



National Assessment of Geologic Carbon Dioxide Storage Resources—Results

U.S. Geological Survey
Department of the Interior

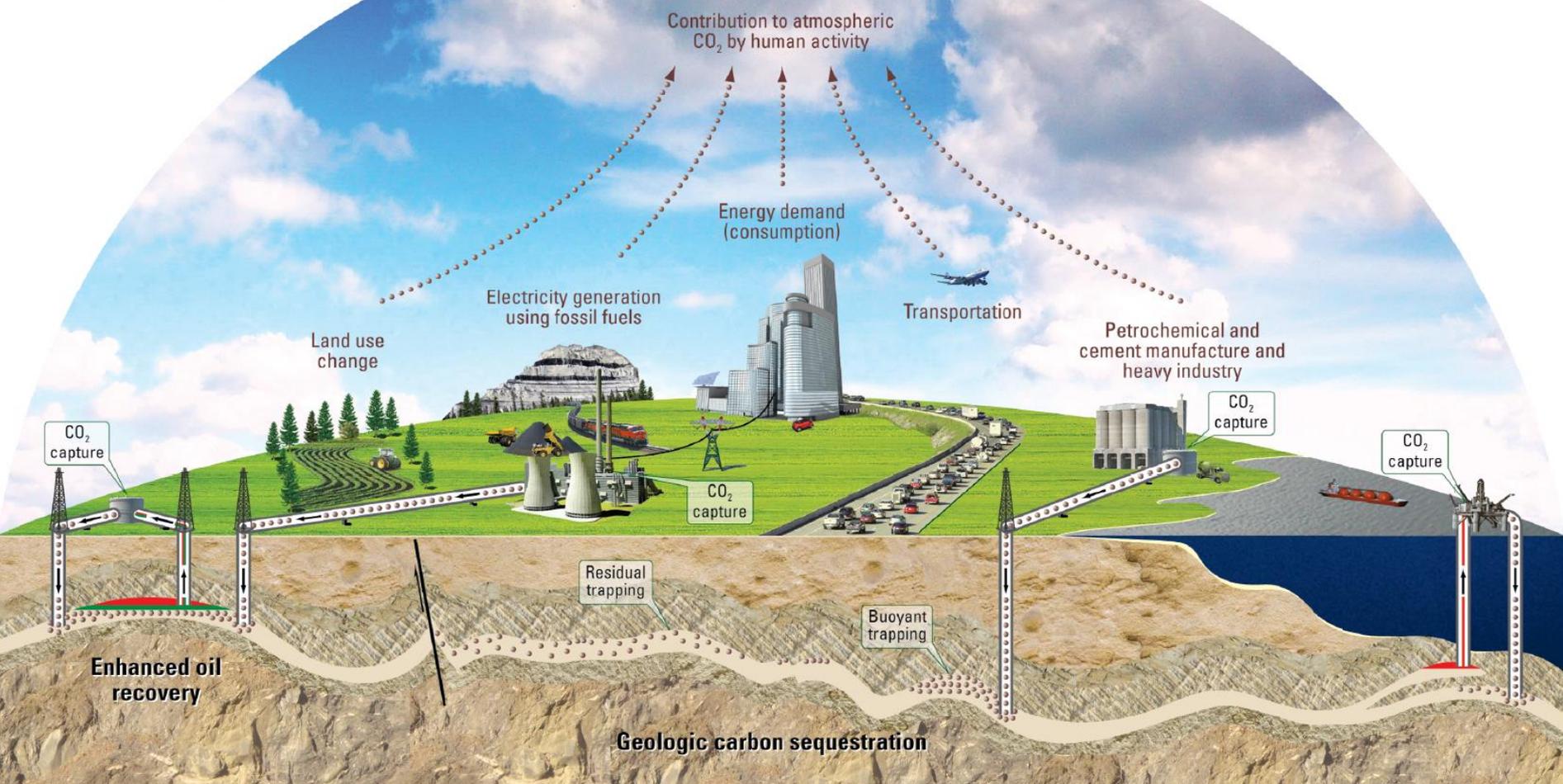


Outline for Briefing

- Overview of geologic carbon dioxide storage
- Energy Independence and Security Act
- USGS assessment methodology
- Geologic model
- Assessment results
- Discussion of results
- Conclusions

What is Geologic CO₂ Storage?

The Concept of Geologic Carbon Sequestration



NOT TO SCALE

Illustration by Douglas W. Duncan and Eric A. Morrissey

EXPLANATION

- CO₂ storage volume
- Gas flow
- Gas
- Oil and gas flow
- Oil
- Seal formation
- CO₂ flow
- Fault—Arrow indicates relative movement
- Storage formation

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.

