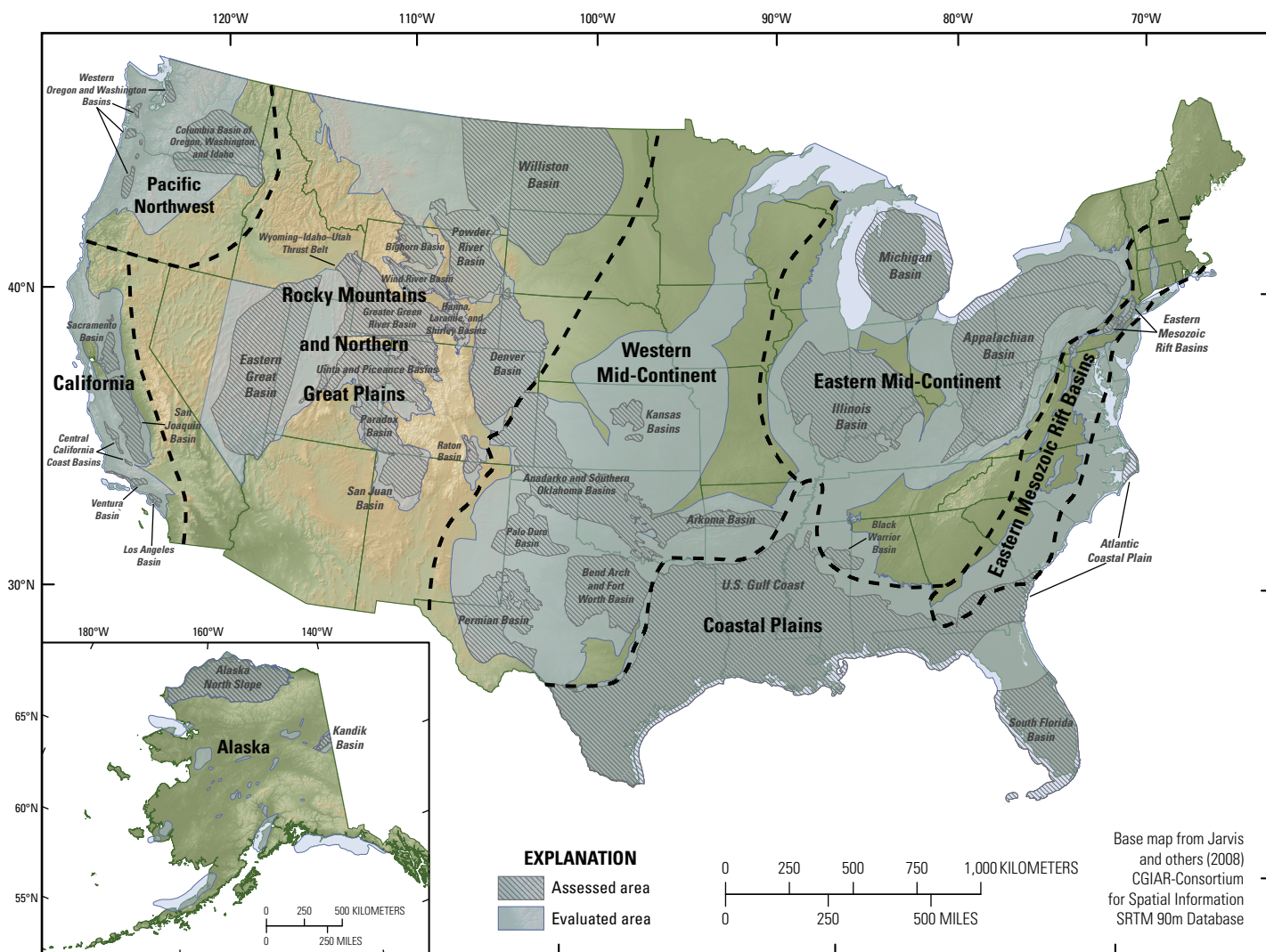


National Assessment of Geologic Carbon Dioxide Storage Resources—Results



Circular 1386
Version 1.1, September 2013

Cover. Map of the conterminous United States and Alaska showing 8 regions (separated by bold dashed lines and labeled in a bold font), evaluated areas (bluish gray) that were not assessed, and 36 areas (pattern) that were assessed by the U.S. Geological Survey for carbon dioxide storage. See figure 2.

National Assessment of Geologic Carbon Dioxide Storage Resources— Results

By U.S. Geological Survey Geologic Carbon Dioxide Storage Resources
Assessment Team

Circular 1386
Version 1.1, September 2013

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

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

Acknowledgments.....	iii
Members of the U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team	iv
Abstract.....	1
Introduction.....	1
Storage Assessment Units.....	3
Study Areas.....	3
Buoyant and Residual Trapping.....	8
Assessment Categories	9
Data Sources.....	9
Assessment Process.....	9
Assessment Assumptions and Constraints.....	9
Resource Calculations.....	10
Aggregation	11
Results of the Assessment of Technically Accessible Storage Resources.....	12
Buoyant Trapping Storage.....	12
Residual Trapping Storage	12
Petroleum Reservoirs.....	12
Discussion of Results	12
Comparison of Results with Findings from Previous Assessments	17
Conclusions.....	17
References Cited.....	18
Glossary.....	21

Figures

1. Pie charts showing mean estimates by the U.S. Geological Survey in 2012 of technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States by (A) type and class and (B) region.....3
2. Map of the conterminous United States and Alaska showing 8 regions (separated by bold dashed lines and labeled in a bold font), evaluated areas (bluish gray) that were not assessed, and 36 areas (pattern) that were assessed by the U.S. Geological Survey for carbon dioxide (CO_2) storage.....4
3. Graph showing the range estimated by the U.S. Geological Survey in 2012 for the technically accessible storage resource (TA_{SR}) for carbon dioxide (CO_2) in each assessed basin in the United States.....5
4. Schematic cross section through a storage assessment unit (SAU) illustrating the relation between buoyant and residual trapping types in the storage formation (SF)8
5. Flow diagram of the key steps for calculating known recovery replacement storage resources (KRR_{SR}), buoyant trapping storage resources (B_{SR}), residual trapping storage resources ($R1_{SR}$, $R2_{SR}$, $R3_{SR}$), and technically accessible storage resources (TA_{SR}).....11

6. Graphs showing empirical cumulative distribution function (CDF) plots of all six categories of technically accessible storage resources (TA_{SR}) for carbon dioxide in the United States, exclusive of federally owned offshore areas	13
7. Pie charts showing mean estimates of technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in selected regions of the United States	14
8. Pie charts showing mean estimates of (A) buoyant trapping storage resources and (B) residual trapping class 2 storage resources for carbon dioxide (CO_2) in the United States, by region.....	16

