

Thirteenth Annual Conference on Carbon Capture, Utilization & Storage

Storage Capacity of CO₂ In Geological Media

U.S. Geological Survey National Assessment of Geologic Carbon Dioxide Storage Resources and Associated Research

Peter D. Warwick and the U.S. Geological Survey Geologic Carbon Dioxide
Storage Resources Assessment Team

U.S. Geological Survey, Reston, VA, USA

April 28-May 1, 2014 • David L. Lawrence Convention Center • Pittsburgh, Pennsylvania

Outline for Presentation

- Energy Independence and Security Act
- Geologic model - national CO₂ storage assessment methodology
- National assessment results
- Current research and assessment activities
- Helium Stewardship Act of 2013
- Summary

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.

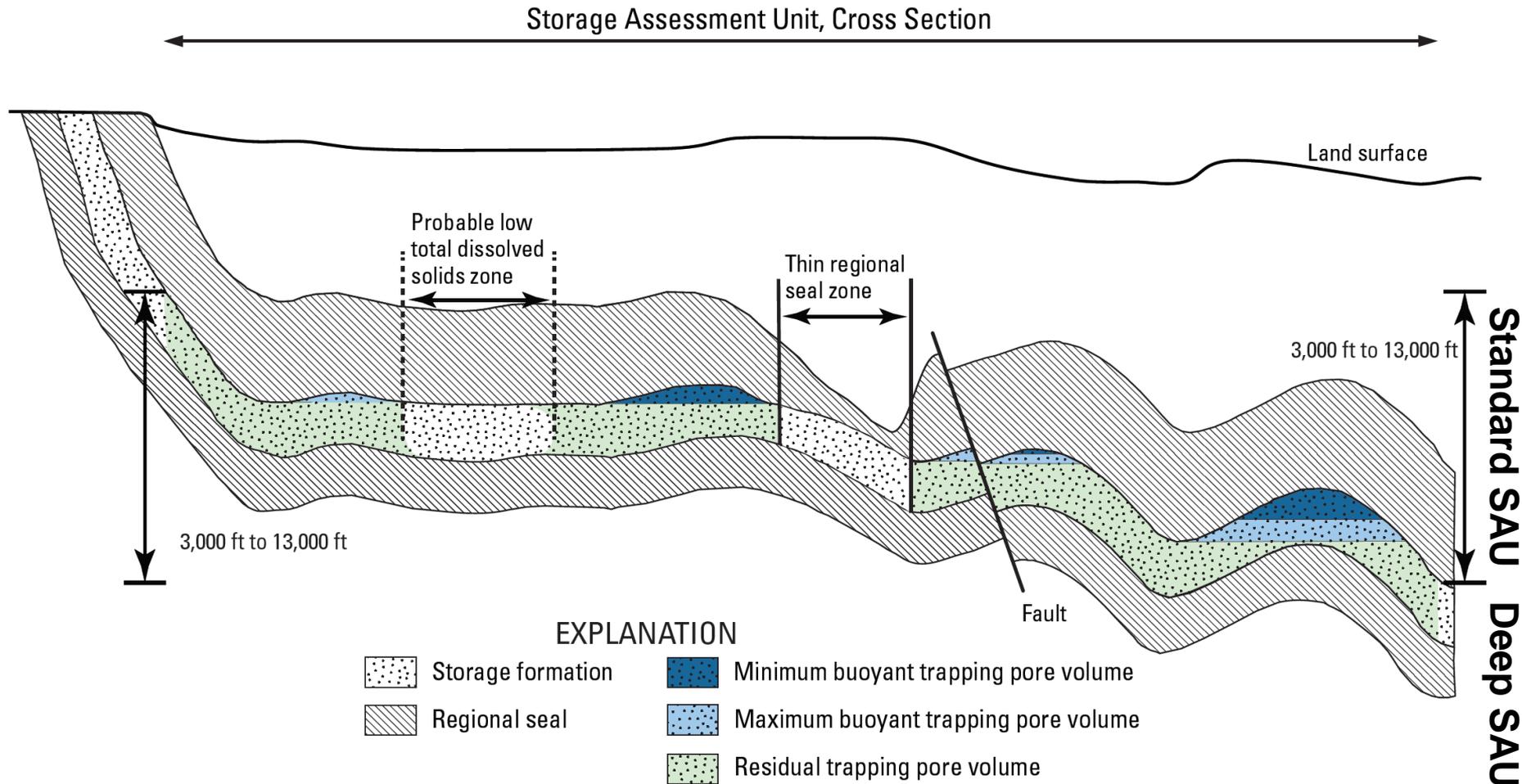
(b) METHODOLOGY— ...shall develop a methodology for conducting an assessment under subsection (f), taking into consideration—