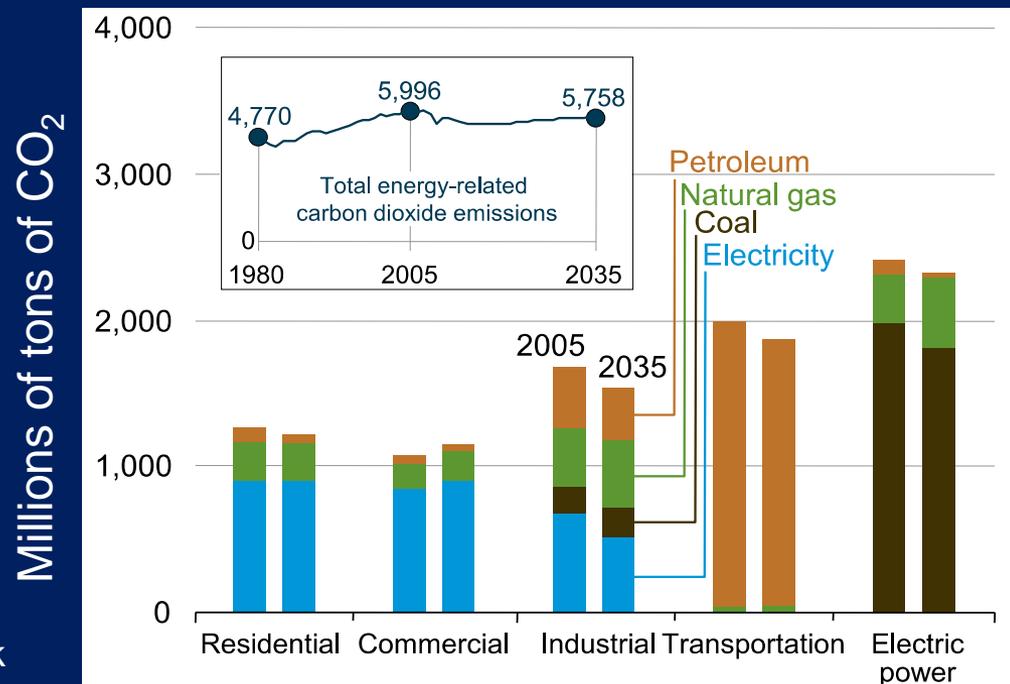
(c) COORDINATION—

- (1) Federal Coordination
- (2) State Coordination

How much CO₂ needs to be stored?

Some examples illustrate the range:

- World: ~ 9.5 Gt carbon/year or ~ 35 Gt CO₂/year (Peters and others, 2013)
- U.S. total all energy sectors in 2011 → ~ 5.5 Gt/year CO₂ (U.S. Energy Information Administration, 2012b)
- Laramie River 2&3 PC plant 1100 MWe → 8.7 Mt/yr CO₂ at 85% capacity factor (Brennan and Burruss, 2006)



Large Stationary Sources of CO₂ in North America

Facilities / Plants

- Agricultural Processing
- Cement
- Electricity Generation
- Ethanol
- Fertilizer
- Industrial
- Petroleum / Natural Gas
- Refinery / Chemical
- Unclassified

Annual CO₂ Emissions (Tonnes)

- 100,000 - 250,000
- > 250,000 - 750,000
- > 750,000



0 255 510 1,020 Kilometers

USGS Methodology

Brennan and others (2010); Blondes and others (2013)

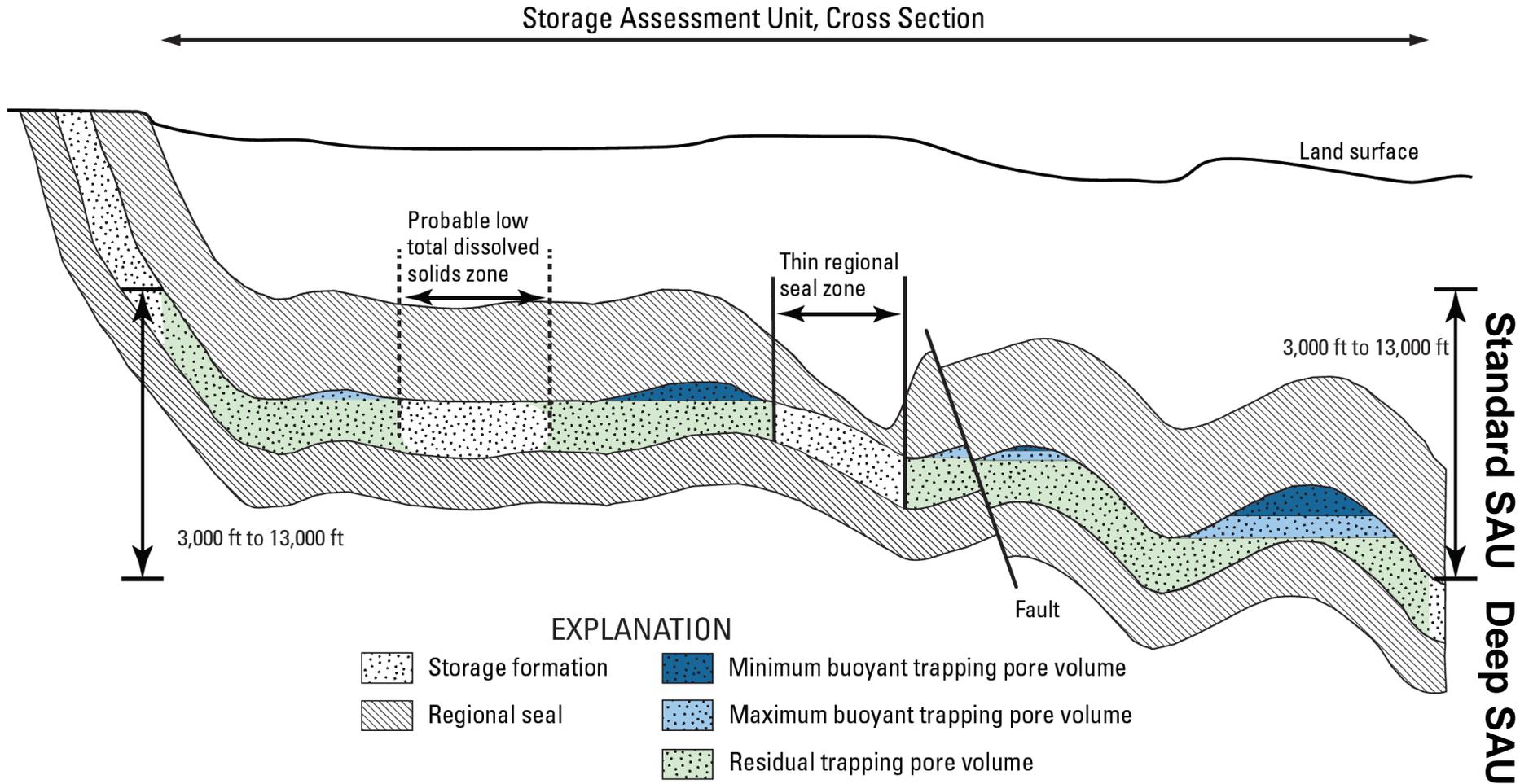
- Geologically-based, statistically-sound hypotheses for quantities of resource
- Comprehensive and consistent treatment (compatible/comparable to USGS assessments in other areas)
- Transparent – published methodology, assumptions
- Probabilistic – range of values to reflect geologic uncertainty
- Storage resources are combined to basin, regional, and national scales using probabilistic aggregation to correctly propagate uncertainty
- Geological models are developed for each region, estimates are regional and not project site specific
- External expert input and multiple reviews
- Does not include coal bed or unconventional (shale or tight sand) reservoirs

