



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

Energy Independence and Security Act 2007

TITLE VII—CARBON CAPTURE AND SEQUESTRATION

Subtitle B—Carbon Capture and Sequestration Assessment and Framework

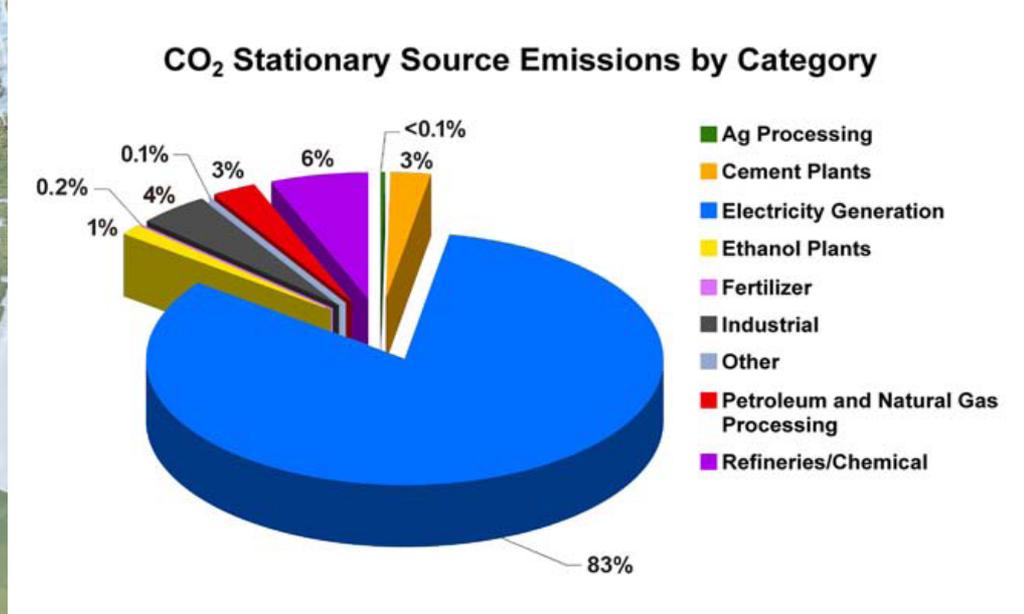
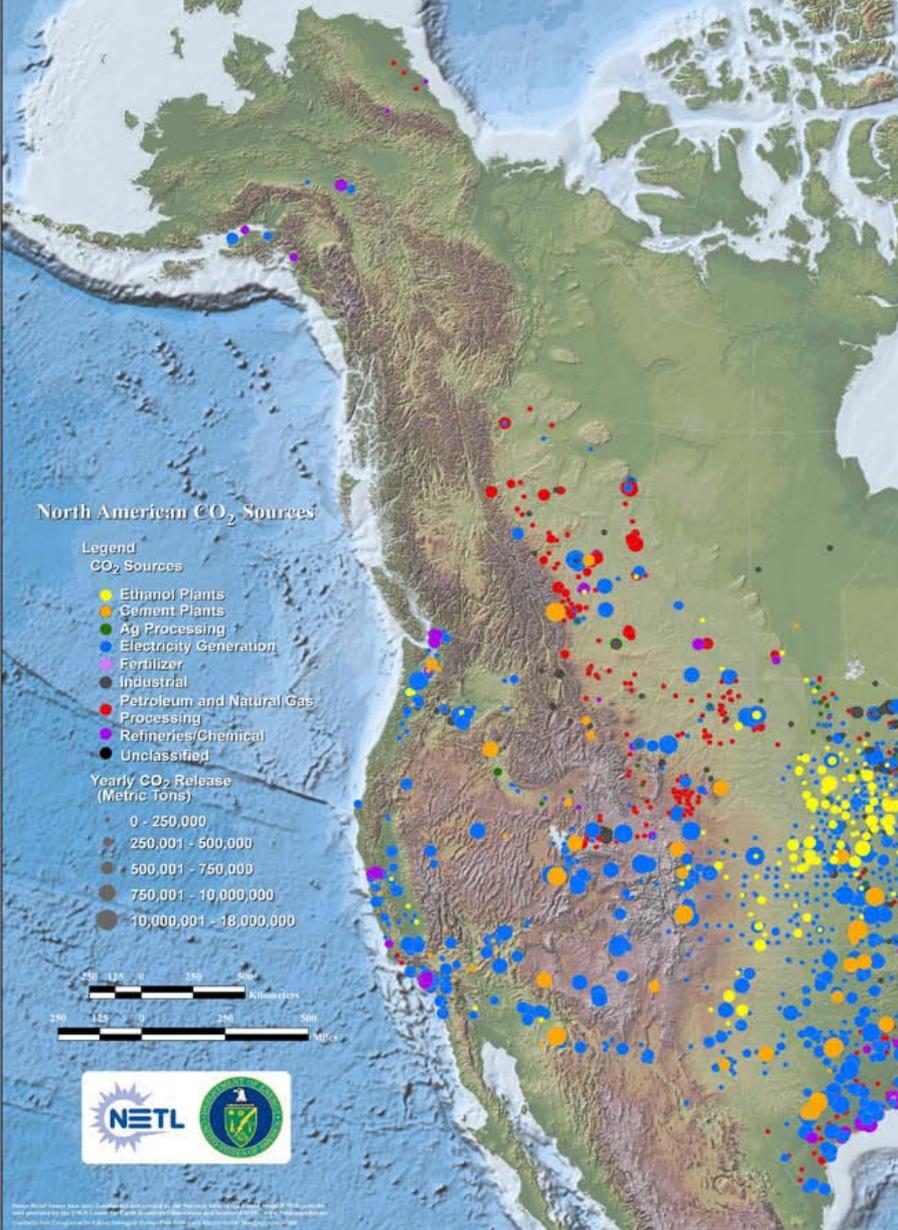
SEC. 711. CARBON DIOXIDE SEQUESTRATION CAPACITY ASSESSMENT.

