



*Energy From the Earth*  
**Geologic Carbon Storage: Feasibility,  
Technology, and Challenges**

**Geological Requirements and Potential for  
Carbon Dioxide Storage in the United States**

July 18, 2014  
Washington, D.C.

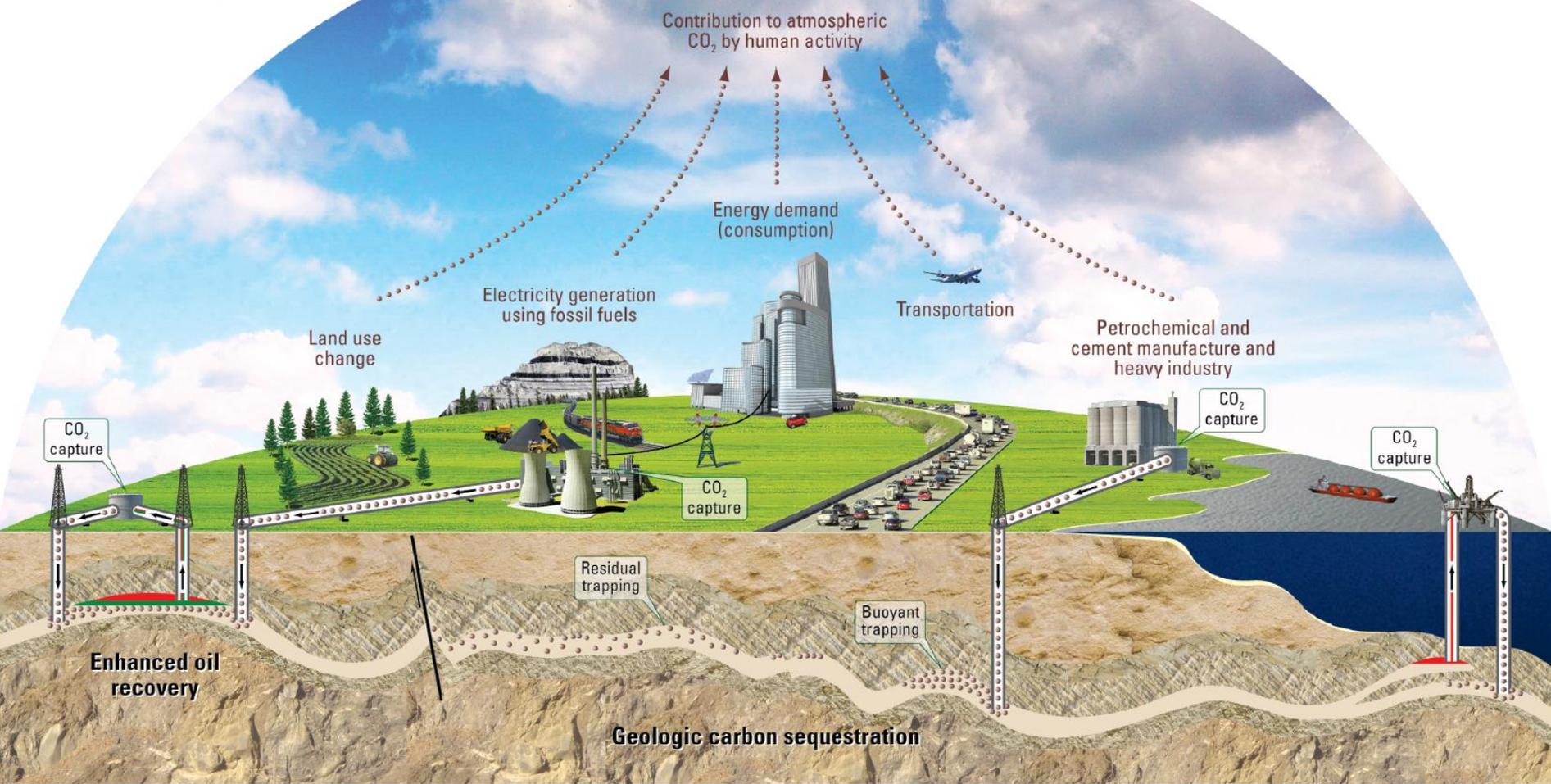
Peter D. Warwick  
**U.S. Geological Survey**  
**Department of the Interior**