USGS Methodology – cont.

Brennan and others (2010); Blondes and others (2013)

- Identifies storage assessment units (SAUs) at depths of 3,000 to 13,000 ft to maintain the CO₂ in a supercritical state and maximize the storage resource per unit volume
- Storage formations must be sealed regionally to retain buoyant CO₂
- Estimates all pore volume within a storage formation available for CO₂ storage
- Incorporates underground source of drinking water (USDW) regulations of the EPA that exclude potential storage formations with water with less than 10,000 milligrams per liter (mg/L) of total dissolved solids (TDS)
- Identifies two storage types: buoyant and residual trapping (with 3 permeability classes)
- Endorsed by the International Energy Agency (IEA) and representatives from multiple national geological surveys, which recommend that regional-scale assessments of geologic CO₂ storage capacities should follow the USGS methodology

Geologic Model



Salinity of water in storage formation must be $> 10,000$ mg/L TDS per EPA regulations

Assessment Assumptions and Constraints

The USGS methodology of Brennan and others (2010) and Blondes and others (2013):

- Does not factor in engineering issues such as injection rate or time-dependent variables to determine the storage potential of SAUs
- Estimates resources without consideration either of accessibility due to land-management or regulatory restrictions or of economic viability
- Assumes that increases in pressure within the reservoir during CO₂ injection can be mitigated by pressure management:
 - By water production from the storage formation
 - To prevent failure of reservoir or seal rock integrity
 - To prevent induced seismicity

Assessment Resource Categories

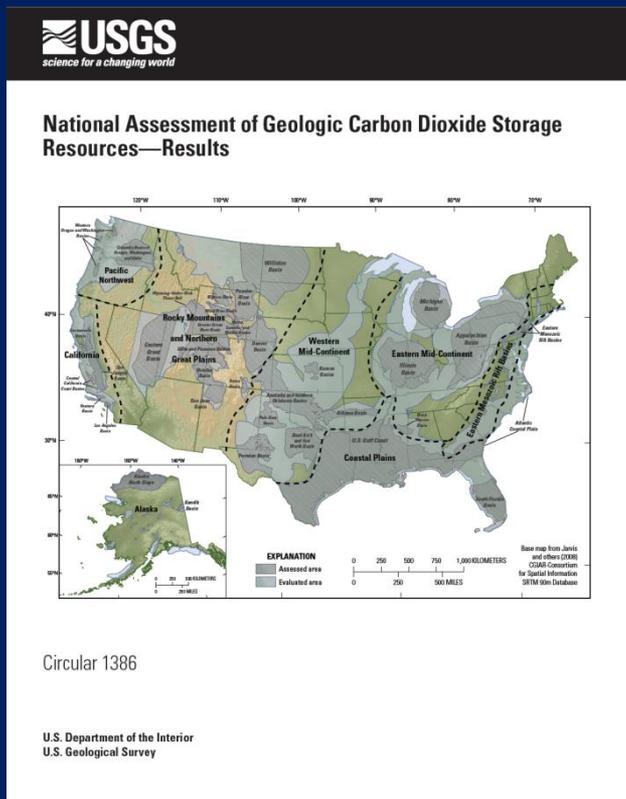
1. B_{SR} , buoyant trapping storage resource: mass of CO_2 that can be stored buoyantly beneath structural or stratigraphic traps with the potential to contain greater than 500,000 barrels of oil equivalent (BOE)
2. $R1_{SR}$, residual trapping class 1 storage resource: mass of CO_2 that can be stored by residual trapping in rocks with permeability greater than 1 D
3. $R2_{SR}$, residual trapping class 2 storage resource: mass of CO_2 that can be stored by residual trapping in rocks with permeability between 1 mD and 1 D
4. $R3_{SR}$, residual trapping class 3 storage resource: mass of CO_2 that can be stored by residual trapping in rocks with permeability less than 1mD
5. TA_{SR} , technically accessible storage resource: total mass of CO_2 that can be stored in the storage assessment unit (SAU)
6. KRR_{SR} , known recovery replacement storage resource: mass of CO_2 that can be stored in existing producing hydrocarbon reservoirs

Data Sources

- USGS National Oil and Gas Assessment publications were a significant source of reservoir characteristics and other geologic input parameters
- Data-sharing agreements with numerous State geological surveys and universities, many of which are members of the DOE National Energy Technology Laboratory (NETL) Regional Carbon Sequestration Partnerships
- Two principal proprietary petroleum databases were mined for a substantial proportion of the data used in the assessments; these are the oil and gas field and reservoir database from Nehring Associates, Inc., and the databases of individual well information from IHS Inc.
- Water-quality data from USGS, NETL, and other datasets available from State sources

USGS National Assessment of Geologic Carbon Dioxide Storage Resources

by U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013a,b,c



Three companion assessment reports:

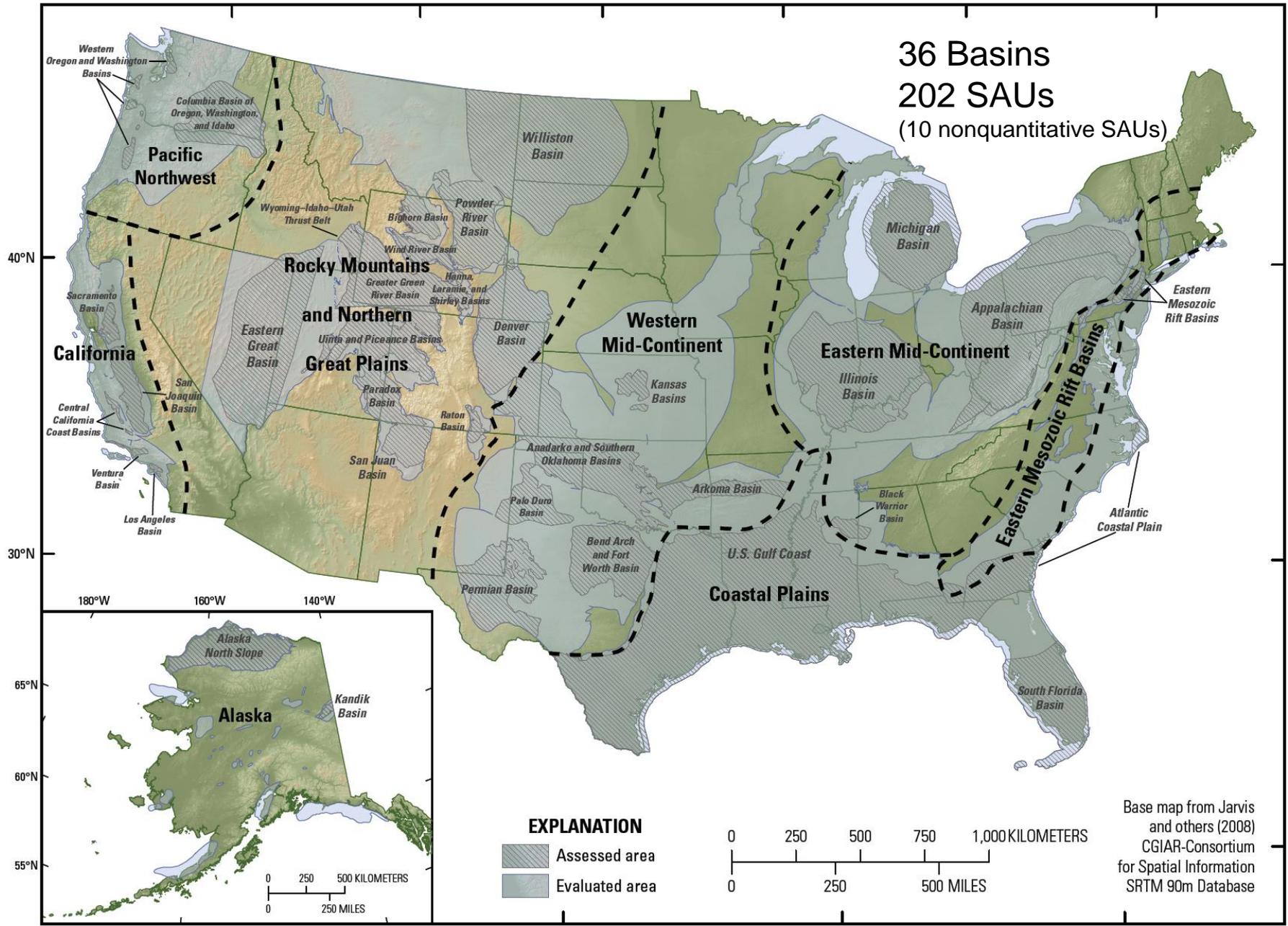
a. Data - USGS Data Series 774:
<http://pubs.usgs.gov/ds/774/>

b. Results - USGS Circular 1386:
<http://pubs.usgs.gov/circ/1386/>

c. Summary - Fact Sheet 2013–3020:
<http://pubs.usgs.gov/fs/2013/3020/>

120°W 110°W 100°W 90°W 80°W 70°W

36 Basins
202 SAUs
(10 nonquantitative SAUs)



Base map from Jarvis and others (2008) CGIAR-Consortium for Spatial Information SRTM 90m Database

