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

Peter D. Warwick

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U.S. Energy Association

U.S. Geological Survey
Department of the Interior
Outline for Presentation

- Overview of geologic carbon dioxide storage
- Energy Independence and Security Act
- USGS assessment methodology
- Geologic model
- Assessment results
- Discussion of results
- Current research and assessment activities
- Helium Stewardship Act of 2013
- Summary
What is Geologic CO$_2$ Storage?
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 CO$_2$ needs to be stored?
Some examples illustrate the range:

- World: ~ 9.5 Gt carbon/year or ~ 35 Gt CO$_2$/year (Peters and others, 2013)
- U.S. total all energy sectors in 2012 → ~ 5.2 Gt/year CO$_2$ (U.S. Energy Information Administration, 2013)
- Laramie River 2&3 PC plant 1100 MWe → 8.7 Mt/yr CO$_2$ at 85% capacity factor (Brennan and Burruss, 2006)

U.S. energy-related carbon dioxide emissions by sector and fuel, 2005 and 2040 (EIA 2014, Annual Energy Outlook)
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 CO$_2$ in a supercritical state and maximize the storage resource per unit volume

- Storage formations must be sealed regionally to retain buoyant CO$_2$

- Estimates all pore volume within a storage formation available for CO$_2$ 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, 2013) and representatives from multiple national geological surveys, which recommend that regional-scale assessments of geologic CO$_2$ storage capacities should follow the USGS methodology
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 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

• Assessment covers on-shore and State water areas of the U.S.

• Assumes that increases in pressure within the reservoir during CO$_2$ 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. **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) ($B_{SR}$)

2. **Residual trapping storage resource**: mass of CO$_2$ that can be stored by residual trapping in rocks
   a) with permeability greater than 1 D ($R_{1SR}$)
   b) with permeability between 1 mD and 1 D ($R_{2SR}$)
   c) with permeability less than 1 mD ($R_{3SR}$)

TOTAL = **Technically accessible storage resource**: total mass of CO$_2$ that can be stored in the storage assessment unit ($TA_{SR}$)

1. **Known recovery replacement storage resource**: mass of CO$_2$ that can be stored in existing producing hydrocarbon reservoirs ($KRR_{SR}$)
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:


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

36 Basins
202 SAUs
(10 nonquantitative SAUs)
Results of the Assessment
Estimates of national totals for technically accessible storage resources (\( T_{A_{SR}} \)) for carbon dioxide (CO\(_2\)) in the United States by resource type and class

<table>
<thead>
<tr>
<th>CO(_2) storage resource type and class</th>
<th>( P_5 )</th>
<th>( P_{50} )</th>
<th>( P_{95} )</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Storage resource estimated from geologic models</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>( B_{SR} )</td>
<td>Buoyant trapping storage resource</td>
<td>19</td>
<td>31</td>
<td>110</td>
</tr>
<tr>
<td>( R1_{SR} )</td>
<td>Residual trapping class 1 storage resource</td>
<td>97</td>
<td>140</td>
<td>200</td>
</tr>
<tr>
<td>( R2_{SR} )</td>
<td>Residual trapping class 2 storage resource</td>
<td>2,100</td>
<td>2,600</td>
<td>3,300</td>
</tr>
<tr>
<td>( R3_{SR} )</td>
<td>Residual trapping class 3 storage resource</td>
<td>58</td>
<td>120</td>
<td>230</td>
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<tr>
<td>( T_{A_{SR}} ) (total)</td>
<td>Technically accessible storage resource</td>
<td>2,300</td>
<td>3,000</td>
<td>3,700</td>
</tr>
<tr>
<td><strong>Storage resource estimated from petroleum production volumes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( KRR_{SR} )</td>
<td>Known recovery replacement storage resource</td>
<td>11</td>
<td>13</td>
<td>15</td>
</tr>
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</table>

Estimates are in billions of metric tons (gigatons, Gt); mean values sum to totals but all values 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 (mostly in the U.S. Gulf Coast), Rocky Mountains and Northern Great Plains, and the Alaska (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 ($T_{A_{SR}}$) for carbon dioxide ($CO_2$) in selected regions of the United States

A. California Region, $T_{A_{SR}} = 90$ Gt

- San Joaquin Basin (51 Gt) 56%
- Ventura Basin (6.0 Gt) 7%
- Los Angeles Basin (3.7 Gt) 4%
- Sacramento Basin (29 Gt) 33%

B. Rocky Mountains and Northern Great Plains Region, $T_{A_{SR}} = 270$ Gt

- Williston Basin (150 Gt) 54%
- Uinta and Piceance Basins (3.8 Gt) 1%
- Uinta and Piceance Basins (3.8 Gt) 1%
- San Juan Basin (0.74 Gt) <1%
- Powder River Basin (18 Gt) 7%
- Paradox Basin (3.4 Gt) 1%
- Hanna, Laramie, and Shirley Basins (2.3 Gt) 1%
- Greater Green River Basin (39 Gt) 15%
- Eastern Great Basin (0.23 Gt) <1%
- Denver Basin (3.7 Gt) 1%
- Bighorn Basin (1.8 Gt) 1%
- Wyoming-Idaho-Utah Thrust Belt (44 Gt) 16%

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

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 $CO_2$. 