# Outline for Presentation

- Overview of geologic carbon dioxide (CO<sub>2</sub>) storage
- How much CO<sub>2</sub> needs to be stored
- Geologic model for CO<sub>2</sub> storage
- USGS assessment results
- Discussion of results

# What is Geologic CO<sub>2</sub> Storage?

## The Concept of Geologic Carbon Sequestration



NOT TO SCALE

Illustration by Douglas W. Duncan and Eric A. Morrissey

### EXPLANATION

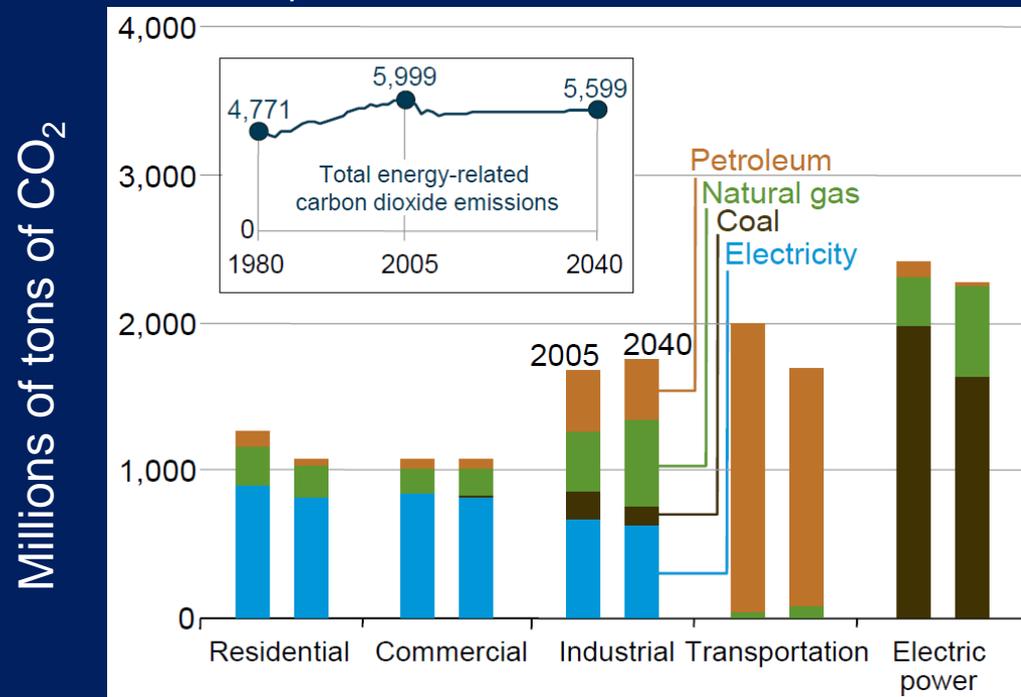
- CO<sub>2</sub> storage volume
- Gas flow
- Gas
- Seal formation
- CO<sub>2</sub> flow
- Oil and gas flow
- Oil
- Storage formation
- Fault—Arrow indicates relative movement

# How much CO<sub>2</sub> needs to be stored?

## Some examples illustrate the range:

- World: ~ 9.5 Gt carbon/year or ~ 35 Gt CO<sub>2</sub>/year (Peters and others, 2013)
- U.S. total all energy sectors in 2012 → ~ 5.2 Gt/year CO<sub>2</sub> (U.S. Energy Information Administration, 2013)
- Laramie River 2&3 PC plant 1100 MWe → 8.7 Mt/yr CO<sub>2</sub> 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)