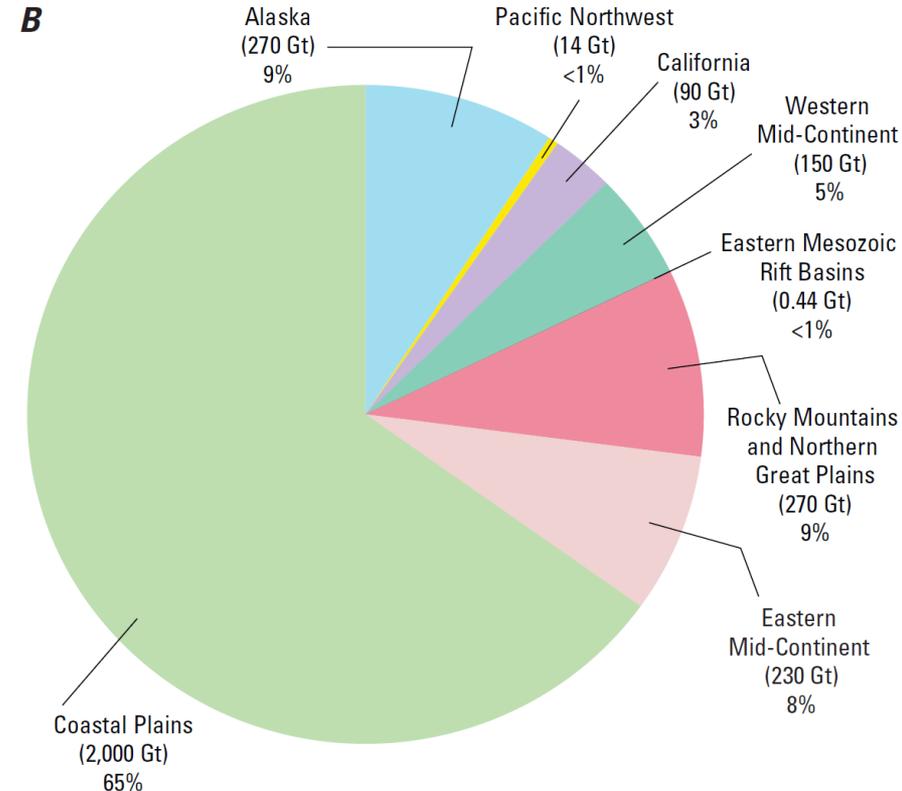
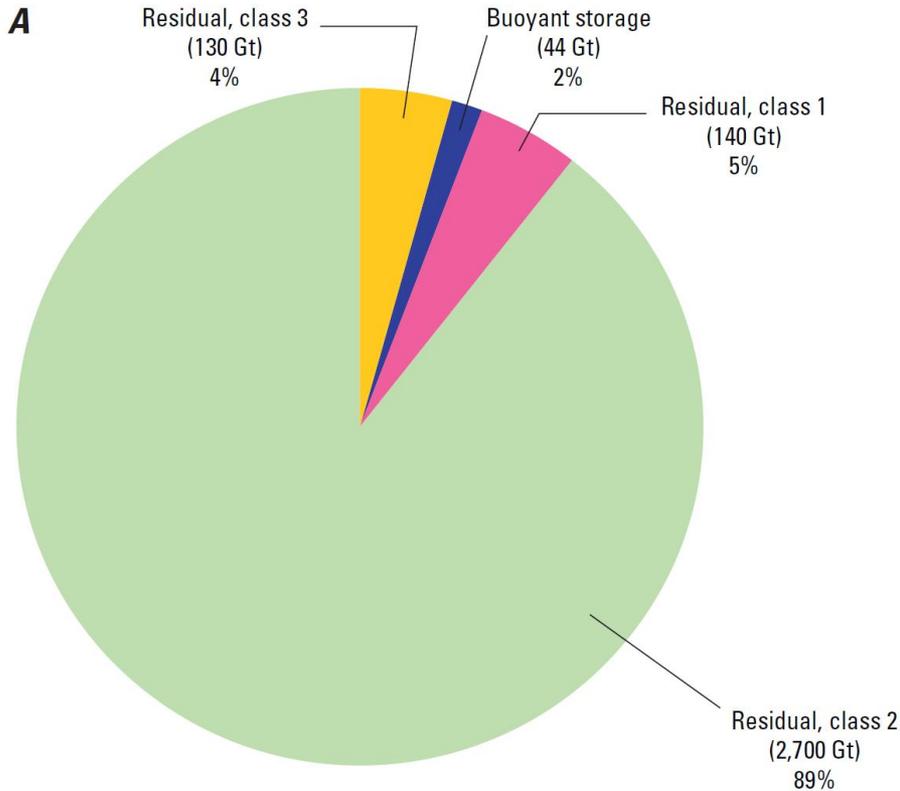
Results of the Assessment

Estimates of national totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States by resource type and class

| CO ₂ storage resource type and class | | P ₅ | P ₅₀ | P ₉₅ | Mean |
|---|---|----------------|-----------------|-----------------|-------|
| Symbol | Name | | | | |
| Storage resource estimated from geologic models | | | | | |
| B_{SR} | Buoyant trapping storage resource | 19 | 31 | 110 | 44 |
| R1_{SR} | Residual trapping class 1 storage resource | 97 | 140 | 200 | 140 |
| R2_{SR} | Residual trapping class 2 storage resource | 2,100 | 2,600 | 3,300 | 2,700 |
| R3_{SR} | Residual trapping class 3 storage resource | 58 | 120 | 230 | 130 |
| TA_{SR} (total) | Technically accessible storage resource | 2,400 | 3,000 | 3,700 | 3,000 |
| Storage resource estimated from petroleum production volumes | | | | | |
| KRR_{SR} | Known recovery replacement storage resource | 11 | 13 | 15 | 13 |

Estimates are in billions of metric tons (gigatons, Gt); mean values sum to totals but are reported to only two significant figures.