(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



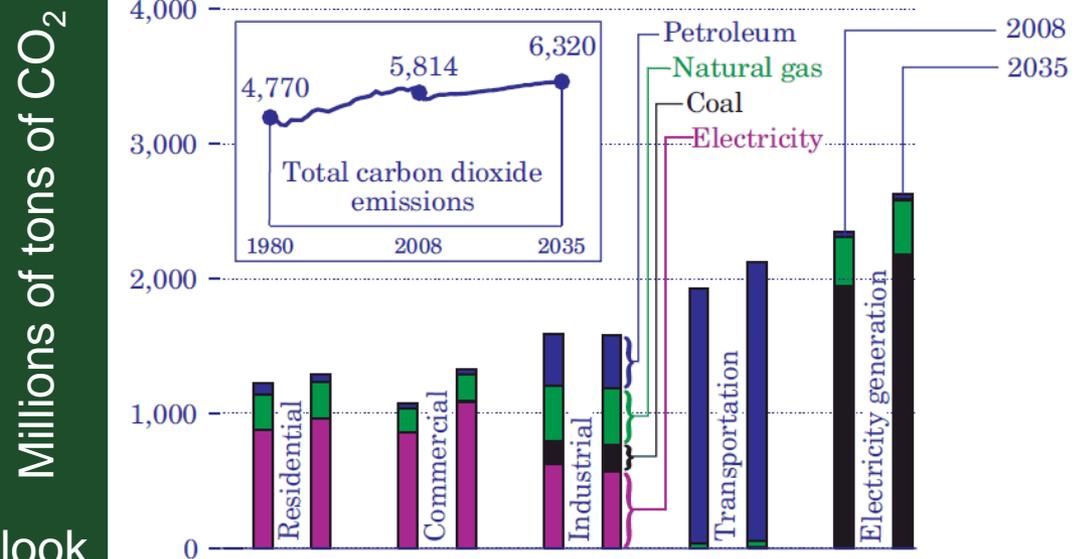
Source: DOE NETL, 2008, Carbon Sequestration Atlas II of the United States and Canada

How much needs to be sequestered?