- (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

Geologic Model



Salinity of water in storage formation must be > 10,000 mg/L TDS per EPA regulations Brennan and others (2010); Blondes and others (2013)

Assessment Resource Categories

1. **Buoyant trapping storage resource**: mass of CO₂ that can be stored buoyantly beneath structural or stratigraphic traps with the potential to contain greater than 500,000 barrels of oil equivalent (BOE) (B_{SR})
 2. **Residual trapping class 1 storage resource**: mass of CO₂ that can be stored by residual trapping in rocks
 - a) with permeability greater than 1 D ($R1_{SR}$)
 - b) with permeability between 1 mD and 1 D ($R2_{SR}$)
 - c) with permeability less than 1mD ($R3_{SR}$)
-
-

TOTAL = Technically accessible storage resource: total mass of CO₂ that can be stored in the storage assessment unit (TA_{SR})

1. **Known recovery replacement storage resource**: mass of CO₂ that can be stored in existing producing hydrocarbon reservoirs (KRR_{SR})

Assessment Assumptions and Constraints

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

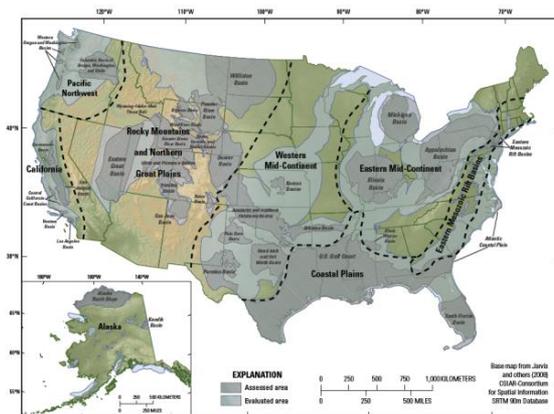
- Does not factor in engineering issues such as injection rate or time-dependent variables to determine the storage potential of storage assessment units (SAUs)
- Estimates resources without consideration of either accessibility due to land-management or regulatory restrictions or of economic viability
- Assessment covers on-shore and State water areas of the U.S.
- 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

USGS National Assessment of Geologic Carbon Dioxide Storage Resources

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



National Assessment of Geologic Carbon Dioxide Storage Resources—Results



Circular 1386
Version 1.1, September 2013

U.S. Department of the Interior
U.S. Geological Survey

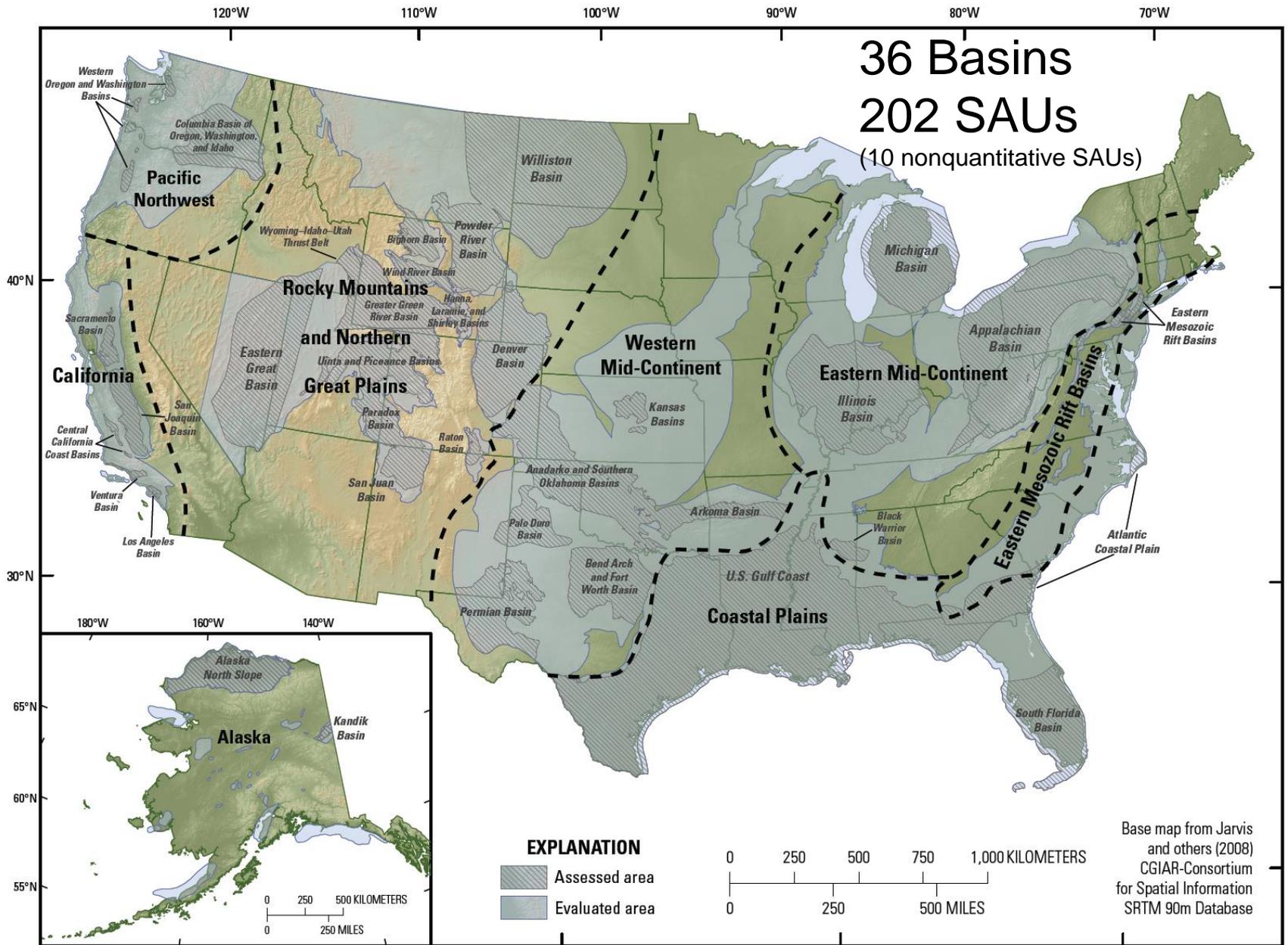
Three companion assessment reports:

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/>





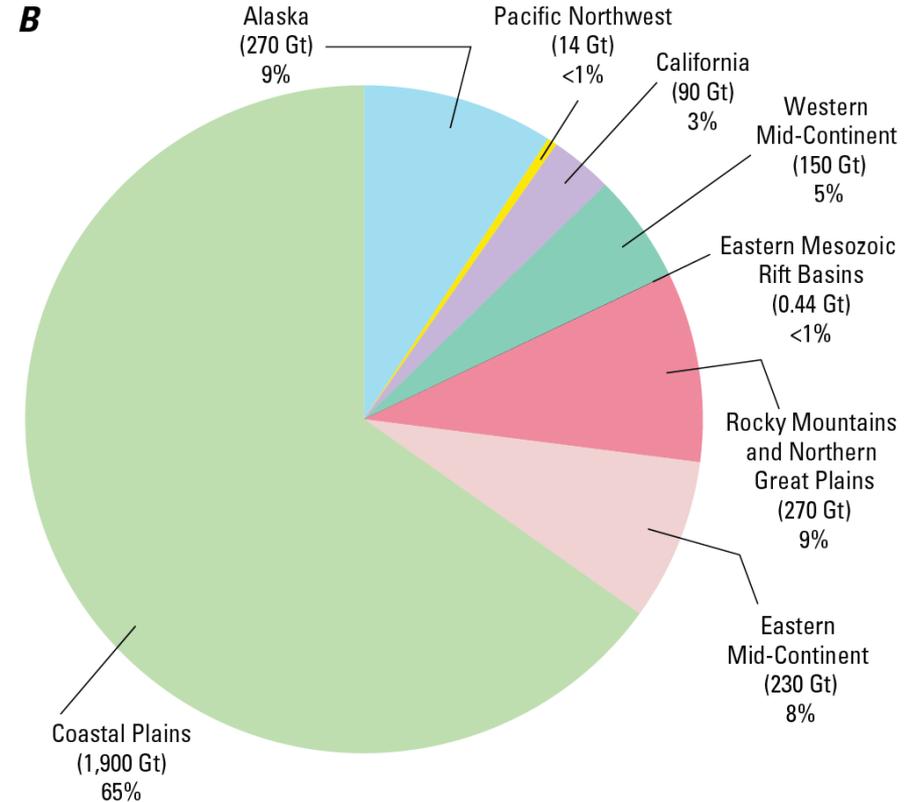
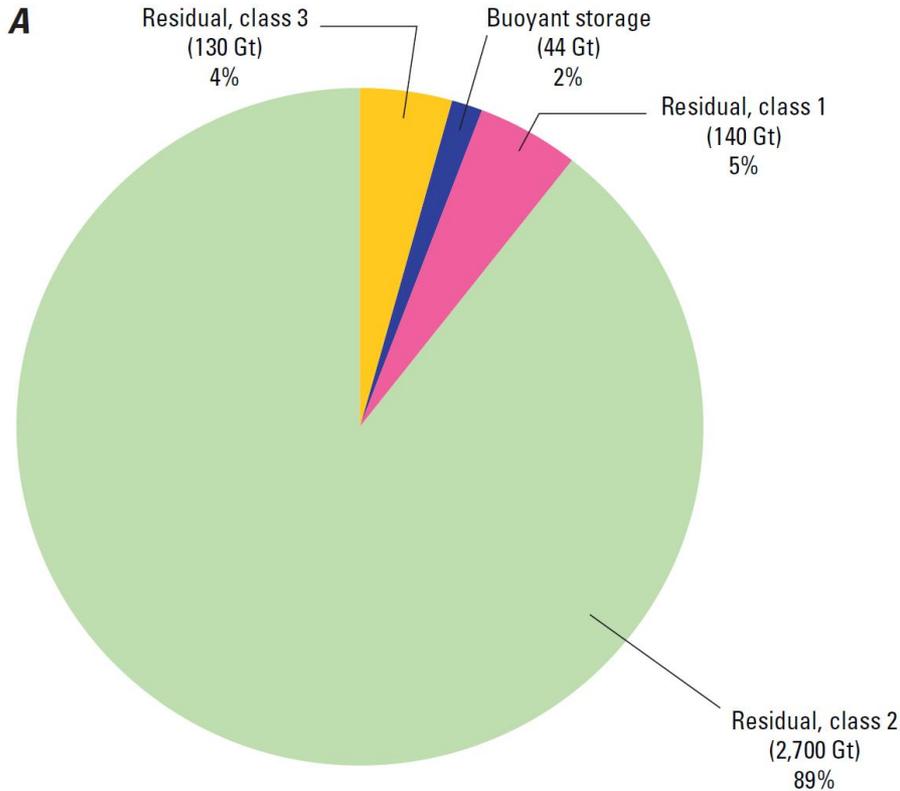
Results of the Assessment