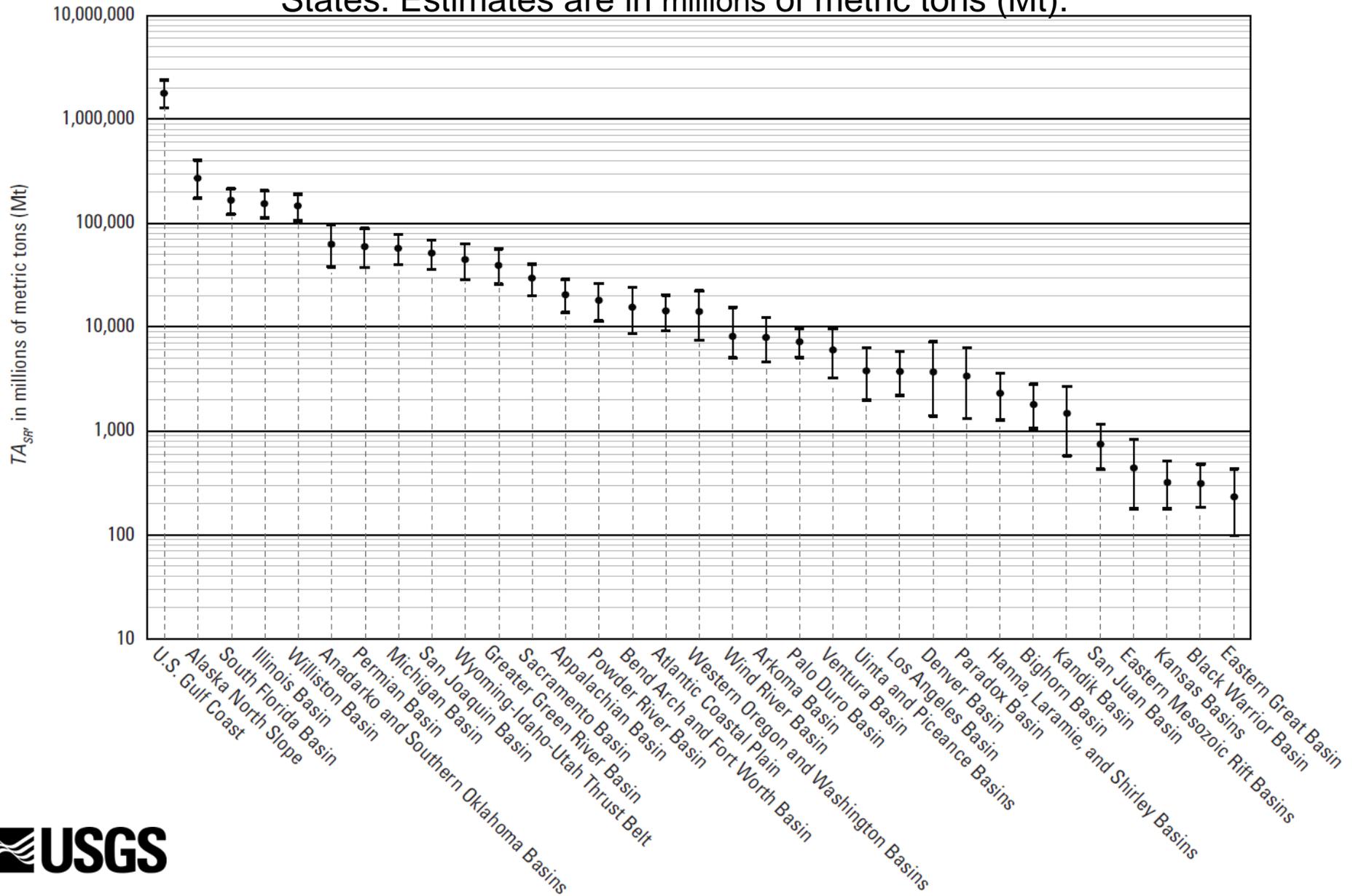
Pie charts showing mean estimates of technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States by (A) type and class and (B) region.



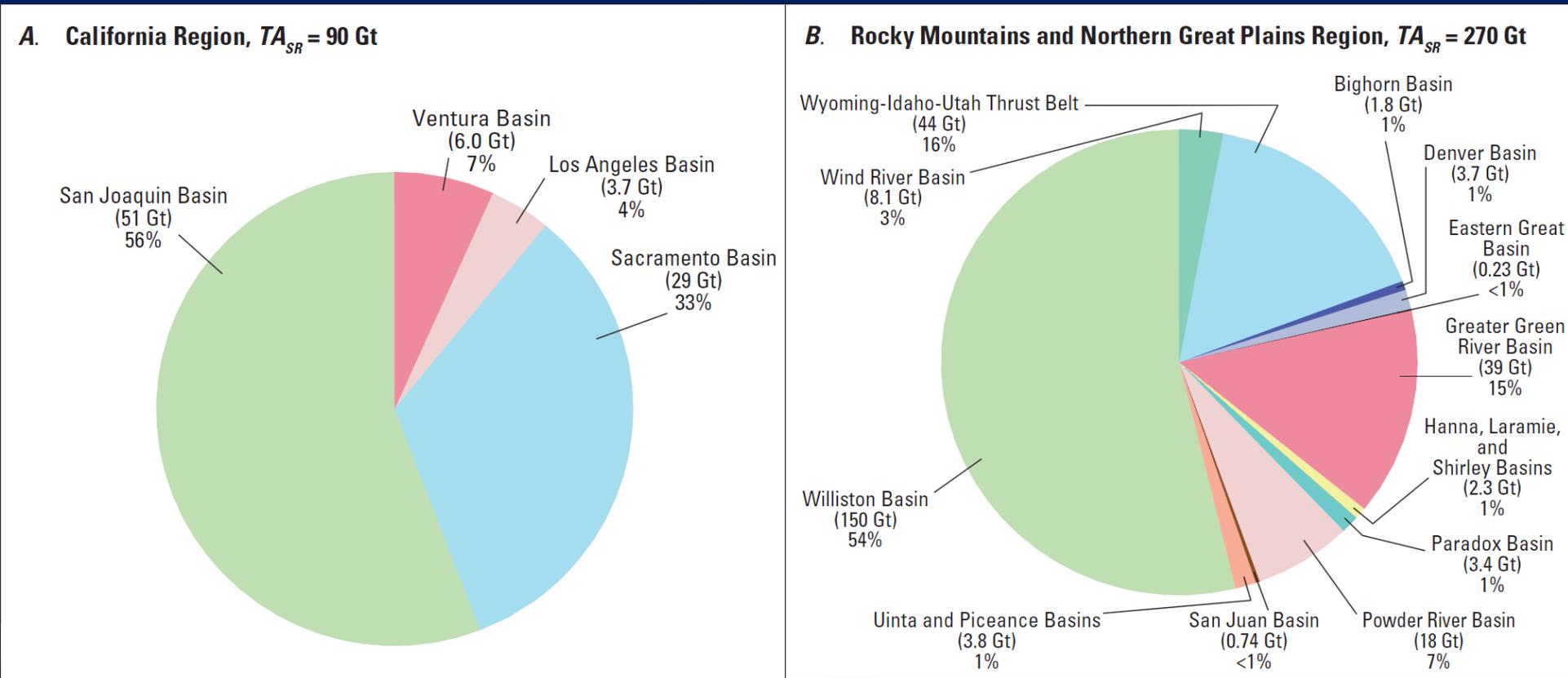
Most (89 percent) of the TA_{SR} is in the residual trapping class 2 storage resource category (mean estimate of 2,700 Gt)

The regions with the largest technically accessible storage resources are the Coastal Plains Region (mostly in the U.S. Gulf Coast) and the Alaska Region (North Slope)

Graph showing the range estimated for the technically accessible storage resource (TA_{SR}) for carbon dioxide (CO_2) in each assessed basin in the United States. Estimates are in millions of metric tons (Mt).