## Large Stationary Sources of CO<sub>2</sub> in North America

### Facilities / Plants

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

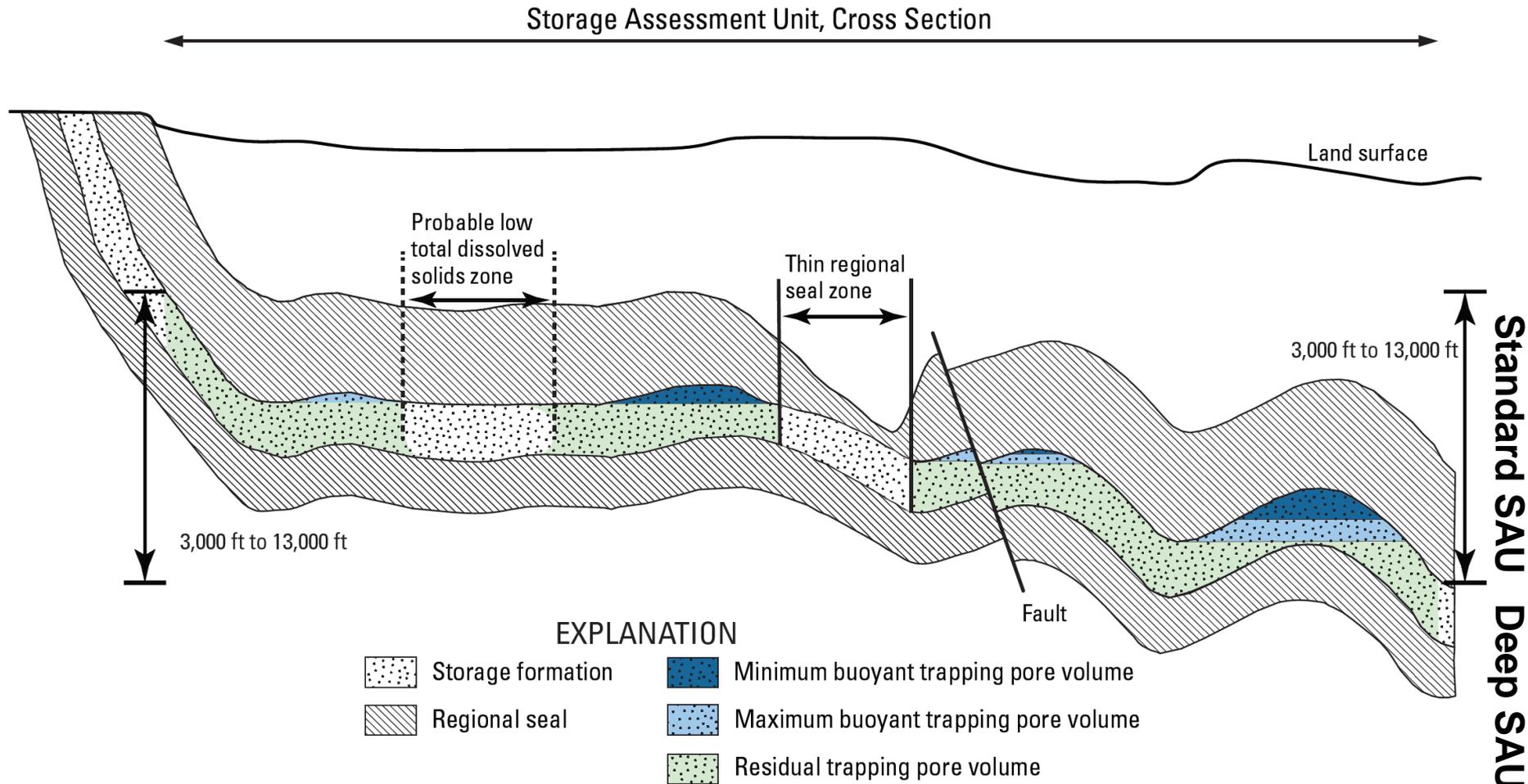
### Annual CO<sub>2</sub> Emissions (Tonnes)

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



0 255 510 1,020 Kilometers

# Geologic Model



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

# Assessment Resource Categories

1. **Buoyant trapping storage resource**: mass of CO<sub>2</sub> 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<sub>SR</sub>***)
2. **Residual trapping storage resource**: mass of CO<sub>2</sub> that can be stored by residual trapping in rocks
  - a) with permeability greater than 1 darcy (***R1<sub>SR</sub>***)
  - b) with permeability between 1 millidarcy and 1 darcy (***R2<sub>SR</sub>***)
  - c) with permeability less than 1 millidarcy (***R3<sub>SR</sub>***)