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	2,300	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. The U.S. Energy Information Administration (2013) estimated that the 2012 national energy-related CO₂ emissions were 5.3 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.

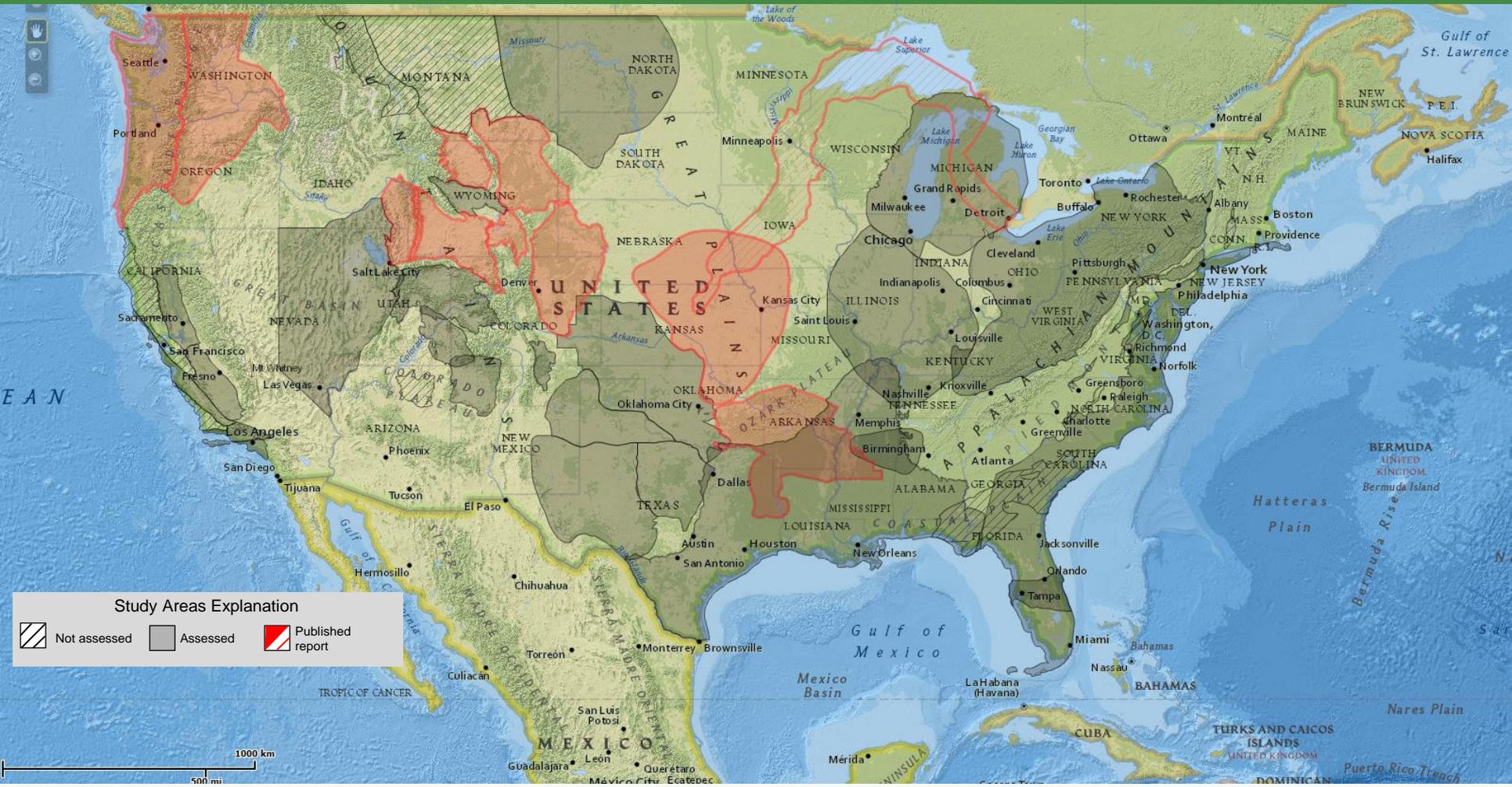
Pie charts showing mean estimates of technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States by (A) type and class and (B) region.