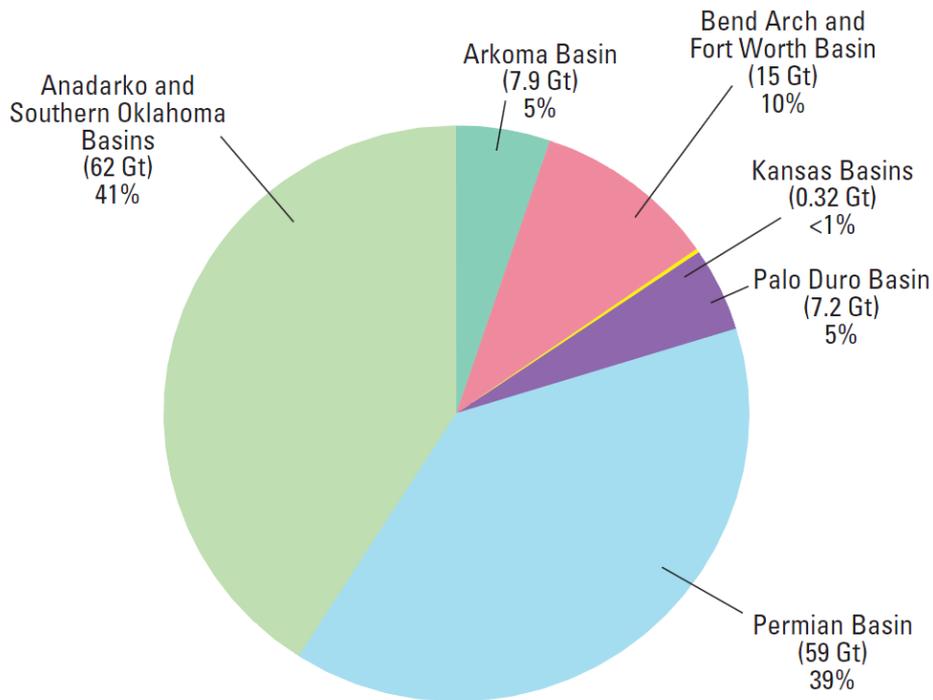
Pie charts showing mean estimates of technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in selected regions of the United States



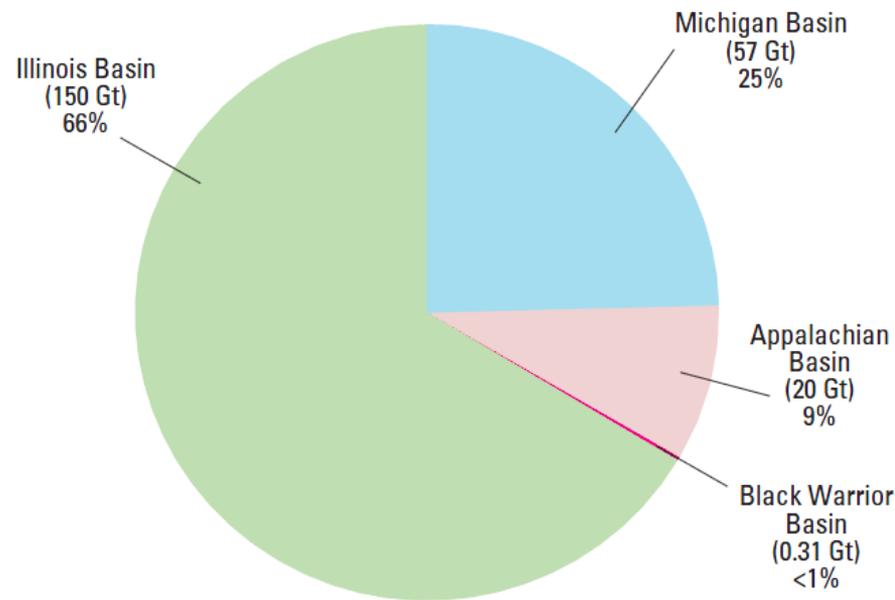
Western U.S. basins contain variable amounts of freshwater (<10,000 mg/L TDS), which will restrict the use of the CO_2 storage resource capacity in these basins

Pie charts showing mean estimates of technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in selected regions of the United States