Tables

1. Estimates by the U.S. Geological Survey in 2012 of national totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States by resource type and class.....	2
2. Estimates by the U.S. Geological Survey in 2012 of basin and regional totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States	6
3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.....	25
4. Mean estimates by the U.S. Geological Survey in 2012 for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in deep storage assessment units (SAUs) in the United States.....	17

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square inch (in²)	6.452	square centimeter (cm²)
	Volume	
gallon (gal)	3.785	liter (L)
barrel (bbl), (petroleum, 1 barrel = 42 gal)	0.1590	cubic meter (m³)
cubic foot (ft³)	0.02832	cubic meter (m³)
liter (L)	0.2642	gallon (gal)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton, long (2,240 lb)	1.016	megagram (Mg)
milligram (mg)	0.00003527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound, avoirdupois (lb)
megagram (Mg) = 1 metric ton (t) (1,000 kg)	1.102	ton, short (2,000 lb)
megagram (Mg)	0.9842	ton, long (2,240 lb)
million metric tons = megaton (Mt)	1.102	million short tons
billion metric tons = gigaton (Gt)	1.102	billion short tons
	Pressure	
bar	100	kilopascal (kPa)
pound-force per square inch (lbf/in² or psi)	6.895	kilopascal (kPa)
kilopascal (kPa)	0.01	bar
kilopascal (kPa)	0.1450	pound-force per square inch (lbf/in²)
	Pressure gradient	
pound-force per square inch per foot (lbf/in²/ft or psi/ft)	22.62	kilopascal per meter (kPa/m)

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Permeability is given in darcies (D) and millidarcies (mD).

1 barrel of oil equivalent (BOE) = 1 barrel of crude oil (42 gallons)
= 6,000 cubic feet of natural gas
= 1.5 barrels of natural gas liquids

Abbreviations, Acronyms, and Symbols

A_{SF}	area of the storage formation within the storage assessment unit
B_{PV}	buoyant trapping pore volume
B_{SE}	buoyant trapping storage efficiency
B_{SR}	buoyant trapping storage resource
B_{SV}	buoyant trapping storage volume
bbl	petroleum barrel or barrels
BOE	barrel of oil equivalent
BOEM	Bureau of Ocean Energy Management
CDF	cumulative distribution function
CO ₂	carbon dioxide
D	darcy
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FVF	formation volume factor
GOR	gas:oil ratio
Gt	gigaton = billion metric tons
k	permeability
KR_{RES}	known recovery production volumes converted to reservoir conditions
KRR_{SR}	known recovery replacement storage resource
LCU	Lower Cretaceous unconformity
mD	millidarcy
Mt	megaton = million metric tons
NETL	National Energy Technology Laboratory
NOGA	USGS National Oil and Gas Assessment
NQ	nonquantitative
P_5	probability percentile—5-percent probability that the true value is less than the given value
P_{50}	probability percentile—50-percent probability that the true value is less than the given value. P_{50} is the median of the probability distribution.
P_{95}	probability percentile—95-percent probability that the true value is less than the given value
psi	pound-force per square inch

R_{PV}	residual trapping pore volume
R_W	the area fraction of the SAU available for storage after consideration of EPA water-quality guidelines or highly fractured seals
$R1_{PV}$	residual trapping class 1 pore volume
$R1_{SE}$	residual trapping class 1 storage efficiency
$R1_{SR}$	residual trapping class 1 storage resource
$R1_{SV}$	residual trapping class 1 storage volume
$R2_{PV}$	residual trapping class 2 pore volume
$R2_{SE}$	residual trapping class 2 storage efficiency
$R2_{SR}$	residual trapping class 2 storage resource
$R2_{SV}$	residual trapping class 2 storage volume
$R3_{PV}$	residual trapping class 3 pore volume
$R3_{SE}$	residual trapping class 3 storage efficiency
$R3_{SR}$	residual trapping class 3 storage resource
$R3_{SV}$	residual trapping class 3 storage volume
R_i	residual trapping injectivity classes 1, 2, or 3
R_{iSE}	residual trapping storage efficiencies for classes 1, 2, or 3
SAU	storage assessment unit used in this assessment
SF	storage formation
SF_{PV}	storage formation pore volume
T_{PI}	thickness of the net porous interval
TA_{SR}	technically accessible storage resource
TA_{SV}	technically accessible storage volume
TDS	total dissolved solids
TPS	total petroleum system
USDW	underground source of drinking water
USGS	U.S. Geological Survey
ρ_{CO_2}	density of carbon dioxide
ϕ	porosity
ϕ_{PI}	porosity of the net porous interval

National Assessment of Geologic Carbon Dioxide Storage Resources—Results

By U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team

Abstract

In 2012, the U.S. Geological Survey (USGS) completed an assessment of the technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in geologic formations underlying the onshore and State waters area of the United States. The formations assessed are at least 3,000 feet (914 meters) below the ground surface. The TA_{SR} is an estimate of the CO_2 storage resource that may be available for CO_2 injection and storage that is based on present-day geologic and hydrologic knowledge of the subsurface and current engineering practices. Individual storage assessment units (SAUs) for 36 basins were defined on the basis of geologic and hydrologic characteristics outlined in the assessment methodology of Brennan and others (2010, USGS Open-File Report 2010–1127) and the subsequent methodology modification and implementation documentation of Blondes, Brennan, and others (2013, USGS Open-File Report 2013–1055). The mean national TA_{SR} is approximately 3,000 metric gigatons (Gt). The estimate of the TA_{SR} includes buoyant trapping storage resources (B_{SR}), where CO_2 can be trapped in structural or stratigraphic closures, and residual trapping storage resources, where CO_2 can be held in place by capillary pore pressures in areas outside of buoyant traps. The mean total national B_{SR} is 44 Gt. The residual storage resource consists of three injectivity classes based on reservoir permeability: residual trapping class 1 storage resource ($R1_{SR}$) represents storage in rocks with permeability greater than 1 darcy (D); residual trapping class 2 storage resource ($R2_{SR}$) represents storage in rocks with moderate permeability, defined as permeability between 1 millidarcy (mD) and 1 D; and residual trapping class 3 storage resource ($R3_{SR}$) represents storage in rocks with low permeability, defined as permeability less than 1 mD. The mean national storage resources for rocks in residual trapping classes 1, 2, and 3 are 140 Gt, 2,700 Gt, and 130 Gt, respectively. The known recovery replacement storage resource (KRR_{SR}) is a conservative estimate that represents only the amount of CO_2 at subsurface conditions that could replace the volume of known hydrocarbon production. The mean national KRR_{SR} , determined from production volumes rather than the geologic model of buoyant and residual traps that make up TA_{SR} , is 13 Gt. The estimated storage

resources are dominated by residual trapping class 2, which accounts for 89 percent of the total resources. The Coastal Plains Region of the United States contains the largest storage resource of any region. Within the Coastal Plains Region, the resources from the U.S. Gulf Coast area represent 59 percent of the national CO_2 storage capacity.