---

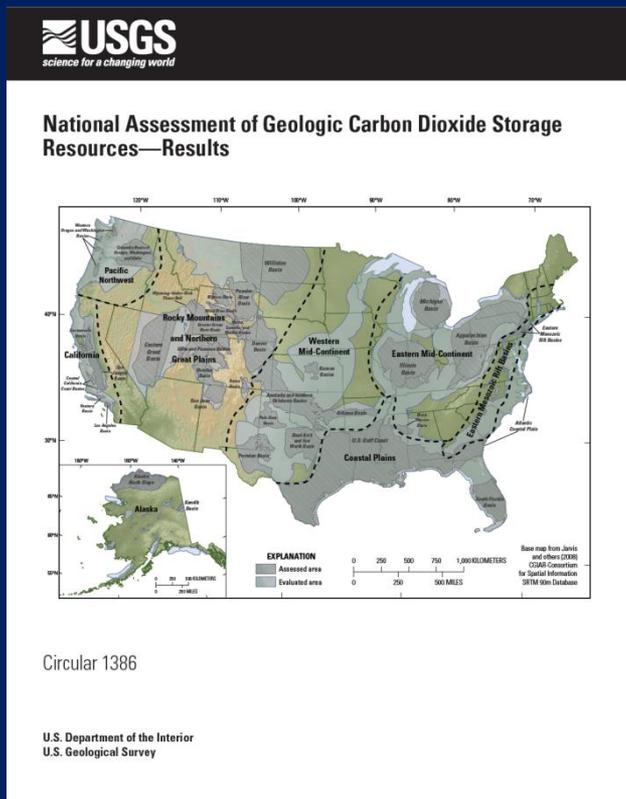
---

**TOTAL = Technically accessible storage resource**: total mass of CO<sub>2</sub> that can be stored in the storage assessment unit (***TA<sub>SR</sub>***)

1. **Known recovery replacement storage resource**: mass of CO<sub>2</sub> that can be stored in existing producing hydrocarbon reservoirs (***KRR<sub>SR</sub>***)