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

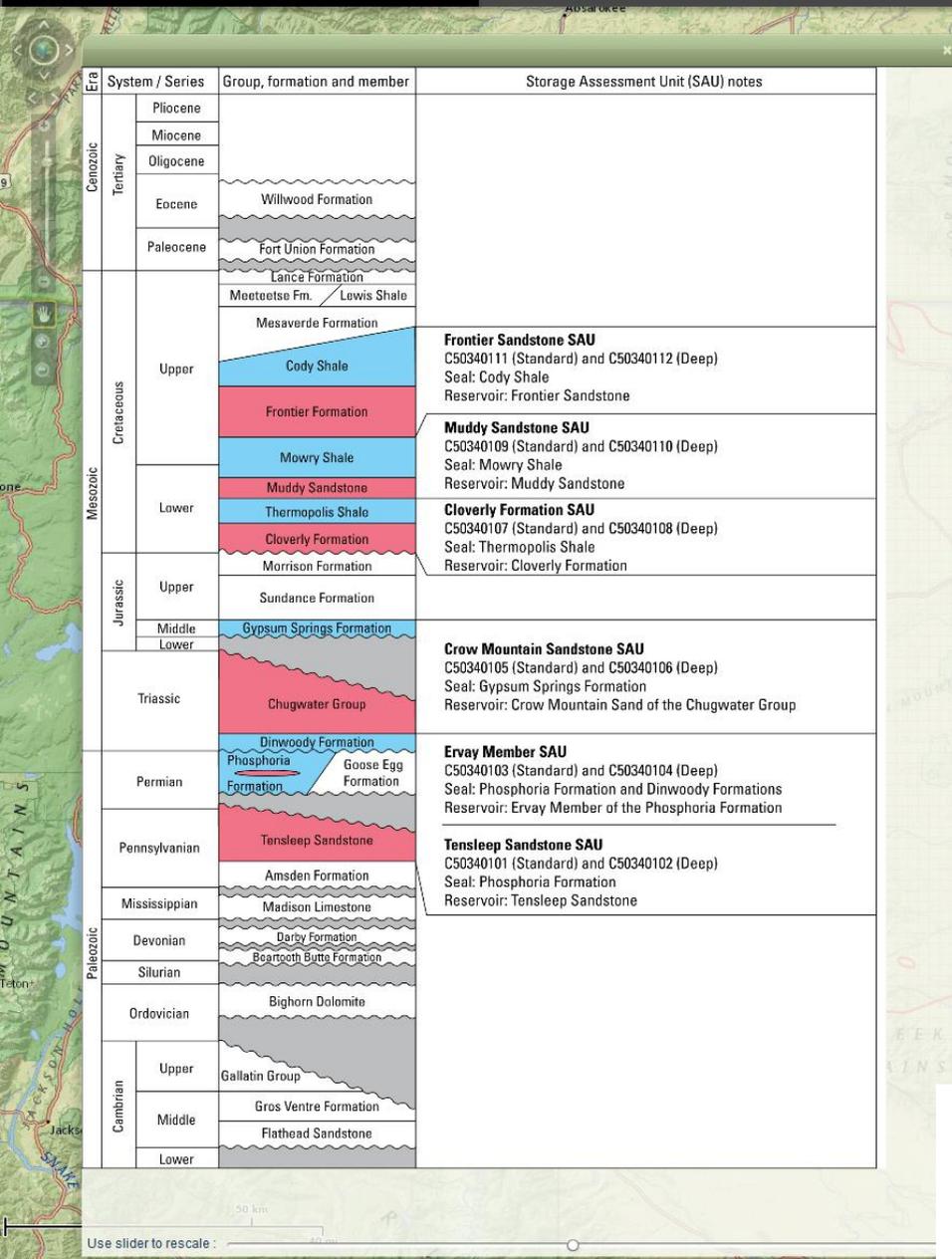
The regions with the largest technically accessible storage resources are the Coastal Plains Region (mostly in the U.S. Gulf Coast) and the Alaska Region (North Slope)