Some examples illustrate the range

- World: ~ 8 Gt carbon/year or ~ 30 Gt CO₂/year
- U.S. total all sectors in 2007 → ~ 6 Gt/year CO₂ (Energy Information Administration, 2009)
- Laramie River 2&3 PC plant 1100 MWe → 8.7 Mt/yr CO₂ at 85% capacity factor (Brennan and Burruss, 2006)

Figure 93. Carbon dioxide emissions by sector and fuel, 2008 and 2035 (million metric tons)



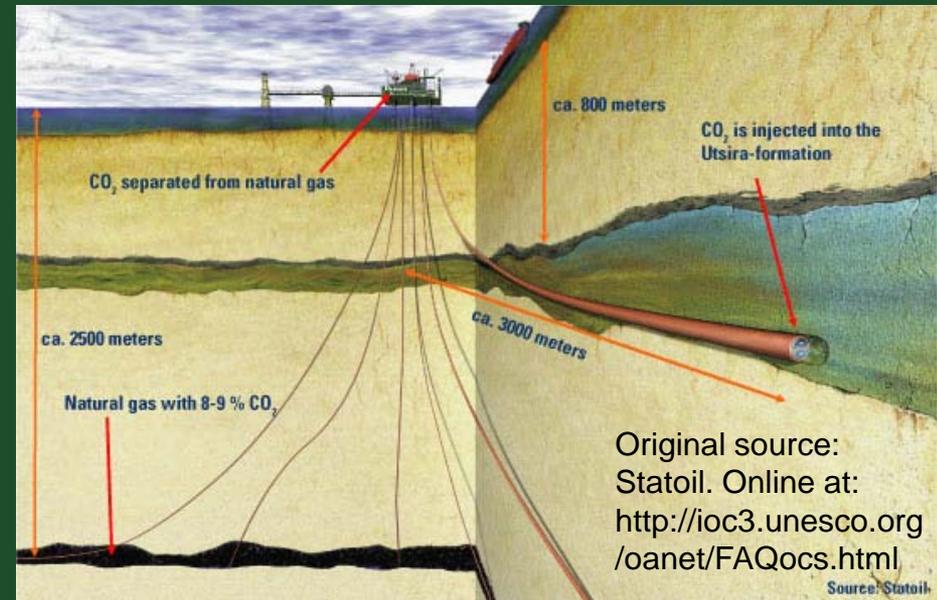
Carbon Capture and Storage

- Capture:

- Flue gas is 5 -15 % CO₂, must be separated for storage
- Compressed to a liquid for pipeline transport

- Geological storage:

- The USGS assessment will focus on CO₂ injected at depths of 3,000 to 13,000 ft
- CO₂ is buoyant and displaces existing water, oil, or gas
- Storage formation must be sealed to retain buoyant CO₂
- USGS assessment methodology addresses buoyant and residual trapping