Introduction

Carbon dioxide (CO_2) is the primary greenhouse gas that is contributing to recent global climate change, and fossil fuel combustion is a major source of CO_2 emissions to the atmosphere (Intergovernmental Panel on Climate Change, 2001; U.S. Environmental Protection Agency, 2013). The U.S. Energy Information Administration (2012a,b) estimated that the annual energy-related CO_2 emissions in the United States during 2011 were 5.5 billion metric tons (gigatons, Gt) and projected that fossil fuel combustion will supply the dominant portion of total global energy demand in both industrialized and developing countries for the next few decades. The overall reduction of CO_2 emissions will likely involve some combination of technologies, but for the immediate future, industrial capture and sequestration (storage) of CO_2 in geologic reservoirs is an available technology because existing knowledge derived from the oil and gas production industries has helped to solve some of the major engineering challenges. A detailed estimate of the national geologic CO_2 storage resources is required to make informed decisions about the implementation of geologic CO_2 sequestration in the United States.

In 2007, the Energy Independence and Security Act (Public Law 110–140; U.S. Congress, 2007) directed the U.S. Geological Survey (USGS) to conduct a national assessment of geologic storage resources for CO_2 in consultation with the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), and State geological surveys. From 2008 to 2009, the USGS developed a preliminary methodology to estimate storage resource potential that may be applied uniformly to geologic formations across the United States (Burruss and others, 2009). This methodology was reviewed by the public and a panel of experts, and revisions

2 National Assessment of Geologic Carbon Dioxide Storage Resources—Results

were incorporated into a final assessment methodology by Brennan and others (2010). During the implementation phase of the assessment (from 2010 to 2012), several practical steps were added to the assessment methodology of Brennan and others (2010). The details of the methodology used in the assessment are described in Blondes, Brennan, and others (2013).

The purpose of this report is to present the results of the USGS national assessment of geologic CO₂ storage resources, which was completed in 2012 (table 1; fig. 1A,B). The goal of this project was to conduct an initial assessment of storage capacity on a regional basis, and results are not intended for use in the evaluation of specific sites for potential CO₂ storage. The national assessment is a geology-based examination of all sedimentary basins in the onshore and State waters area of the United States that contain storage assessment units (SAUs) that could be defined following the methodology outlined in Brennan and others (2010) and Blondes, Brennan, and others (2013) (figs. 2, 3; table 2). Although geologic storage of CO₂ may be possible in some areas not assessed by the USGS, the SAUs identified in this assessment represent those areas within sedimentary basins that met the assessment criteria. A geologic description of each SAU was prepared during the assessment; descriptions of SAUs in several basins are in the basin report series, “Geologic Framework for the National Assessment of Carbon Dioxide Storage Resources,” edited by Warwick and Corum (2012).

Two other reports are being published with this assessment results report, and the reader should refer to them for additional information. The U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team’s (2013a) data report contains (1) individual SAU assessment forms with all input parameters and details on the allocation of the SAU surface land area by State and general land-ownership category; (2) figures representing the distribution of all storage classes for each SAU; (3) a comprehensive data table containing most input data and assessment result values for each SAU, and (4) a pairwise correlation matrix specifying geological and methodological dependencies between SAUs that are needed for aggregation of results. The U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team’s (2013b) Fact Sheet summarizes the final results of this assessment.

This assessment does not include an estimate of the CO₂ storage potential in “unmineable coal seams” because no standard definition indicates which coal seams are unmineable (Brennan and others, 2010). Nor does this assessment include estimates of the potential for CO₂ storage in unconventional or continuous reservoirs such as shale, low-permeability “tight” sandstone, or basaltic rocks. Little is known about the large-scale CO₂ storage potential in these unconventional reservoirs, and USGS assessment methodologies still need to be developed to address these types of resources (Jones and others, 2012).

Table 1. Estimates by the U.S. Geological Survey in 2012 of national totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO₂) in the United States by resource type and class.

[Estimates are in billions of metric tons (gigatons, Gt). P_5 , P_{50} , and P_{95} are probability percentiles and represent the 5-, 50-, and 95-percent probabilities, respectively, that the true storage resource is less than the value shown. The terminology used in this report differs from that used by the petroleum industry and follows standard statistical practice (for example, Everitt and Skrondal, 2010), where percentiles, or fractiles, represent the value of a variable below which a certain proportion of observations falls. The percentiles were calculated by using the aggregation method described in the “Aggregation” section of this report and in Blondes, Schuenemeyer, and others (2013). Percentile values do not sum to totals because the aggregation procedure used partial dependencies between storage assessment units. The P_{50} (median) values are generally less than mean values because most output distributions are right skewed. The known recovery replacement storage resource (KRR_{SR}) is listed separately as determined from petroleum production volumes; the same type of resource is also included in the buoyant storage type estimated from a geologic model. Mean values sum to totals but are reported to only two significant figures]