# USGS National Assessment of Geologic Carbon Dioxide Storage Resources

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

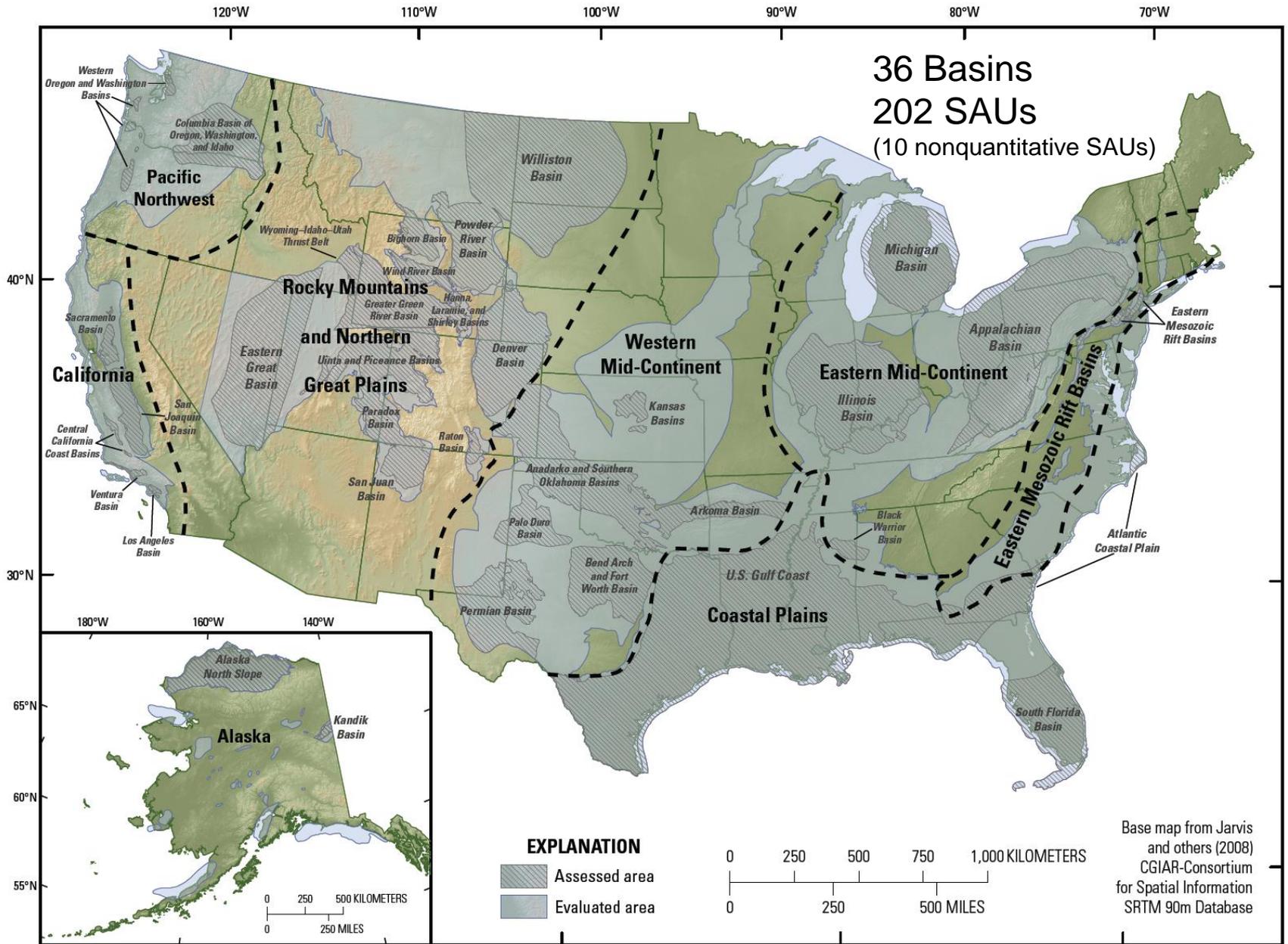