E. Coastal Plains Region, $TA_{SR} = 1,900$ Gt

- Atlantic Coastal Plain (14 Gt) 1%
- South Florida Basin (170 Gt) 8%
- U.S. Gulf Coast (1,800 Gt) 91%

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

- Kandik Basin (1.5 Gt) 1%
- Alaska North Slope (270 Gt) 99%
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 $T_{A_{SR}}$. 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$_2$. 
The U.S. Energy Information Administration (2013) estimated that the 2012 national energy-related CO\textsubscript{2} emissions were 5.2 Gt. The mean estimate by the USGS of the technically accessible geologic storage resource (\textit{TA\textsubscript{SR}}) for CO\textsubscript{2} in the United States is 3,000 Gt, which is more than 500 times the annual energy-related CO\textsubscript{2} emissions.

However, the mean buoyant trapping storage resource (\textit{B\textsubscript{SR}}) of 44 Gt is approximately eight times the annual energy-related CO\textsubscript{2} emissions, which means that the use of residual trapping storage resources for CO\textsubscript{2} will be required to significantly reduce anthropogenic CO\textsubscript{2} emissions into the atmosphere during the next few decades.
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
• Comparison of carbonate reservoirs within the U.S. for CO₂ sequestration
• Seal character and effects of hydrofracturing for shale gas development
Task 3: Natural CO$_2$ reservoirs as analogues for CO$_2$ storage and resources for EOR

- California Sedimentary Basins
- Northern Rocky Mountains
- Southern Rocky Mountains
- Southern Permian Basin
- Jackson Dome, Mississippi
- Evaluate natural CO$_2$ and helium resources

Task 4: Economics of CO$_2$ storage and CO$_2$-EOR

- Develop model projects to evaluate sequestration and CO$_2$-EOR projects
- Focus on geologic storage
**Task 5**: Storage of CO$_2$ in unconventional geologic reservoirs
- Develop and publish maps of U.S. deep coal and shale units suitable for potential storage of CO$_2$

**Task 6**: Induced seismicity associated with CO$_2$ geologic storage
- Seismic monitoring at Decatur and FutureGen projects, IL

**Task 7**: Outreach
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

SUMMARY

- The USGS has completed an evaluation of the $T_A^{SR}$ for CO$_2$ for 36 sedimentary basins in the onshore areas and State waters of the United States. The mean assessment results are: $T_A^{SR} = 3,000$ 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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<tr>
<th>Name</th>
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<tbody>
<tr>
<td>Peter Warwick, Project Chief</td>
<td>Hossein Jahediesfanjani¹</td>
</tr>
<tr>
<td>Steve Anderson</td>
<td>Kevin Jones</td>
</tr>
<tr>
<td>Madalyn Blondes</td>
<td>Gary Lecain</td>
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<tr>
<td>Sean Brennan</td>
<td>Celeste Lohr</td>
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<td>Laurie Burke</td>
<td>Jennifer McIntosh</td>
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<td>Marc Buursink</td>
<td>Matthew Merrill</td>
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<td>Steven Cahan</td>
<td>Ricardo Olea</td>
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<td>Margo Corum</td>
<td>Phil Nelson</td>
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<td>William Craddock</td>
<td>Tina Roberts-Ashby</td>
</tr>
<tr>
<td>Christina DeVera</td>
<td>Jacqueline Roueche¹</td>
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<tr>
<td>Colin Doolan</td>
<td>Ernie Slucher</td>
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<tr>
<td>Ronald Drake II</td>
<td>Steve Suitt</td>
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<td>Lawrence Drew</td>
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<td>Joseph East</td>
<td>Amjad Umari</td>
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<tr>
<td>Philip Freeman</td>
<td>Brian Varela</td>
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<tr>
<td>Nickolas Gianoutsos</td>
<td>Mahendra Verma</td>
</tr>
<tr>
<td>Steve Hickman</td>
<td></td>
</tr>
</tbody>
</table>

¹Contractor
For more information contact:

Peter Warwick
pwarwick@usgs.gov
703-648-6469

Margo Corum
mcorum@usgs.gov
703-648-6488

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)
References