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

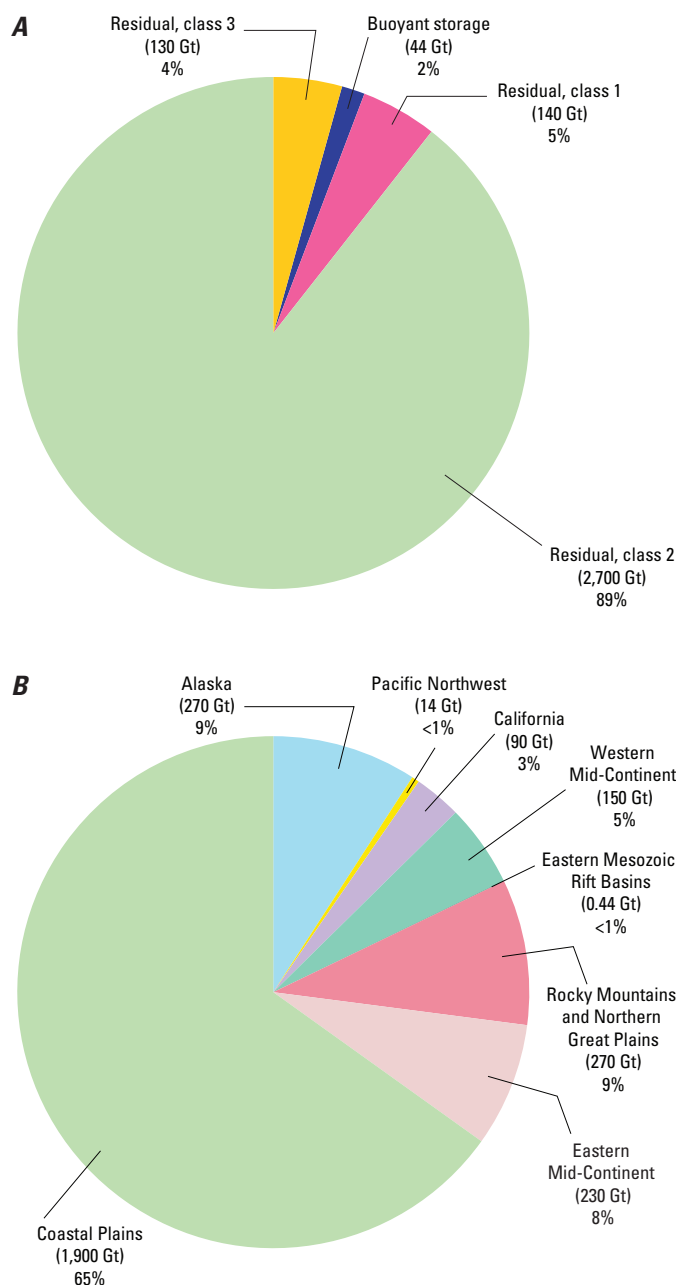


Figure 1. Pie charts showing mean estimates by the U.S. Geological Survey in 2012 of technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States by (A) type and class and (B) region. Resources were estimated for eight geographic regions shown in figure 2. A mean total of 3,000 metric gigatons (Gt) of storage resources was estimated to exist in buoyant and residual storage types. The known recovery replacement storage resource (KRR_{SR}) is not shown in part A but is included in the buoyant storage type. Resources in federally owned offshore areas were not assessed. Mean values sum to totals but are reported to only two significant figures. Percentages were calculated from unrounded resource estimates.

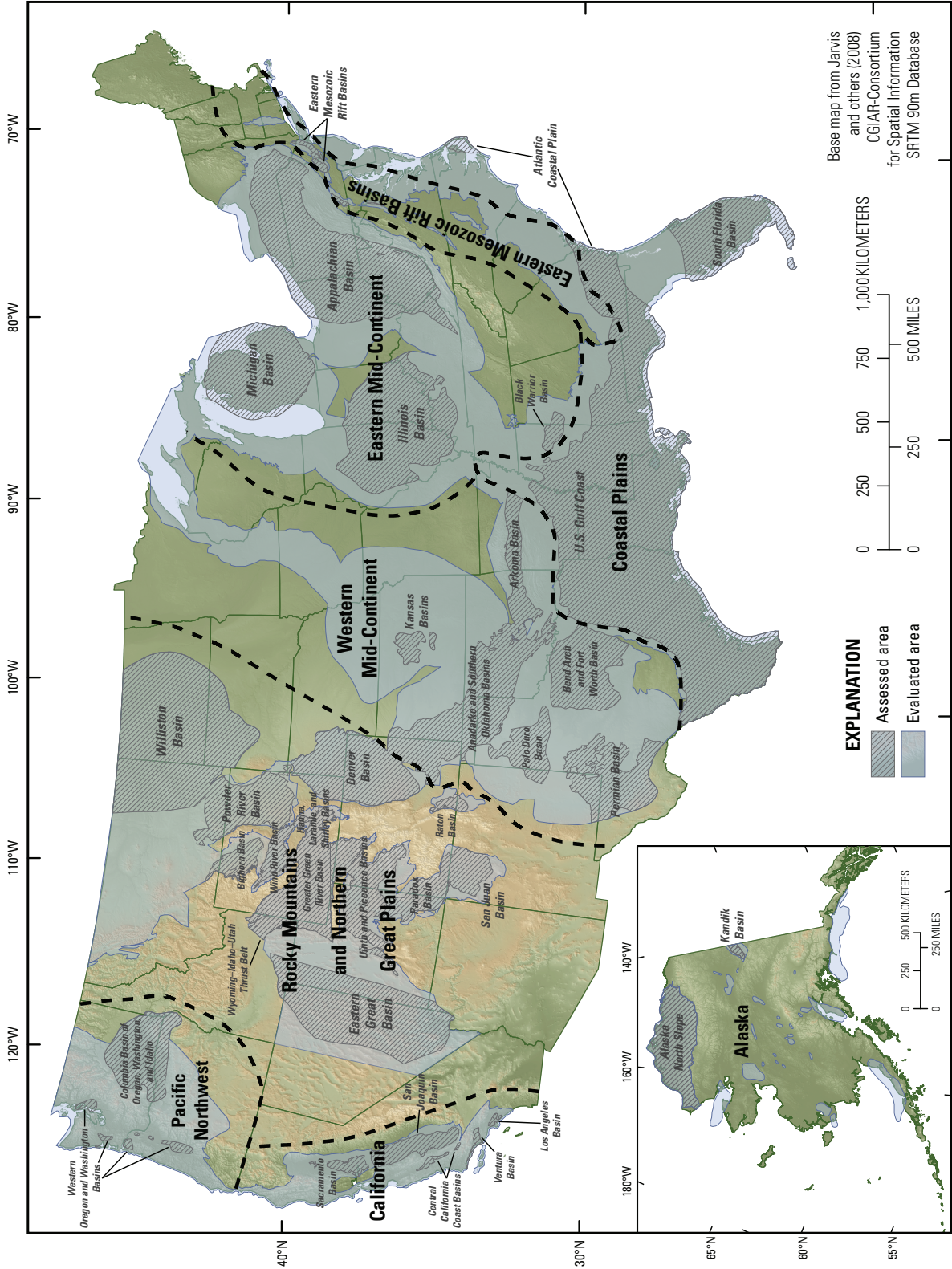
Storage Assessment Units

The SAU is a mappable volume of rock that consists of a porous reservoir and a bounding regional sealing formation (Brennan and others, 2010). Within the SAU, the porous reservoir is defined as the storage formation (SF). A schematic cross section that extends downdip through a hypothetical SAU is shown in figure 4. The parts of the SF that contain buoyant trapping storage resources and residual trapping storage resources are shown in color (fig. 4).