C. Western Mid-Continent Region, $TA_{SR} = 150$ Gt

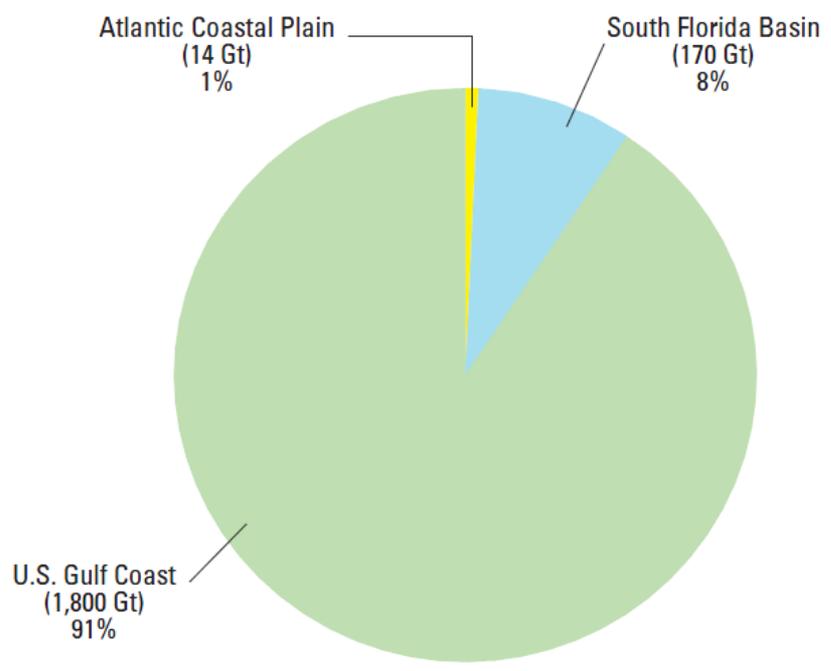


D. Eastern Mid-Continent Region, $TA_{SR} = 230$ Gt

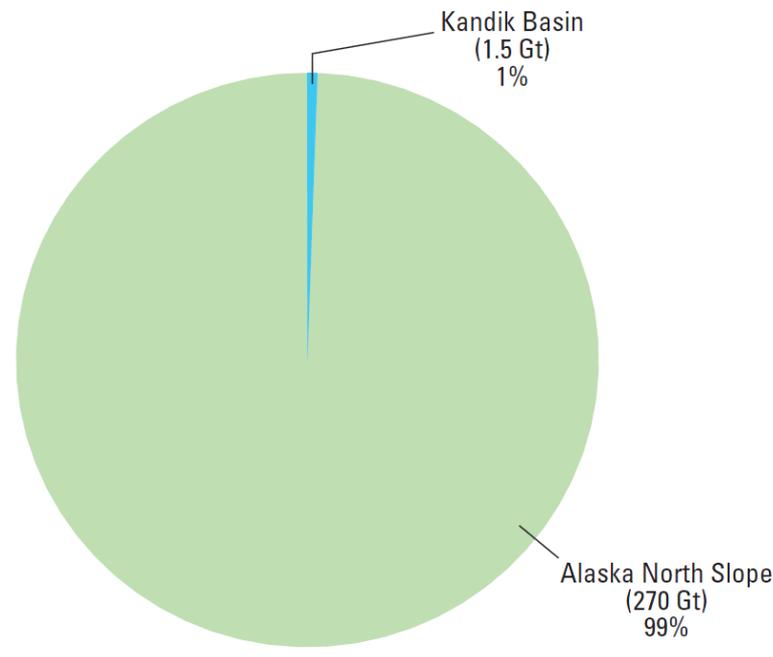


Pie charts showing mean estimates of technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in selected regions of the United States

E. Coastal Plains Region, $TA_{SR} = 2,000$ Gt



F. Alaska Region, $TA_{SR} = 270$ Gt



The Alaska North Slope petroleum industry may utilize subsurface petroleum reservoirs for storage of CO_2 that is coproduced with hydrocarbons or stored during the enhanced-oil-recovery process using CO_2 .

Discussion of Results

- The 44 Gt (mean estimate) of buoyant trapping storage resources includes non-hydrocarbon-bearing reservoir formations, but most of the resources are well defined by hydrocarbon exploration data
- Deep SAUs account for 16 percent of the total TA_{SR} . Any potential developer of the deep SAUs has to consider the increased operational pressures needed to inject CO_2 at depths greater than 13,000 ft.
- The total geologic storage resources for CO_2 in the United States are large, and both types (buoyant and residual) will probably be needed to store anthropogenic CO_2

Discussion of Results – cont.

- The U.S. Energy Information Administration (2012b) estimated that the 2011 national energy-related CO₂ emissions were 5.5 Gt. The mean estimate by the USGS of the technically accessible geologic storage resource (TA_{SR}) for CO₂ in the United States is 3,000 Gt, which is more than 500 times the annual energy-related CO₂ emissions
- However, the mean buoyant trapping storage resource (B_{SR}) of 44 Gt is approximately eight times the annual energy-related CO₂ emissions, which means that the use of residual trapping storage resources for CO₂ will be required to significantly reduce anthropogenic CO₂ emissions into the atmosphere during the next few decades

Conclusions

- The USGS has completed an evaluation of the TA_{SR} for CO_2 for 36 sedimentary basins in the onshore areas and State waters of the United States
- The mean assessment results are:
 - $TA_{SR} = 3,000$ Gt of total subsurface CO_2 storage capacity that is technically accessible in onshore areas and State waters
 - $B_{SR} = 44$ Gt of storage by buoyant trapping in structural or stratigraphic closures
 - $R1_{SR} = 140$ Gt of Residual Class 1 storage resources
 - $R2_{SR} = 2,700$ Gt of Residual Class 2 storage resources
 - $R3_{SR} = 130$ Gt of Residual Class 3 storage resources
 - $KRR_{SR} = 13$ Gt of known oil and gas recovery replacement storage resources
- The regions with the largest technically accessible storage resources are the Coastal Plains Region (mostly in the U.S. Gulf Coast) and the Alaska Region (North Slope)

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<http://energy.usgs.gov>

<http://go.usa.gov/8X8> (USGS geologic CO₂ project website)

<http://pubs.usgs.gov/ds/774/> (USGS CO₂ storage assessment data)

<http://pubs.usgs.gov/circ/1386/> (USGS CO₂ storage assessment results)

<http://pubs.usgs.gov/fs/2013/3020/> (USGS CO₂ storage assessment summary)

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