USGS Methodology

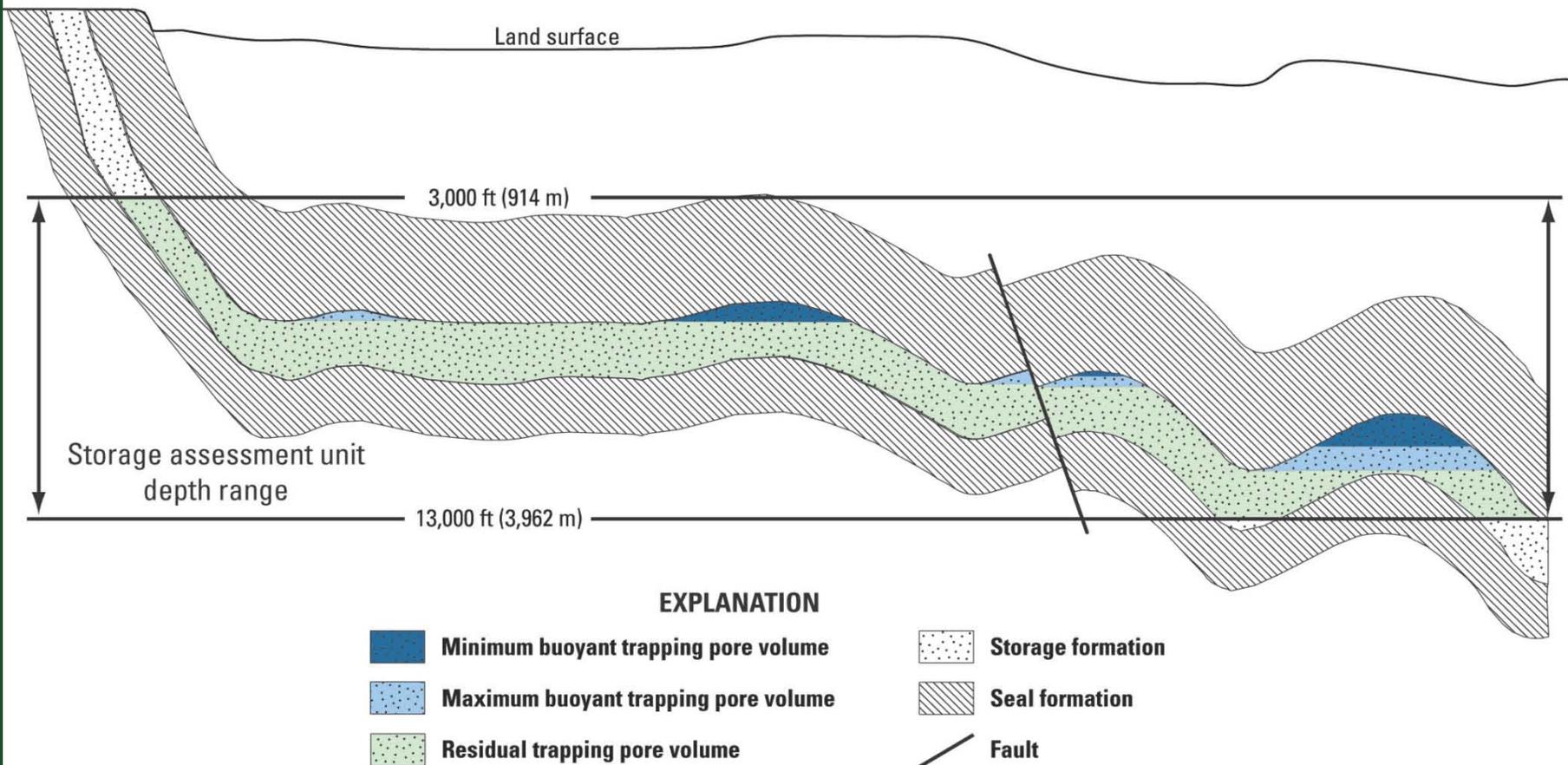
- Geologically-based, statistically-sound hypotheses for quantities of resource
- Comprehensive & consistent treatment (compatible/comparable to assessments in other areas)
- Transparent – methodology, assumptions
- Probabilistic – range of values to reflect uncertainty
- Not project site specific, estimates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

To create a methodology for storage resources:

- Define the geologic resource
 - Pore space accessible for storage (injection and retention) of CO₂
- 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