Map showing basins assessed by USGS for CO₂ storage potential

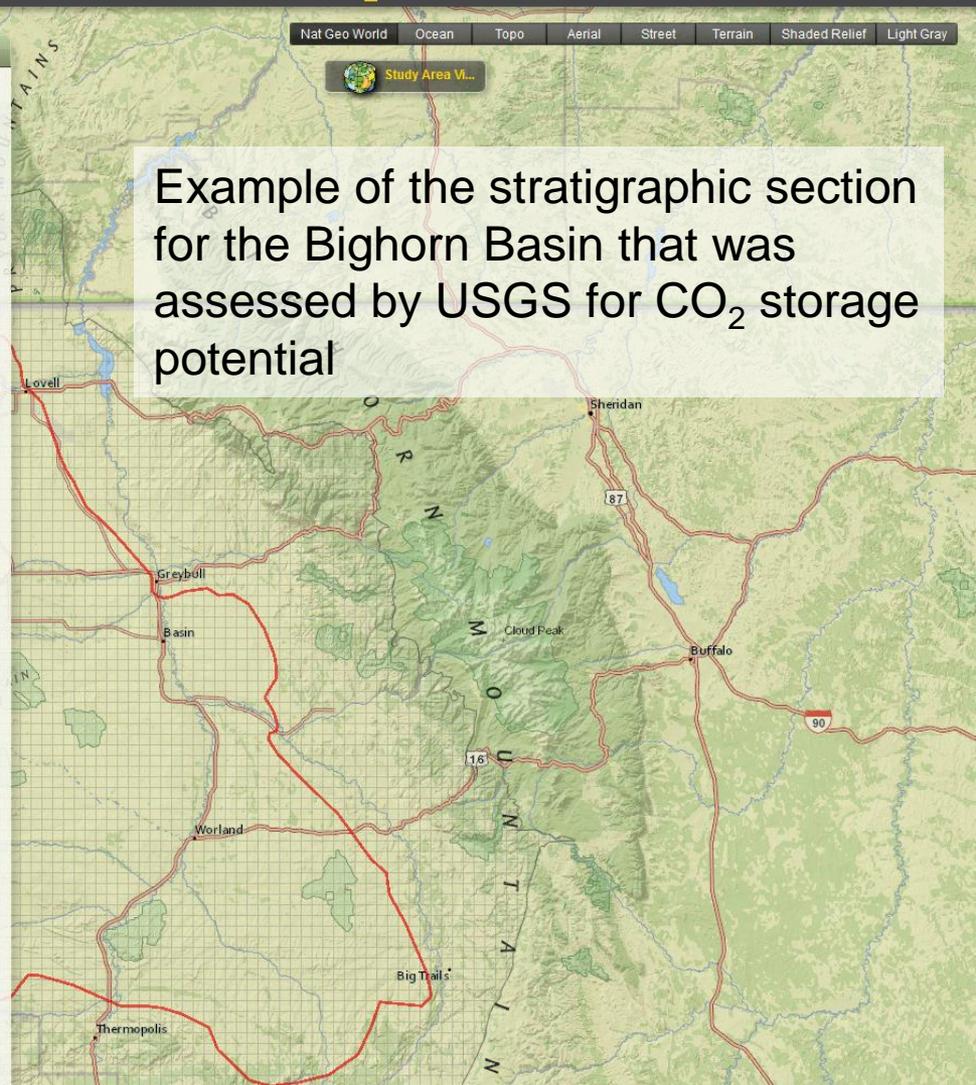


<http://co2public.er.usgs.gov/viewer/>

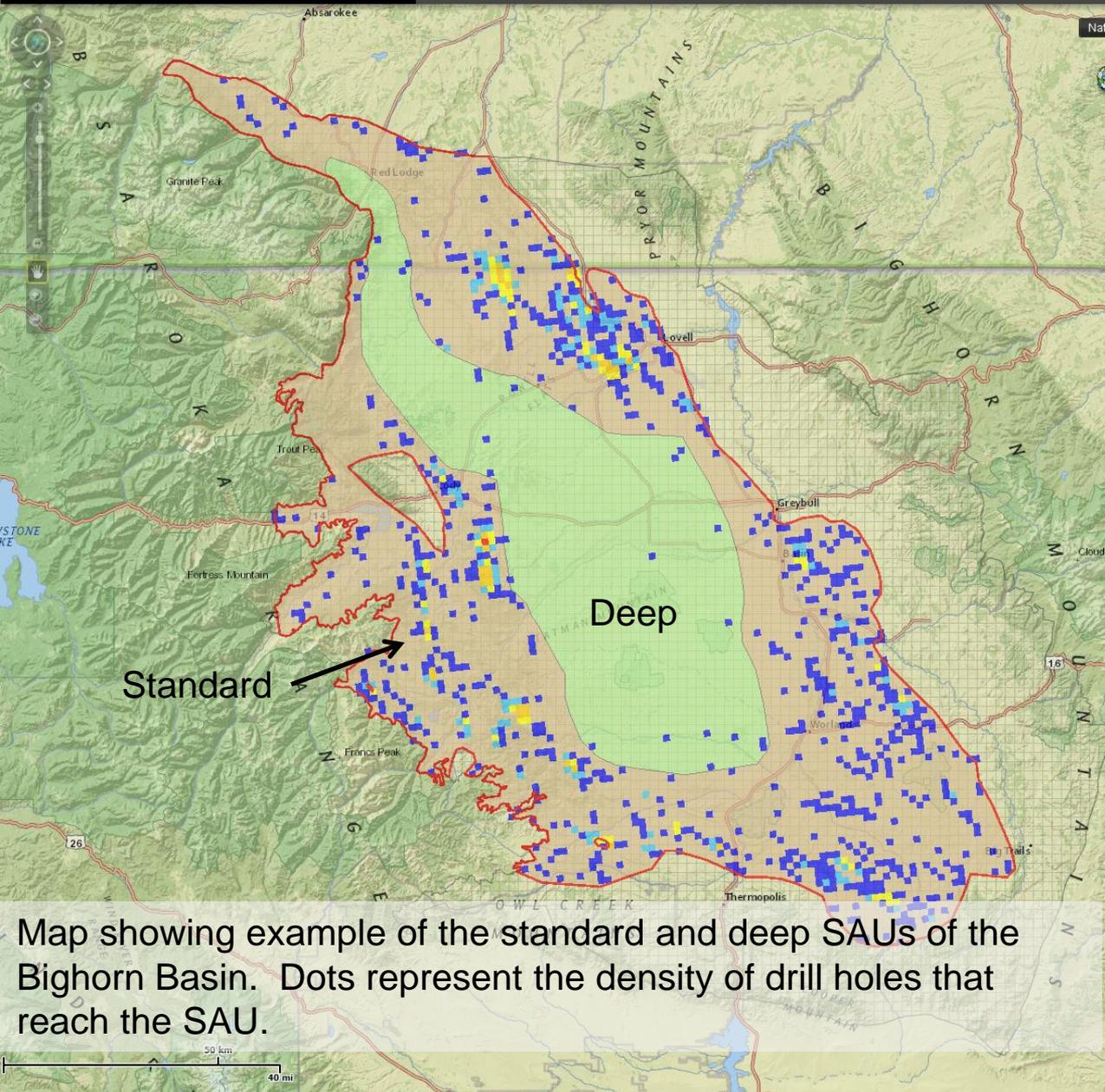




Example of the stratigraphic section for the Bighorn Basin that was assessed by USGS for CO₂ storage potential



Generalized stratigraphic column of geologic formations in the Bighorn Basin, Wyoming and Montana. Storage assessment units consist of a reservoir (red) and regional seal (blue). Wavy lines indicate unconformable contacts, and gray sections represent eroded section. In some cases, subdivisions of units are not shown (modified from Fox and Dolton, 1995).



Nat Geo World Ocean Topo Aerial Street Terrain Shaded Relief Light Gray

Study Area Viewer

Vis.	Layer	Transparency
<input type="checkbox"/>	Study Areas	<input type="range"/>
<input checked="" type="checkbox"/>	Geologic Provinces	<input type="range"/>
<input type="checkbox"/>	Sedimentary Basins	<input type="range"/>

Home Report/Data Strat Chart

Layer Visibility

- Bighorn Basin
 - C5034_Area_Assessed
 - Frontier Sandstone
 - Muddy Sandstone
 - Cloverly Formation
 - Crow Mountain Sandstone
 - Envay Member
 - Tensleep Sandstone
 - Cell_C50340102
 - 1-3
 - 4-11
 - 12-31
 - 32-63
 - 64+
 - SAU_C50340102
 - Cell_C50340101
 - 1-3
 - 4-11
 - 12-31
 - 32-63
 - 64+
 - SAU_C50340101

Map showing example of the standard and deep SAUs of the Bighorn Basin. Dots represent the density of drill holes that reach the SAU.