Three companion assessment reports:

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/>



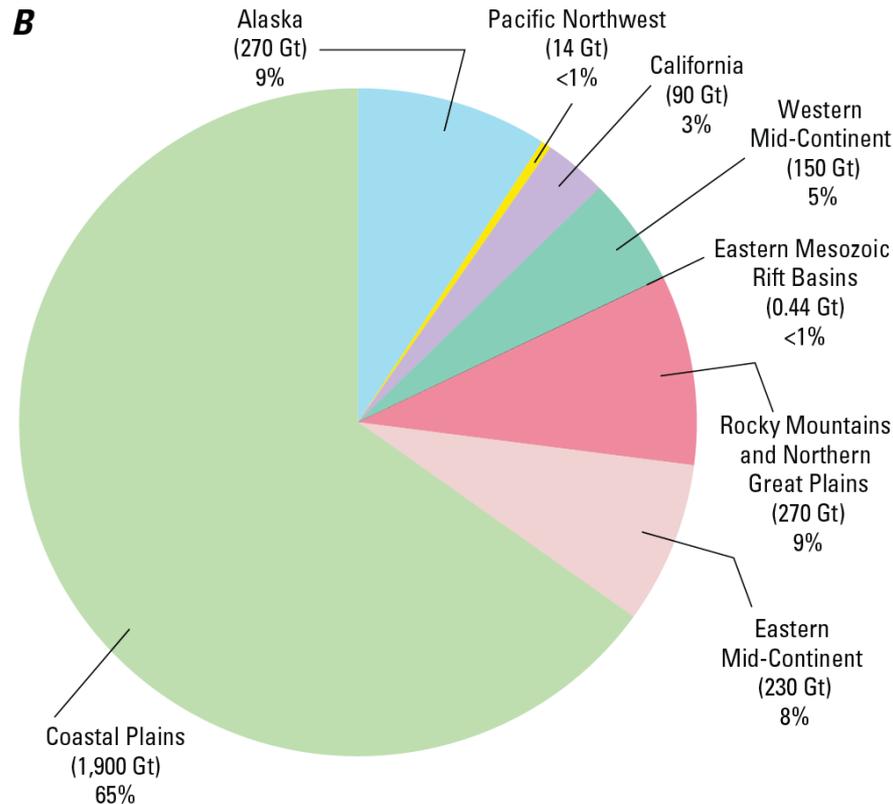
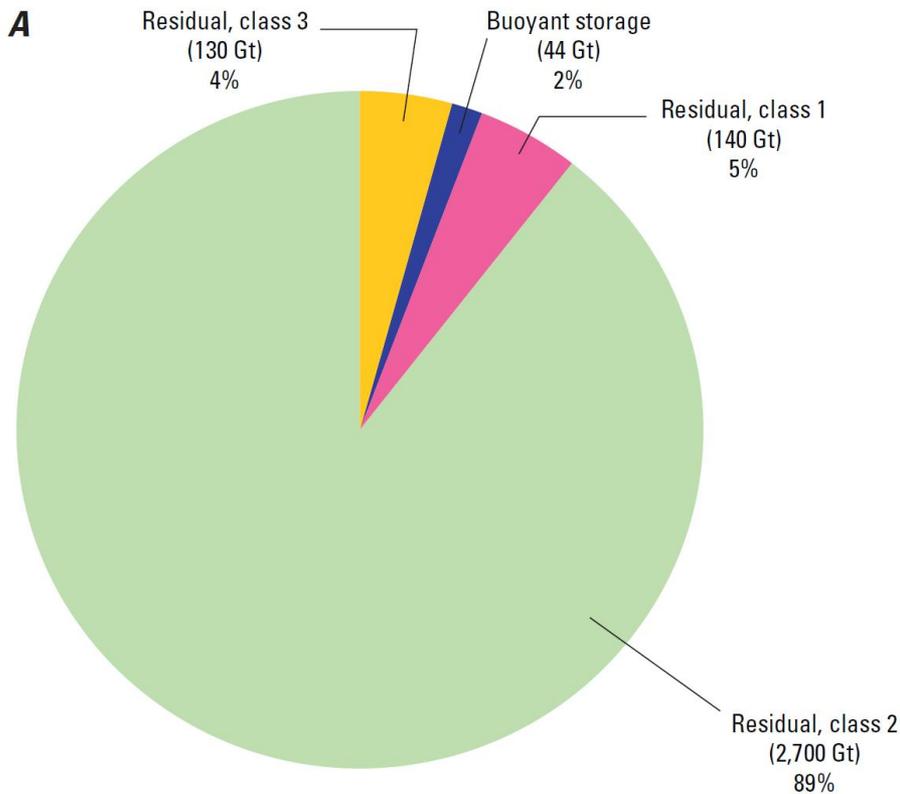
# Results of the Assessment