Schematic Storage Formation Model

Storage Assessment Unit, Cross Section



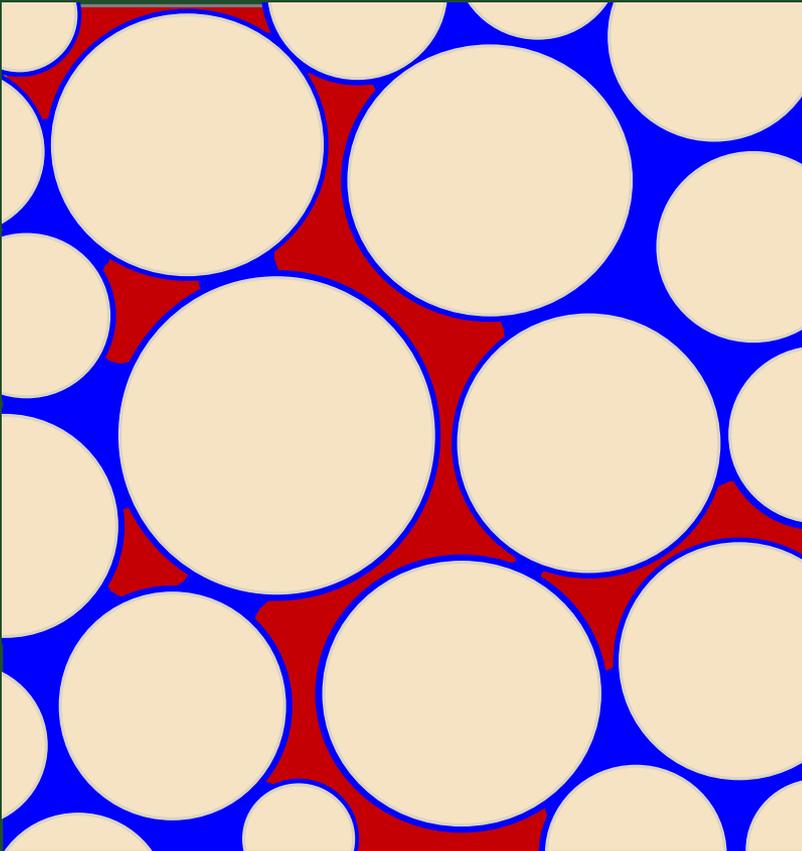
Basics of USGS CO₂ Storage Formation Assessment Methodology