The extent of the SF is defined, in part, by the physical properties of CO_2 . The upper vertical limit chosen by Brennan and others (2010) for this assessment was 3,000 feet (914 meters) because CO_2 at this depth is typically subjected to temperatures and pressures that maintain the CO_2 in a supercritical state and maximize the storage resource per unit volume. Supercritical CO_2 has density values much higher than those of gaseous CO_2 (Lemmon and others, 2009). The lower vertical limit for the SAU of 13,000 ft (3,962 m) is based on the potential CO_2 injection depth at pipeline pressures without additional compression at the surface. The rationale for these limits was discussed in more detail by Burruss and others (2009). All SAUs between depths of 3,000 ft (914 m) and 13,000 ft (3,962 m) are referred to as *standard SAUs*. If reservoir rock properties suggested that a viable storage resource is present at depths below 13,000 ft (3,962 m), the assessment geologist may have added an additional *deep SAU* for this deeper reservoir. The areal extent of the SAU on a map is defined by contours showing depths from the surface to the top of the SF.

Study Areas

Sedimentary rocks of deep saline formations and of existing oil and gas fields were evaluated. Specifically, 33 sedimentary basins, or combined basin areas, within 8 regions of the United States were assessed (fig. 1B, table 2). Numerous other basins (study areas shown in bluish gray in fig. 2) were evaluated but not assessed because existing geologic conditions and available data indicated that the areas failed to meet the minimum requirements for CO_2 storage as outlined in Brennan and others (2010). Within the assessed basins, a total of 202 SAUs (table 3, at back of report) were identified as having good storage potential because of the presence of a robust regional seal, adequate reservoir rock, and sufficient areas containing saline formation waters. Ten of the SAUs did not have sufficient data to build a robust geologic model to accurately estimate the storage resource and were designated as nonquantitative SAUs (table 3). No storage resources were estimated for the 10 nonquantitative SAUs; surficial geographic boundaries were defined and geologic descriptions were prepared.



(SAUs). Resources in federally owned offshore areas were not assessed, and Hawaii was considered unlikely to have significant storage resources. Regions and study areas are plotted over a shaded-relief image showing higher elevations in brown and tan and lower elevations in green.

Figure 2. Map of the conterminous United States and Alaska showing 8 regions (separated by bold dashed lines and labeled in a bold font), evaluated areas (bluish gray) that were not assessed, and 36 areas (pattern) that were assessed by the U.S. Geological Survey for carbon dioxide (CO₂) storage. The assessed areas contain multiple storage assessment units

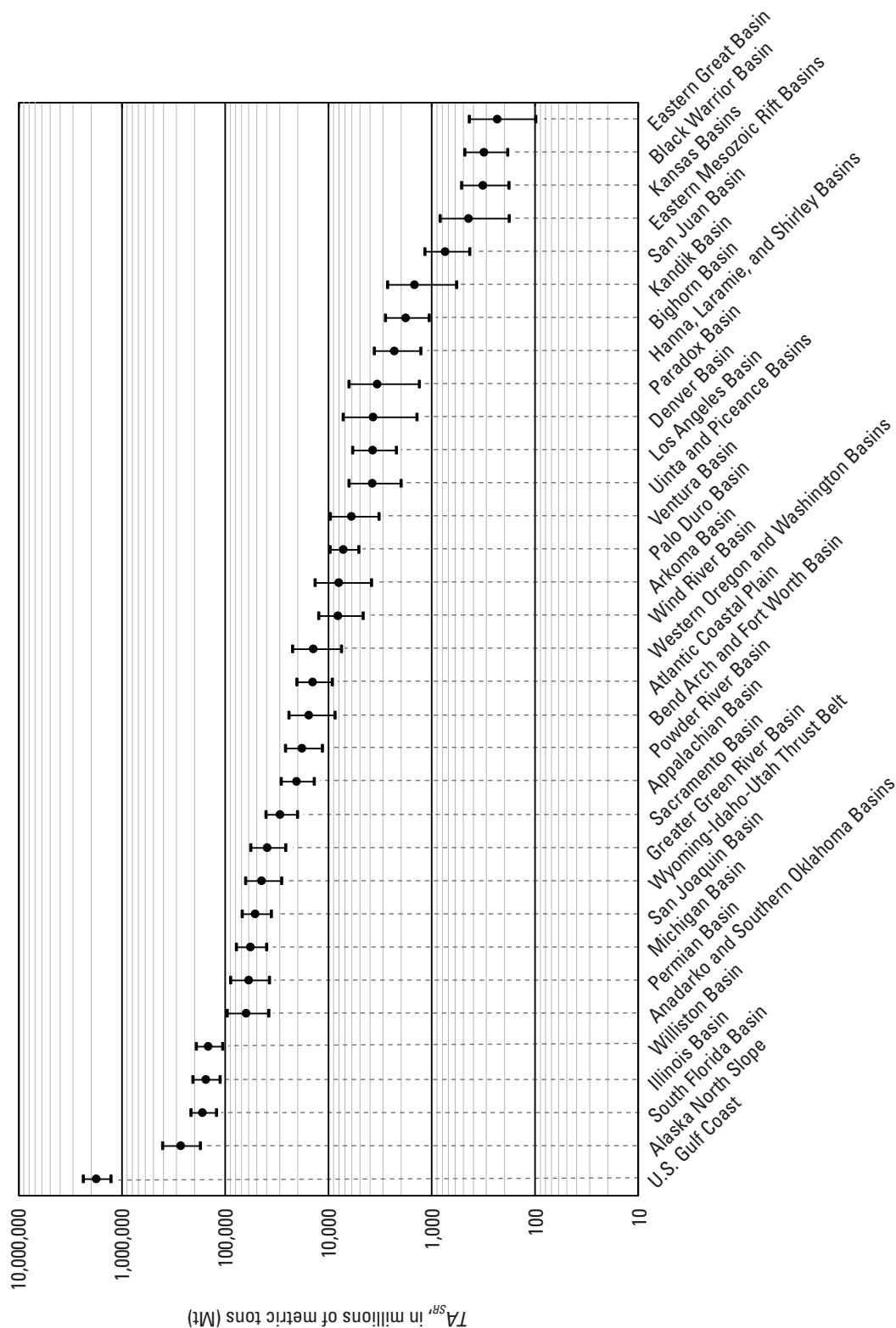


Figure 3. Graph showing the range estimated by the U.S. Geological Survey in 2012 for the technically accessible storage resource (TA_{SR}) for carbon dioxide (CO_2) in each assessed basin in the United States. Estimates are in millions of metric tons (Mt). Each center dot represents the mean storage resource. The lower bound is the P_5 percentile, representing a

5-percent probability that the true storage resource is less than the value shown. The upper bound is the P_{95} percentile, representing a 95-percent probability that the true storage resource is less than the value shown. Values are presented on a logarithmic scale. Basins are shown in figure 2, and resource estimates are summarized in table 2.

