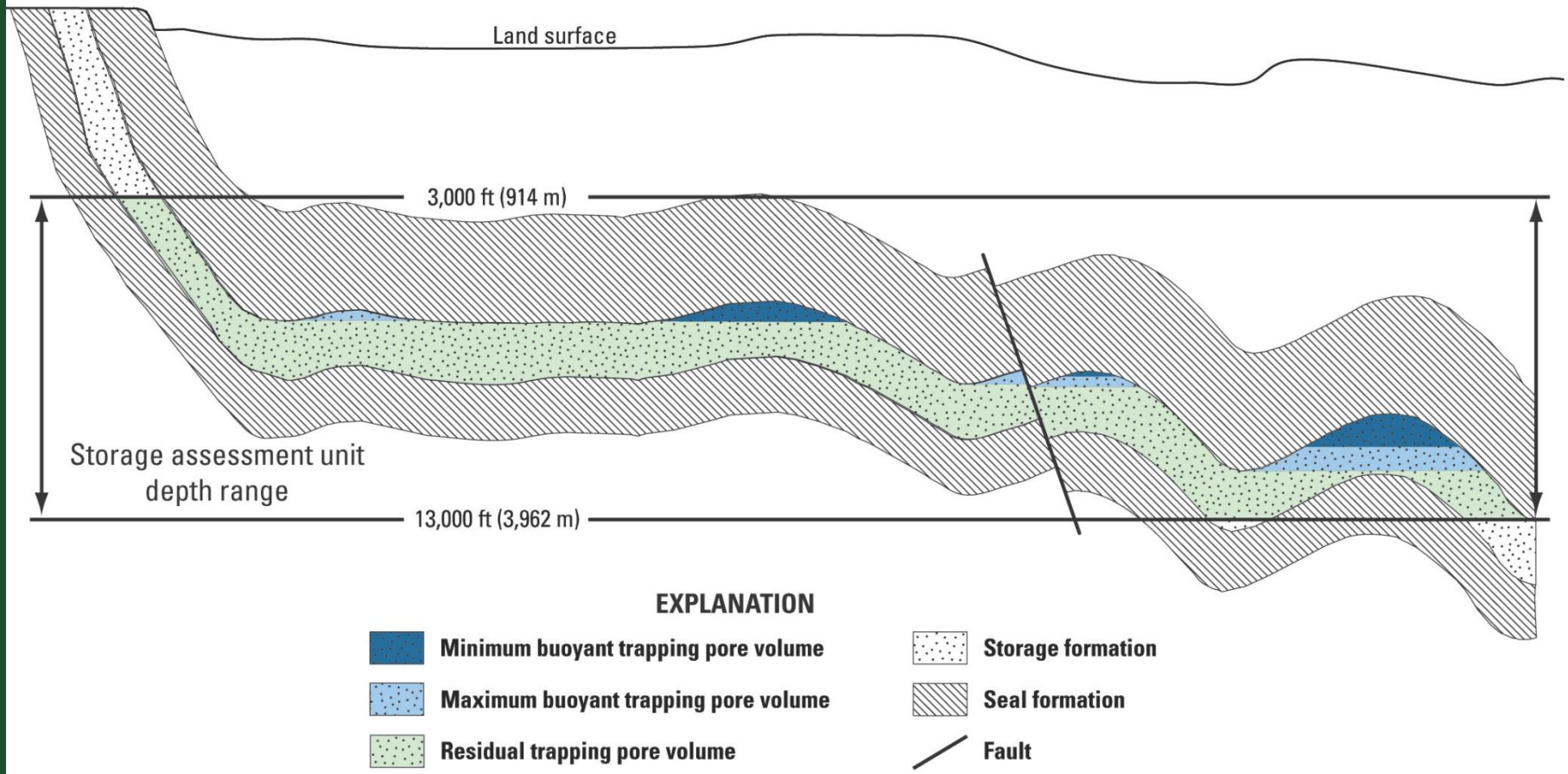
Schematic Storage Formation Model

Storage Assessment Unit, Cross Section



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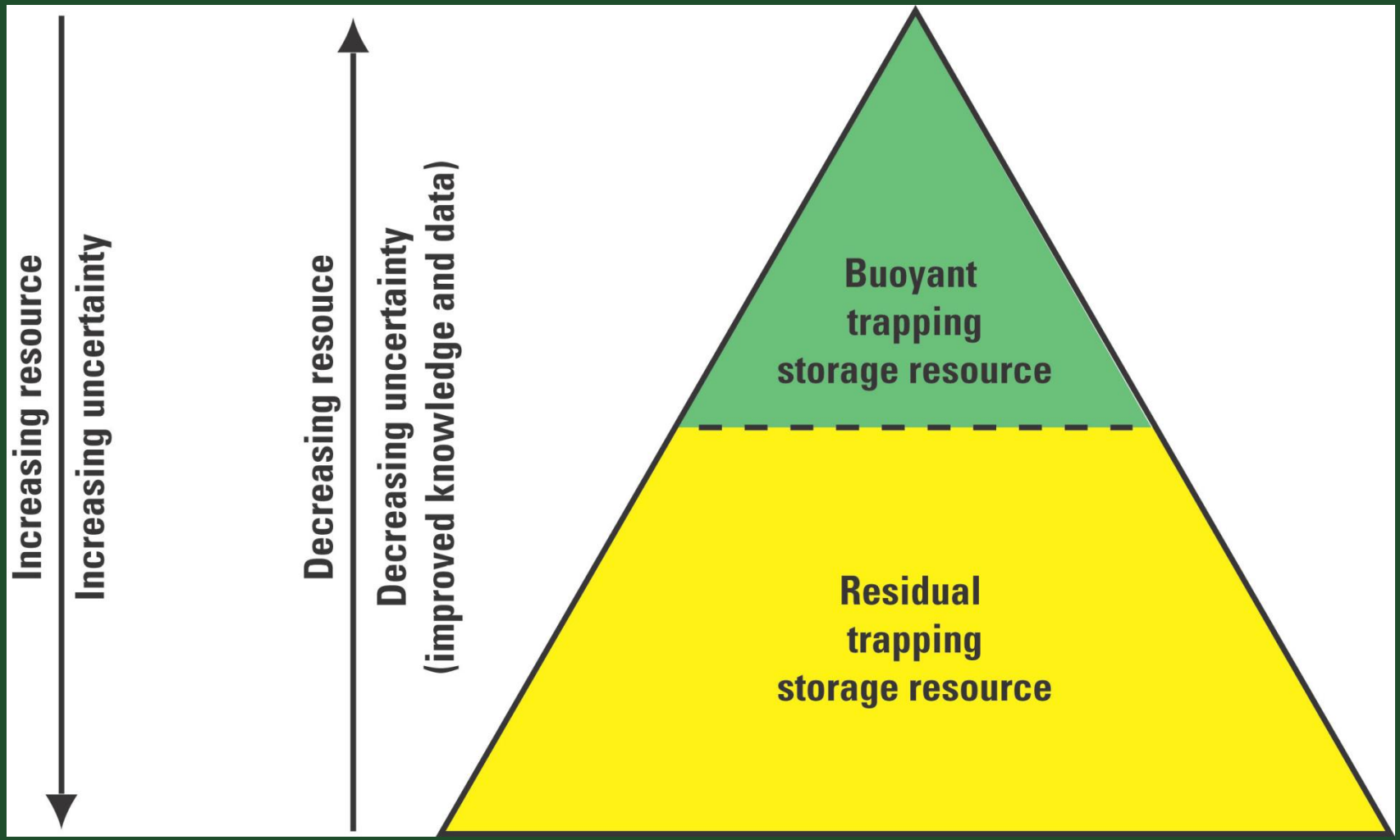
Resource Triangle

Technically accessible CO_2 storage resources



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To estimate CO_2 storage resource we need to:

- Develop a robust geologic model using the geologic properties of the Storage Formation
- Estimate the pore volume of the Storage Formation
- Determine the buoyant trapping pore volume
- Determine the percentages of Class 1, 2, and 3 rocks within the Storage Formation.
- Estimate buoyant and residual storage resources using a Monte Carlo simulator
- Aggregate those storage resource values to estimate total storage within the Storage Formation

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Implementation

- The U.S. Geological Survey has started the assessment to estimate the CO_2 storage resource of formations within sedimentary basins throughout the United States
  - The buoyant storage resource, the three classes of the residual storage resource, and the total aggregate storage resource of the Storage Formation, will be estimated for each suitable formation
- The assessment will be completed within three years, resource estimates will be made available at that time
- This assessment methodology will be used to assess the storage resource of the U.S., but it is applicable throughout the world

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Conclusions

- This method can estimate the technically accessible CO_2 storage resource at a variety of levels of uncertainty across a formation
- The methodology uses geologic data, processes, geologic models, and rock properties to populate probabilistic analysis models to produce a robust estimate of CO_2 storage resource within a Storage Assessment Unit (SAU)
- By calculating the buoyant storage resource separately from the residual storage resource, the user is provided with estimates that can be used to evaluate different scenarios

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