- 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

CO₂ Trapping Types

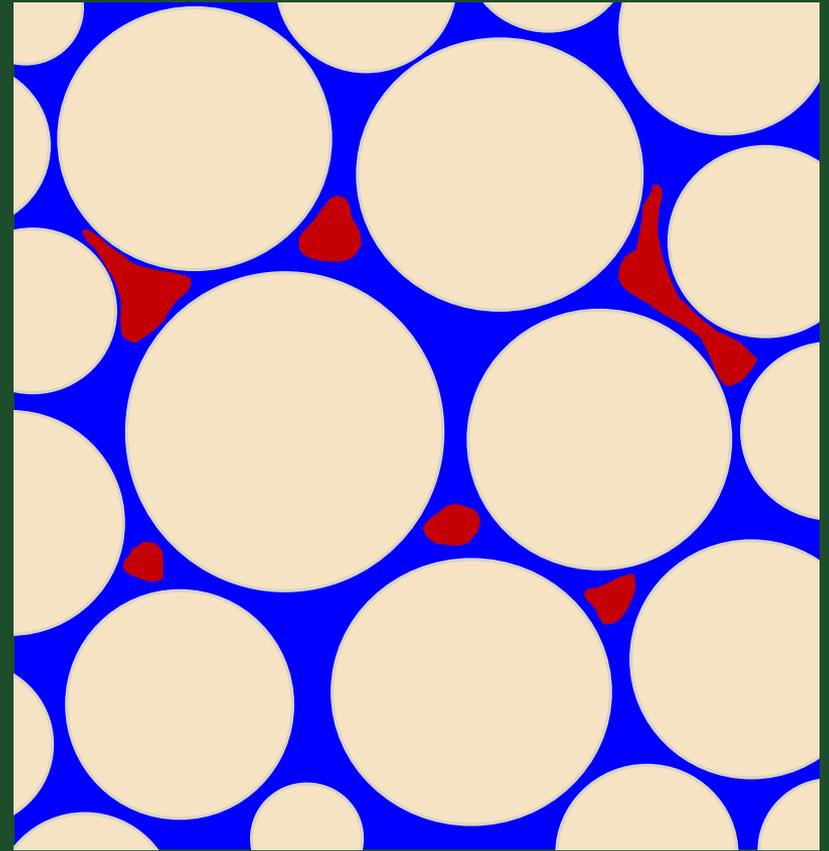
Buoyant Trapping

CO₂ fills pore space, held in place by top and lateral seals



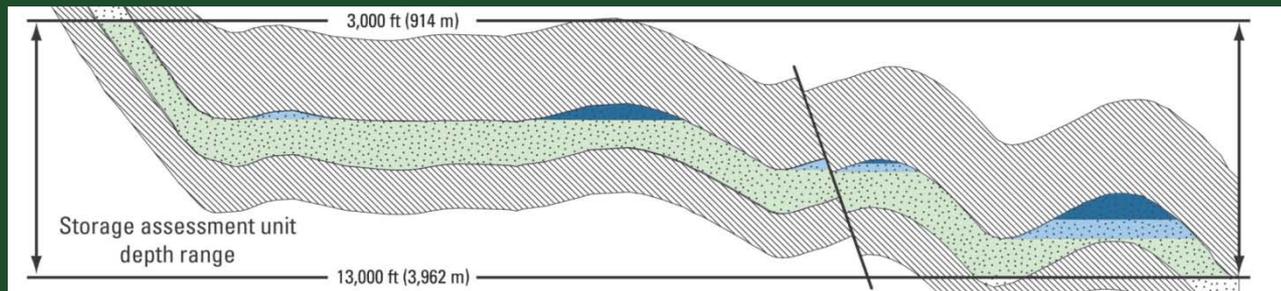
Residual Trapping

CO₂ droplets left behind by mobile plume, trapped by surface tension



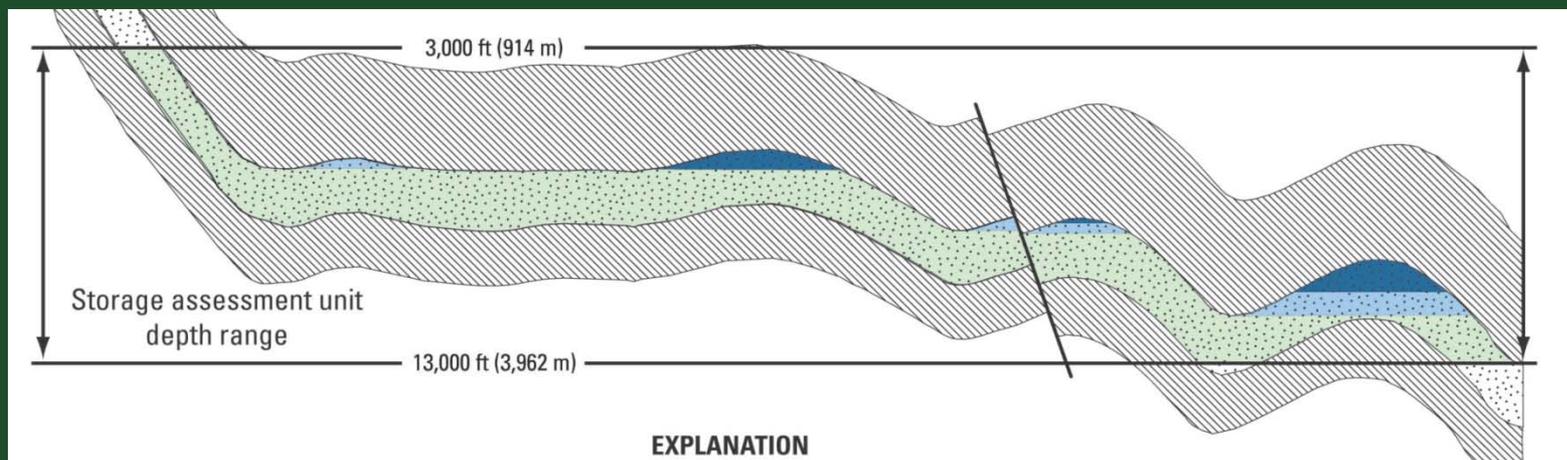
Buoyant Storage

- The buoyant storage resource is based on petroleum reservoir-sized enclosures that will trap CO₂
- 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 CO₂ 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)



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 CO₂ 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