6 National Assessment of Geologic Carbon Dioxide Storage Resources—Results

Table 2. Estimates by the U.S. Geological Survey in 2012 of basin and regional totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.

[Estimates are in millions of metric tons (megatons, Mt). P_5 , P_{50} , and P_{95} are probability percentiles and represent the 5-, 50-, and 95-percent probabilities, respectively, that the true storage resource is less than the value shown. The percentiles were calculated by using the aggregation method described in the “Aggregation” section of this report and in Blondes, Schuenemeyer, and others (2013). Percentile values do not sum to totals because the aggregation procedure used partial dependencies between storage assessment units. Mean values sum to totals but are reported to only two significant figures if the value is greater than 1 Mt and are rounded to the nearest 0.1 Mt if the value is less than 1 Mt. Regions are listed from northwest to east; basins are listed alphabetically]

Basin name	<i>KRR_{SR}</i> Known recovery replacement storage resource				<i>B_{SR}</i> Buoyant trapping storage resource				<i>R1_{SR}</i> Residual trapping class 1 storage resource			
	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
Alaska Region												
Alaska North Slope	700	910	1,100	910	2,400	8,600	62,000	18,000	510	770	1,100	790
Kandik Basin	0.0	0.0	0.0	0.0	1.1	13	150	38	0.0	0.0	0.0	0.0
Aggregated totals	700	910	1,100	910	2,400	8,600	62,000	18,000	510	770	1,100	790
Pacific Northwest Region												
Western Oregon and Washington Basins	0.0	0.0	0.0	0.0	0.1	1.5	35	8.2	860	1,600	2,700	1,700
Aggregated totals	0.0	0.0	0.0	0.0	0.1	1.5	35	8.2	860	1,600	2,700	1,700
California Region												
Los Angeles Basin	10	13	16	13	43	75	140	81	66	130	230	130
Sacramento Basin	34	48	67	49	42	57	180	80	460	740	1,100	760
San Joaquin Basin	18	24	32	25	31	98	980	270	1,600	2,400	3,400	2,500
Ventura Basin	23	32	43	32	29	52	290	93	76	160	300	170
Aggregated totals	94	120	150	120	180	320	1,500	520	2,500	3,500	4,700	3,500
Rocky Mountains and Northern Great Plains Region												
Bighorn Basin	75	93	110	93	89	120	290	150	0.0	0.0	0.0	0.0
Denver Basin	76	100	130	100	110	170	850	300	35	100	250	120
Eastern Great Basin	0.9	1.2	1.6	1.2	1.2	2.2	23	6.6	0.0	0.0	0.0	0.0
Greater Green River Basin	380	500	650	500	440	580	1,500	740	0.0	0.0	0.0	0.0
Hanna, Laramie, and Shirley Basins	0.9	1.1	1.4	1.1	17	74	370	120	5.2	12.0	23	12
Paradox Basin	36	51	71	52	45	63	160	78	0.0	0.0	0.0	0.0
Powder River Basin	96	120	150	120	120	180	710	280	0.3	1.8	4.1	2.0
San Juan Basin	9.4	12	16	12	11	15	37	19	3.8	8.4	17	9.1
Uinta and Piceance Basins	46	58	75	59	47	73	280	110	0.0	0.0	0.0	0.0
Williston Basin	150	180	230	180	340	710	2,000	880	1,600	2,700	4,400	2,800
Wind River Basin	52	66	81	66	63	86	280	130	0.6	1.4	3.3	1.6
Wyoming-Idaho-Utah Thrust Belt	240	310	390	310	290	370	600	400	0.0	0.0	0.0	0.0
Aggregated totals	1,300	1,500	1,800	1,500	1,800	2,700	6,300	3,200	1,700	2,900	4,600	3,000
Western Mid-Continent Region												
Anadarko and Southern Oklahoma Basins	220	300	420	310	1,000	1,400	3,300	1,700	450	920	1,700	990
Arkoma Basin	3.7	5.2	7.3	5.3	14	25	66	31	0.0	0.0	0.0	0.0
Bend Arch and Fort Worth Basin	210	290	370	290	230	310	500	340	330	660	1,100	680
Kansas Basins	4.5	5.6	6.9	5.7	4.8	6.1	9.2	0.0	0.0	0.0	0.0	0.0
Palo Duro Basin	120	150	190	150	1.6	4.1	32	9.3	72	110	170	120
Permian Basin	1,000	1,300	1,700	1,300	1,600	2,000	4,000	2,400	2,200	3,900	6,700	4,100
Aggregated totals	1,700	2,100	2,500	2,100	3,100	3,800	7,800	4,500	3,600	5,700	8,900	5,900
Eastern Mid-Continent Region												
Appalachian Basin	21	28	37	28	38	79	370	130	160	270	440	280
Black Warrior Basin	14	23	32	23	13	17	30	19	0.0	0.0	0.0	0.0
Illinois Basin	69	85	100	85	94	290	1,300	440	900	1,400	2,300	1,500
Michigan Basin	140	180	220	180	190	280	790	360	2,800	4,500	6,800	4,600
Aggregated totals	260	310	370	320	380	740	2,200	940	4,100	6,200	9,100	6,400
Coastal Plains Region												
Atlantic Coastal Plain	0.0	0.0	0.0	0.0	39	100	270	120	2,000	3,100	4,700	3,200
South Florida Basin	6.7	8.5	10	8.5	21	97	900	240	0.0	0.0	0.0	0.0
U.S. Gulf Coast	6,400	8,000	9,800	8,000	7,800	11,000	39,000	16,000	75,000	120,000	170,000	120,000
Aggregated totals	6,400	8,000	9,900	8,000	8,000	11,000	40,000	17,000	78,000	120,000	180,000	120,000
Eastern Mesozoic Rift Basins Region												
Eastern Mesozoic Rift Basins	0.0	0.0	0.0	0.0	1.3	2.0	19	5.9	0.0	0.0	0.0	0.0
Aggregated totals	0.0	0.0	0.0	0.0	1.3	2.0	19	5.9	0.0	0.0	0.0	0.0

Table 2. Estimates by the U.S. Geological Survey in 2012 of basin and regional totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.—Continued