Estimates of national totals for technically accessible storage resources ( $TA_{SR}$ ) for CO<sub>2</sub> in the United States by resource type and class

CO <sub>2</sub> storage resource type and class		P <sub>5</sub>	P <sub>50</sub>	P <sub>95</sub>	Mean
Symbol	Name				
<b>Storage resource estimated from geologic models</b>					
$B_{SR}$	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
<b>Storage resource estimated from petroleum production volumes</b>					
$KRR_{SR}$	Known recovery replacement storage resource	11	13	15	13

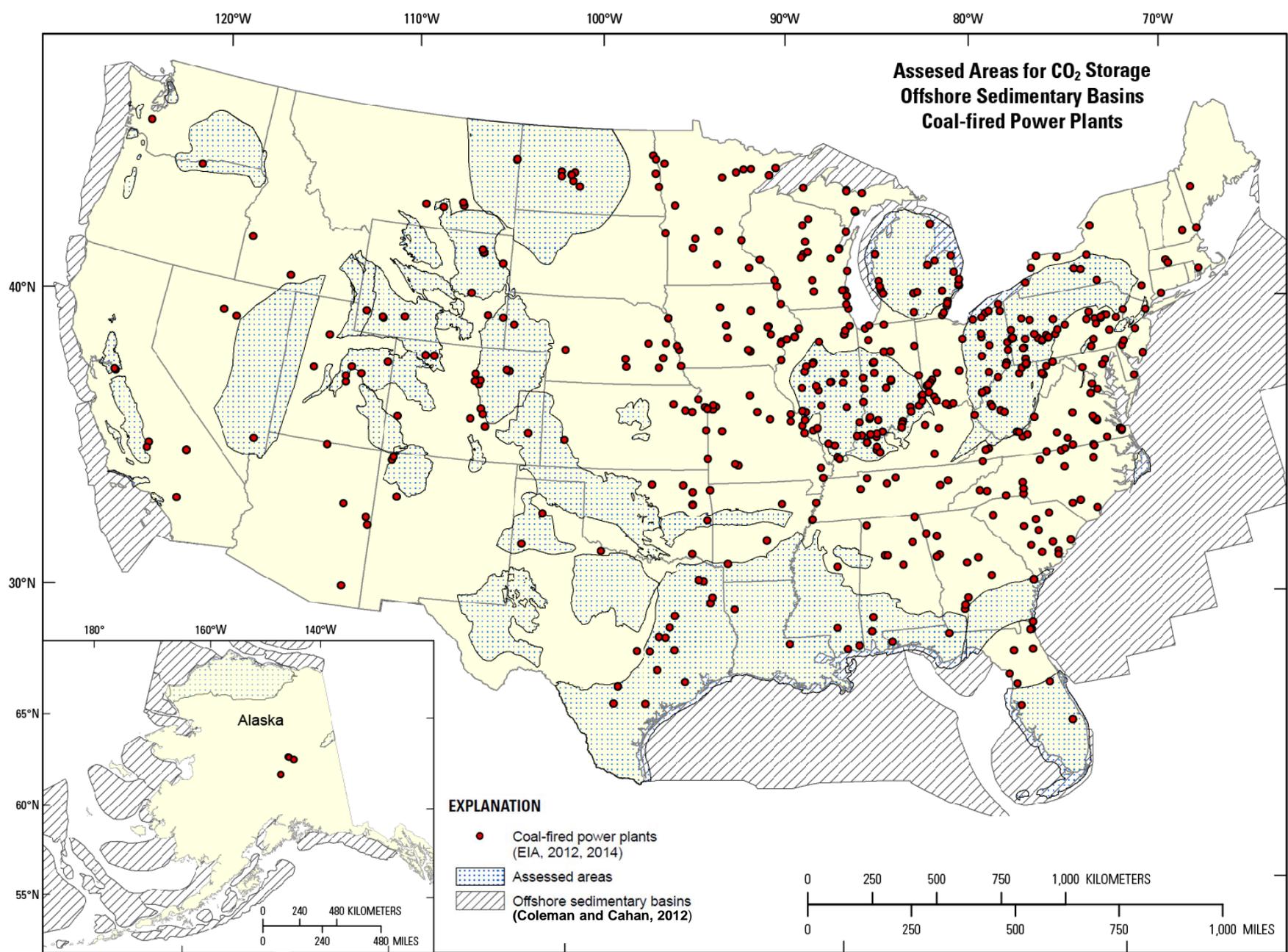
Estimates are in billions of metric tons (gigatons, Gt); mean values sum to totals but all values are reported to only two significant figures.

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



Most (89 %) 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 Alaska (mostly North Slope)



# Conclusions

- The total geologic storage resources for CO<sub>2</sub> in the United States are large (3,000 Gt), and both types (buoyant and residual) will probably be needed to store anthropogenic CO<sub>2</sub>
- The U.S. Energy Information Administration (2013) estimated that the 2012 national energy-related CO<sub>2</sub> emissions were 5.2 Gt. The mean estimate by the USGS of the technically accessible geologic storage resource ( $TA_{SR}$ ) for CO<sub>2</sub> in the United States is 3,000 Gt, which is more than 500 times the annual energy-related CO<sub>2</sub> emissions
- Industrial sources of CO<sub>2</sub> emissions are not always near onshore areas that have potential for geologic CO<sub>2</sub> storage. Major CO<sub>2</sub> transport infrastructure (pipelines) will be needed if carbon storage technology is utilized across the country. Offshore storage areas may need to be utilized

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 CO<sub>2</sub> project website)

<http://pubs.usgs.gov/ds/774/> (USGS CO<sub>2</sub> storage assessment data)

<http://pubs.usgs.gov/circ/1386/> (USGS CO<sub>2</sub> storage assessment results)

<http://pubs.usgs.gov/fs/2013/3020/> (USGS CO<sub>2</sub> storage assessment summary)