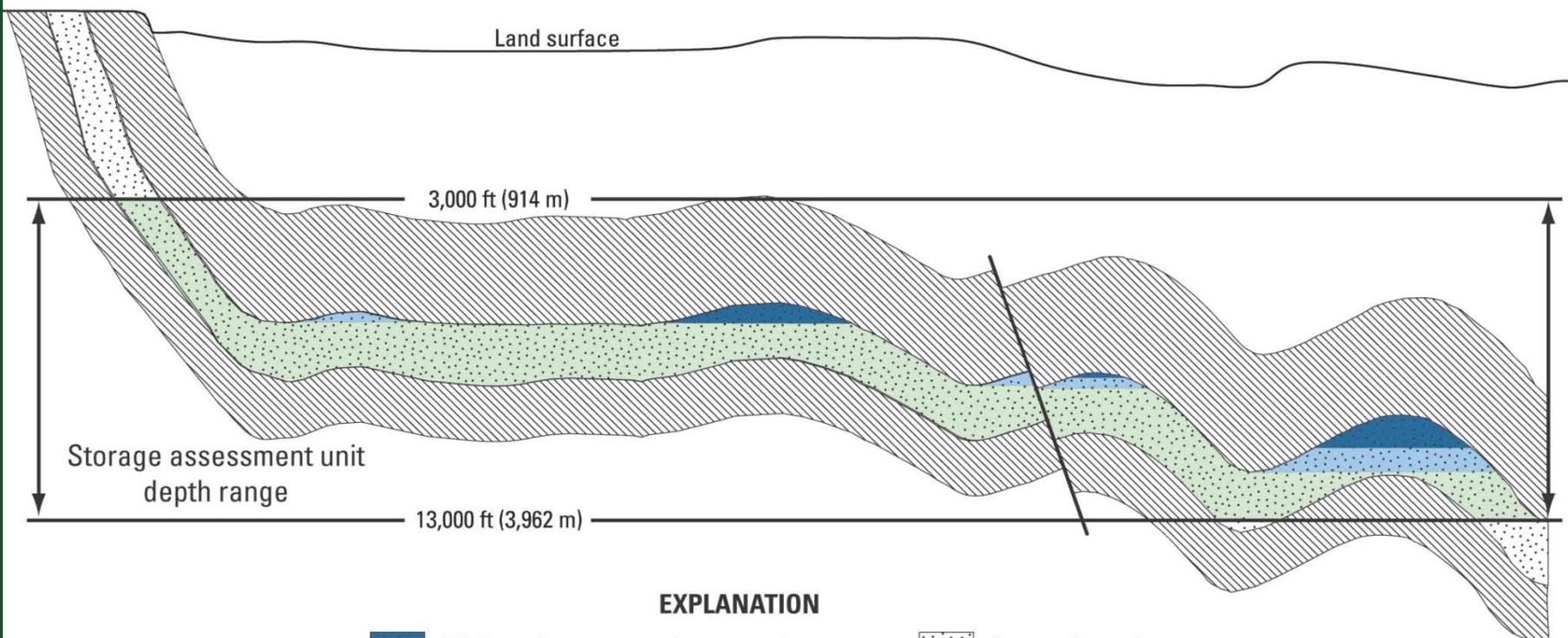


Residual Storage Resource Classes

- Class 1, High Permeability ($> \sim 1$ 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 ($< \sim 1$ Darcy, $> \sim 1$ millidarcy)
 - Little to no injectivity problems
 - Highest potential for residual trapping, due to lower flow rates
- Class 3, Low Permeability ($< \sim 1$ 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