Carbon Sequestration – Geologic Research and Assessments

2014 – 2018

Task 1: Methodology development and assessment of national CO₂ enhanced oil recovery (CO₂-EOR) and associated CO₂ storage potential

- Requested by EISA legislation; Goal to complete methodology and conduct an assessment
- Topics of interest: CO₂ utilization, oil recovery factors, reservoir characterization

Task 2: Geological studies of reservoirs and seals in selected basins with high potential for CO₂ storage

- Geopressure and geothermal gradient study of mid-continent sedimentary basins
- Upper Jurassic-Lower Cretaceous rocks of the South Florida Basin
- Comparison of carbonate reservoirs within the U.S. for CO₂ sequestration
- Lower Paleozoic in the Permian Basin
- Seal character and effects of hydrofracturing for shale gas development

Carbon Sequestration – Geologic Research and Assessments

Task 3: Natural CO₂ reservoirs as analogues for CO₂ storage and resources for EOR

- California Sedimentary Basins
- Northern Rocky Mountains
- Southern Rocky Mountains
- Southern Permian Basin
- Jackson Dome, Mississippi
- Life cycle of CO₂ in the EOR reservoir
- Evaluate natural CO₂ resources



Task 4: Economics of CO₂ storage and enhanced oil recovery

- Develop model projects to evaluate sequestration and EOR projects
- Focus on geologic storage



CARBON SEQUESTRATION – GEOLOGIC RESEARCH AND ASSESSMENTS

Task 5: Storage of CO₂ in unconventional geologic reservoirs

- Develop and publish maps of U.S. deep coal and shale units suitable for potential storage of CO₂

Task 6: Induced seismicity associated with CO₂ geologic storage

- Seismic monitoring at Decatur and FutureGen projects, IL
(See Hickman presentation today in the MMV session @ 4:10 pm)

Task 7: Outreach



Photo By: Eelco Kruijff

HELIUM STEWARDSHIP ACT OF 2013

PUBLIC LAW 113-40—OCT. 2, 2013

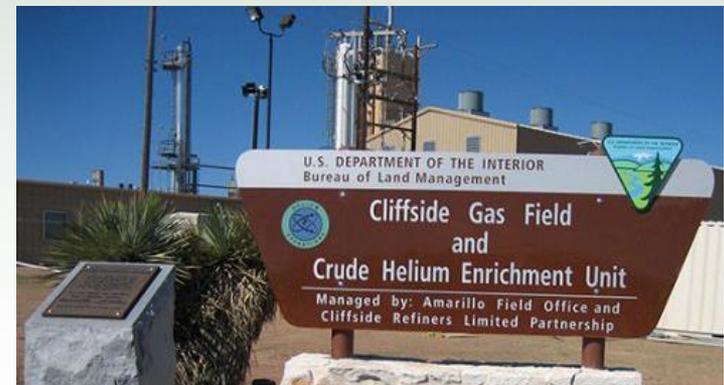
SEC. 16. HELIUM GAS RESOURCE ASSESSMENT.

....the United States Geological Survey, shall—

(1) in coordination with appropriate heads of State geological surveys—
complete a national helium gas assessment that identifies and quantifies the quantity of helium, including the isotope helium-3, in each reservoir, including assessments of the constituent gases found in each helium resource, such as carbon dioxide, nitrogen, and natural gas...

USGS plans to work with U.S. Bureau of
Land Management and State geological surveys

http://www.blm.gov/nm/st/en/prog/energy/helium_program.html



SUMMARY

- 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
- New assessments are underway for recoverable hydrocarbons associated with CO_2 -EOR; and natural CO_2 and helium resources
- New research is focused on natural CO_2 reservoirs as analogues for CO_2 storage, storage of CO_2 in unconventional reservoirs, and induced seismicity associated with CO_2 injection
- Economic evaluations will focus on the results of the USGS assessment of recoverable hydrocarbons associated with CO_2 -EOR and the 2013 National CO_2 storage assessment

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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)

Selected References

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- U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013b, National assessment of geologic carbon dioxide storage resources—Results (ver. 1.1, September 2013): U.S. Geological Survey Circular 1386, 41 p., <http://pubs.usgs.gov/circ/1386/>. (Supersedes ver. 1.0 released June 26, 2013.)
- U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013c, National assessment of geologic carbon dioxide storage resources—Summary (ver. 1.1, September 2013): U.S. Geological Survey Fact Sheet 2013–3020, 6 p., <http://pubs.usgs.gov/fs/2013/3020/>. (Supersedes ver. 1.0 released June 26, 2013.)