# References

- Blondes, M.S., Brennan, S.T., Merrill, M.D., Buursink, M.L., Warwick, P.D., Cahan, S.M., Cook, T.A., Corum, M.D., Craddock, W.H., DeVera, C.A., Drake, R.M., II, Drew, L.J., Freeman, P.A., Lohr, C.D., Olea, R.A., Roberts-Ashby, T.L., Slucher, E.R., and Varela, B.A., 2013, National assessment of geologic carbon dioxide storage resources—Methodology implementation: U.S. Geological Survey Open-File Report 2013–1055, 26 p., available online at <http://pubs.usgs.gov/of/2013/1055/>.
- Brennan, S.T., and Burruss, R.C., 2006, Specific storage volumes-A useful tool for CO<sub>2</sub> storage capacity assessment: *Natural Resources Research*, v. 15, no. 3, p. 165-182, DOI: 10.1007/s11053-006-9019-0.
- Brennan, S.T., Burruss, R.C., Merrill, M.D., Freeman, P.A., and Ruppert, L.F., 2010, A probabilistic assessment methodology for the evaluation of geologic carbon dioxide storage: U.S. Geological Survey Open-File Report 2010–1127, 31 p., available online at <http://pubs.usgs.gov/of/2010/1127>.
- Coleman, J.L., Jr., and Cahan, S.M., 2012, Preliminary catalog of the sedimentary basins of the United States: U.S. Geological Survey Open-File Report 2012–1111, 27 p. (plus 4 figures and 1 table available as separate files) Available online at <http://pubs.usgs.gov/of/2012/1111/>.
- Duncan, D.W., and Morrissey, E.A., 2011, The concept of geologic carbon sequestration: U.S. Geological Survey Fact Sheet 2010-3122, 2 p., available online at <http://pubs.usgs.gov/fs/2010/3122/>.
- Jarvis, A., Reuter, H.I., Nelson, Andrew, and Guevara, Edward, 2008, Hole-filled SRTM [Shuttle Radar Topographic Mission] for the globe, version 4: available from the CGIAR [Consultative Group for International Agricultural Research]-Consortium for Spatial Information SRTM 90m Database; Jarvis, A., Reuter, H.I., Nelson, Andrew, and Guevara, Edward, 2008, Hole-filled SRTM [Shuttle Radar Topographic Mission] for the globe, version 4: available from the CGIAR [Consultative Group for International Agricultural Research]-Consortium for Spatial Information SRTM 90m Database; available online at <http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1#acknowledgements>.
- North American Carbon Atlas Partnership, 2012, The North American carbon storage atlas (1st ed.): U.S. Department of Energy, National Energy Technology Laboratory, 52 p., available online at [http://www.netl.doe.gov/technologies/carbon\\_seq/refshelf/NACSA2012.pdf](http://www.netl.doe.gov/technologies/carbon_seq/refshelf/NACSA2012.pdf).
- Peters, G.P., Andrew, R.M., Boden, Tom, Canadell, J.G., Ciais, Philippe, Le Quééré, Corinne, Marland, Gregg, Raupach, M.R., and Wilson, Charlie, 2013, The challenge to keep global warming below 2 °C: *Nature Climate Change*, v. 3, p. 4-6, doi:10.1038/nclimate1783 [may require subscription to access].
- U.S. Energy Information Agency, 2012, Form EIA-860 detailed data: Annual electricity generator data, <http://www.eia.gov/electricity/data/eia860/>.
- U.S. Energy Information Administration, 2014, Annual energy outlook 2014 with projections to 2040: U.S. Energy Information Administration [Report] DOE/EIA-0383(2014), ES1 – G1 p., accessed June 4, 2014, at [http://www.eia.gov/forecasts/aeo/pdf/0383\(2014\).pdf](http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf).
- U.S. Energy Information Agency, 2014, Form EIA-923 detailed data: Annual electricity utility data, available online at <http://www.eia.gov/electricity/data/eia923/>.
- U.S. Energy Information Administration, 2013, U.S. energy-related carbon dioxide emissions, 2012: U.S. Energy Information Administration Web site, accessed June 4, 2014, at [http://www.eia.gov/environment/emissions/carbon/pdf/2012\\_co2analysis.pdf](http://www.eia.gov/environment/emissions/carbon/pdf/2012_co2analysis.pdf).
- U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013a, National assessment of geologic carbon dioxide storage resources—Data: U.S. Geological Survey Data Series 774, 13 p., plus 2 appendixes and 2 large tables in separate files, available online at <http://pubs.usgs.gov/ds/774/>.
- U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013b, National assessment of geologic carbon dioxide storage resources—Results: U.S. Geological Survey Circular 1386, 41 p., available online at <http://pubs.usgs.gov/circ/1386/>.
- U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013c, National assessment of geologic carbon dioxide storage resources—Summary: U.S. Geological Survey Fact Sheet 2013–3020, 6 p., available online at <http://pubs.usgs.gov/fs/2013/3020/>.