$R2_{SR}$ Residual trapping class 2 storage resource				$R3_{SR}$ Residual trapping class 3 storage resource				TA_{SR} Technically accessible storage resource			
P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
Alaska Region—Continued											
150,000	200,000	280,000	210,000	7,600	38,000	110,000	45,000	170,000	260,000	400,000	270,000
480	1,100	2,200	1,200	22	170	630	230	570	1,400	2,700	1,500
150,000	200,000	280,000	210,000	7,700	39,000	110,000	45,000	180,000	260,000	410,000	270,000
Pacific Northwest Region—Continued											
6,600	12,000	20,000	12,000	0.6	10	43	14	7,500	14,000	22,000	14,000
6,600	12,000	20,000	12,000	0.6	10	43	14	7,500	14,000	22,000	14,000
California Region—Continued											
2,000	3,300	5,600	3,500	0.1	1.6	6.2	2.2	2,200	3,500	5,800	3,700
19,000	28,000	39,000	29,000	0.0	2.3	10	3.2	20,000	29,000	40,000	29,000
33,000	48,000	65,000	48,000	25	120	300	130	36,000	51,000	69,000	51,000
3,100	5,500	9,200	5,700	0.5	9.0	35	12	3,200	5,700	9,600	6,000
63,000	85,000	110,000	86,000	35	130	320	150	67,000	90,000	120,000	90,000
Rocky Mountains and Northern Great Plains Region—Continued											
890	1,500	2,400	1,500	21	86	230	100	1,100	1,700	2,800	1,800
1,000	2,700	5,900	3,000	37	210	830	300	1,400	3,300	7,200	3,700
80	170	360	190	1.9	24	97	34	98	210	430	230
21,000	30,000	43,000	31,000	1,700	6,200	17,000	7,400	26,000	38,000	57,000	39,000
1,100	2,000	3,200	2,100	25	91	240	110	1,300	2,200	3,600	2,300
1,000	2,500	5,300	2,800	28	380	1,600	530	1,300	3,100	6,300	3,400
11,000	17,000	25,000	18,000	39	170	510	210	11,000	18,000	26,000	18,000
380	640	1,100	670	5.2	30	94	37	430	710	1,200	740
1,300	2,200	3,300	2,200	290	1,200	3,300	1,400	2,000	3,500	6,300	3,800
99,000	140,000	180,000	140,000	1,100	5,200	14,000	6,000	110,000	140,000	190,000	150,000
4,100	7,100	11,000	7,300	150	580	1,500	670	4,600	7,800	12,000	8,100
26,000	39,000	55,000	39,000	780	3,800	12,000	4,700	28,000	43,000	63,000	44,000
180,000	240,000	310,000	240,000	7,300	19,000	43,000	22,000	200,000	270,000	350,000	270,000
Western Mid-Continent Region—Continued											
34,000	55,000	88,000	57,000	670	2,500	6,100	2,800	38,000	60,000	96,000	62,000
3,500	7,000	13,000	7,400	39	360	1,300	480	3,800	7,500	13,000	7,900
7,000	13,000	20,000	13,000	170	1,100	3,800	1,400	8,600	15,000	24,000	15,000
160	280	480	300	1.5	12	48	17	180	300	510	320
4,900	6,900	9,400	7,000	9.0	56	170	67	5,100	7,100	9,600	7,200
31,000	48,000	75,000	50,000	460	2,200	6,400	2,600	37,000	57,000	89,000	59,000
93,000	130,000	190,000	130,000	2,600	6,800	15,000	7,500	110,000	150,000	210,000	150,000
Eastern Mid-Continent Region—Continued											
13,000	18,000	27,000	19,000	180	840	2,500	1,000	14,000	20,000	29,000	20,000
170	280	450	290	0.2	2.1	7.2	2.7	180	300	480	310
110,000	140,000	200,000	150,000	1,000	5,100	14,000	6,100	110,000	150,000	210,000	150,000
33,000	47,000	66,000	48,000	560	3,300	11,000	4,200	40,000	56,000	78,000	57,000
160,000	210,000	280,000	210,000	2,700	9,900	25,000	11,000	170,000	230,000	300,000	230,000
Coastal Plains Region—Continued											
6,900	11,000	16,000	11,000	0.0	0.1	4.7	1.1	9,200	14,000	20,000	14,000
120,000	160,000	200,000	160,000	1,400	7,600	21,000	9,000	120,000	160,000	210,000	170,000
1,100,000	1,600,000	2,200,000	1,600,000	6,600	30,000	83,000	35,000	1,300,000	1,700,000	2,400,000	1,800,000
1,300,000	1,700,000	2,400,000	1,800,000	11,000	38,000	96,000	44,000	1,400,000	1,900,000	2,600,000	1,900,000
Eastern Mesozoic Rift Basins Region—Continued											
130	280	510	290	7.6	100	410	140	180	400	830	440
130	280	510	290	7.6	100	410	140	180	400	830	440

Three basins (Central California Coast Basins; Columbia Basin of Oregon, Washington, and Idaho; and Raton Basin) contain only nonquantitative SAUs, bringing the total number of basins listed in table 3 and shown in figure 2 to 36. Because they lack resource estimates, these three basins are not included in table 2 or figure 3.

Areas of the Nation evaluated for CO₂ storage potential are shown as “Evaluated areas” in figure 2, and the combined extents of the areas that were quantitatively assessed within each basin are shown as “Assessed areas.” USGS National Oil and Gas Assessment (NOGA) total petroleum system (TPS) boundaries (see <http://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment.aspx>) were used as starting points for the evaluation of many specific basins. In some areas, the assessed storage reservoir continues beyond, or is smaller than, the TPS outline of that basin because SAU boundaries are defined differently than TPS boundaries. Additionally, some sedimentary basins were lumped into a composite-basin evaluation area because the SAUs are continuous throughout these areas (for example, the Hanna, Laramie, and Shirley Basins, fig. 2).

Buoyant and Residual Trapping

Two general storage types, buoyant and residual, were defined in the methodology used in this assessment (Brennan and others, 2010; Blondes, Brennan, and others, 2013). Carbon dioxide storage capacity was estimated for buoyant and residual storage traps that occur in sedimentary basins. For buoyant traps, CO₂ can be held in place in porous formations by top and lateral seals. For residual traps, CO₂ can be held in porous formations as individual droplets within pores by capillary forces (fig. 4). The residual storage resource consists of three injectivity classes based on reservoir permeability: residual trapping class 1 ($R1_{SR}$) represents storage in rocks with permeability greater than 1 darcy (D); residual trapping class 2 ($R2_{SR}$) represents storage in rocks with moderate permeability, defined as permeability between 1 millidarcy (mD) and 1 D; and residual trapping class 3 ($R3_{SR}$) represents storage in rocks with low permeability, defined as permeability less than 1 mD.