Schematic Storage Formation Model

Storage Assessment Unit, Cross Section

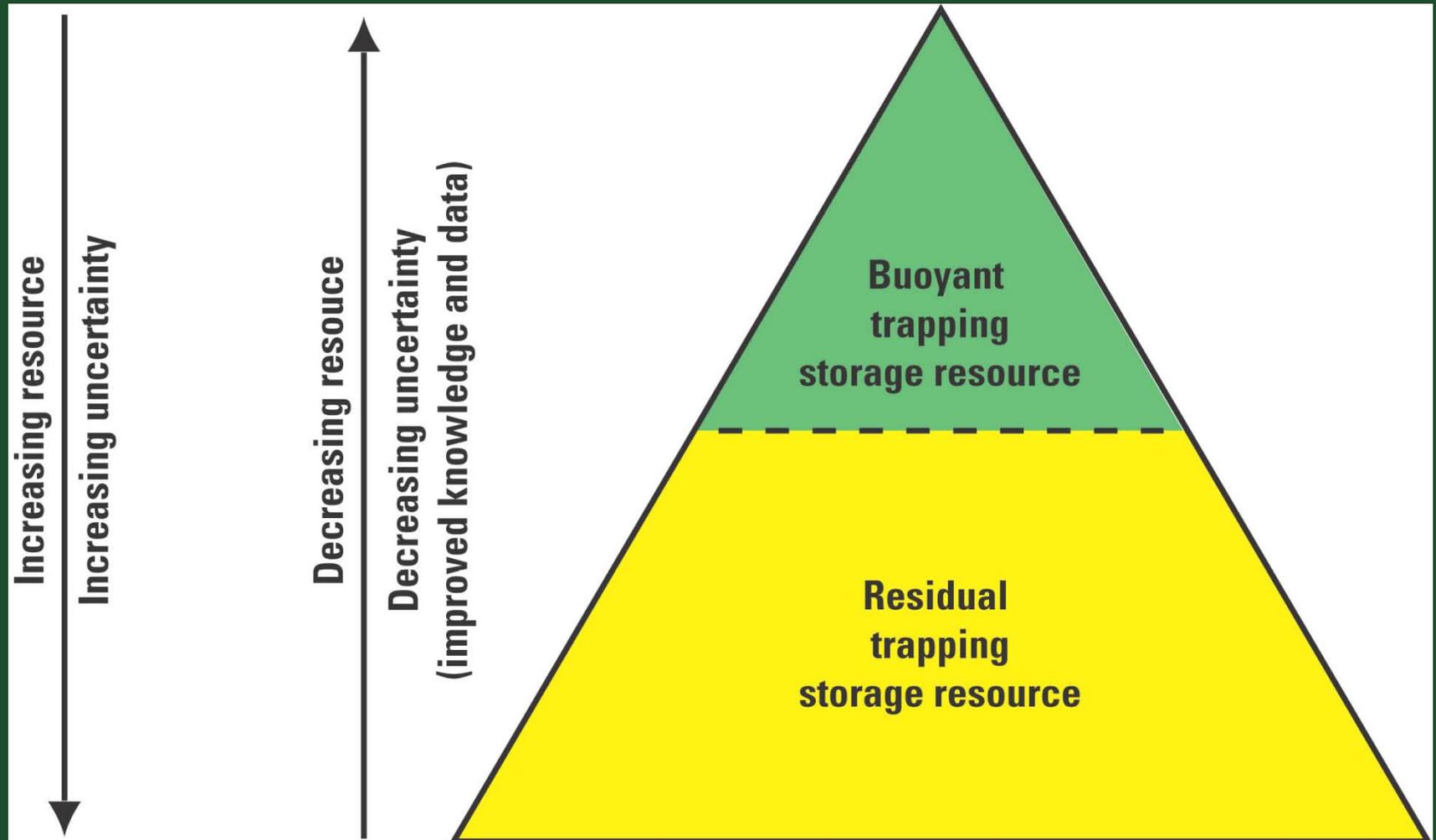


EXPLANATION

- | | |
|--|---|
|  Minimum buoyant trapping pore volume |  Storage formation |
|  Maximum buoyant trapping pore volume |  Seal formation |
|  Residual trapping pore volume |  Fault |

Resource Triangle

Technically accessible CO₂ storage resources



To estimate CO₂ 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

Implementation

- The U.S. Geological Survey has started the assessment to estimate the CO₂ 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

Conclusions

- This method can estimate the technically accessible CO₂ 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 CO₂ 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

References

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<http://energy.usgs.gov>

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