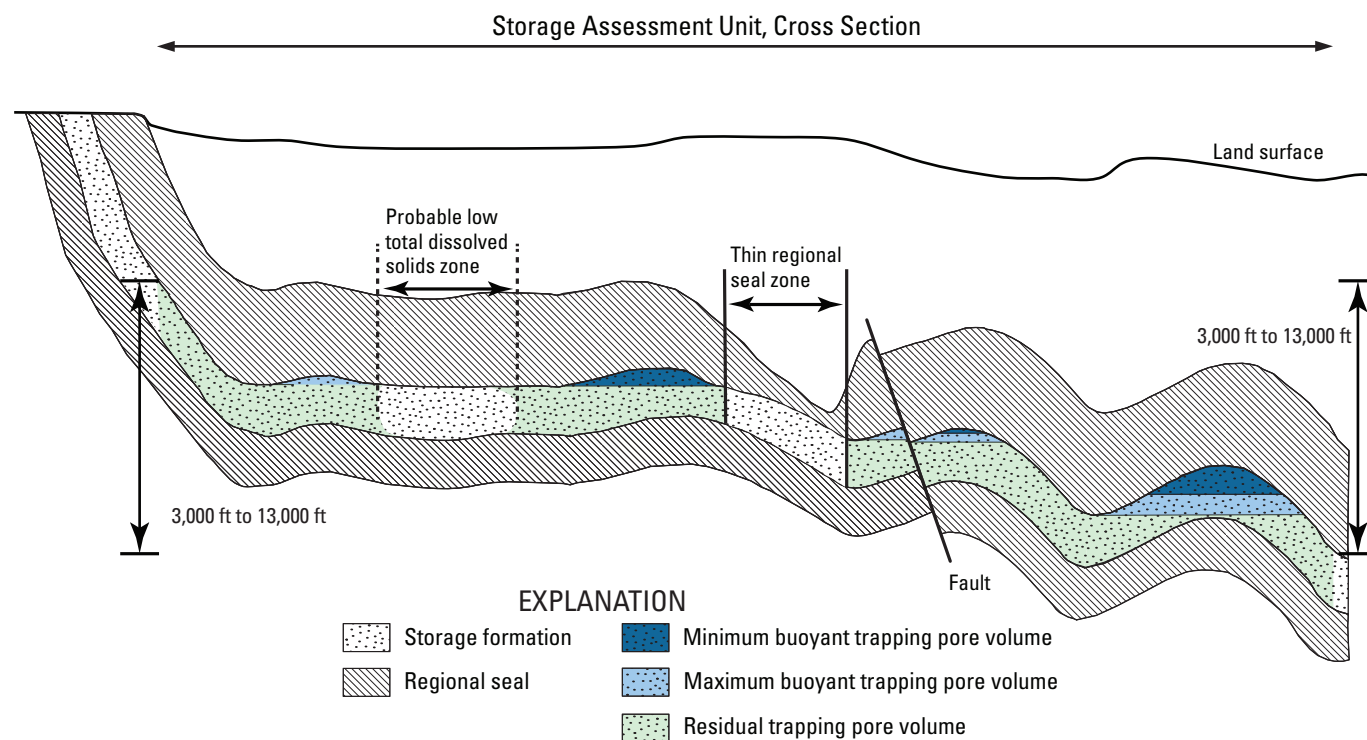


Figure 4. Schematic cross section through a storage assessment unit (SAU) illustrating the relation between buoyant and residual trapping types in the storage formation (SF). The SAU minimum depth limit of 3,000 feet (914 meters, or almost 1 kilometer) ensures that carbon dioxide (CO₂) is in a supercritical state to maximize the storage resource per unit volume. A depth of 13,000 ft (3,962 m, or almost 4 km) is the lower limit accessible with average injection pressures and is the lower limit for a standard SAU. A deep SAU can be defined for depths greater than 13,000 ft

(3,962 m) if favorable reservoir conditions exist. The lateral limit of the SAU is defined by the location where the top of the storage formation reaches the defined depth limit. Also shown are zones that may be excluded from an SAU because the regional seals are thin or because water in the storage formation is probably low in total dissolved solids (TDS less than 10,000 milligrams per liter). Modified from Brennan and others (2010) and Blondes, Brennan, and others (2013).

Assessment Categories

The six storage resource categories for the assessment are summarized below.

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 1 mD.
5. **TA_{SR} , technically accessible storage resource:** total mass of CO_2 that can be stored in the SAU.
6. **KRR_{SR} , known recovery replacement storage resource:** mass of CO_2 that can be stored in existing hydrocarbon reservoirs. The KRR_{SR} is a minimum range of values that represent the amount of CO_2 at subsurface conditions that could replace the volume of known hydrocarbons in petroleum reservoirs. KRR_{SR} is determined from production volumes rather than the geologic model of buoyant and residual resources that make up the TA_{SR} (Brennan and others, 2010; Blondes, Brennan, and others, 2013). The same type of resource is also included in the buoyant storage type estimated from a geologic model.

Data Sources

Several publicly available data sources and proprietary databases were used for this assessment. Lists of the data sources used in assessing SAUs in several basins are available in the basin-specific geologic framework publication series (Warwick and Corum, 2012). A general list of data sources used in the resource and allocation calculation processes is included in the companion assessment data publication (U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013a).

USGS National Oil and Gas Assessment publications were a significant source of reservoir characteristics and other geologic input parameters (see <http://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment.aspx>). Data-sharing agreements with numerous State geological surveys and universities (see “Acknowledgments” for the names of the organizations), many of which are members of the DOE National Energy Technology Laboratory (NETL) Regional

Carbon Sequestration Partnerships, provided assessment geologists with reports, maps, and ancillary displays, as well as digital databases that were integral to the success of the project. In addition, peer-reviewed publications from the petroleum and carbon sequestration literature provided access to other interpretations and datasets.

Two principal proprietary petroleum databases were mined for a substantial proportion of the data used in the assessments; these are the “Significant Oil and Gas Fields of the United States Database” from Nehring Associates, Inc. (2010), and the databases of individual well information from IHS Inc. (2010, 2011a,b). Water-quality data from Breit (2002), Blondes and Gosai (2011), and the National Energy Technology Laboratory (NETL) Brine Database (Hovorka and others, 2000), amongst others, and other datasets available from State sources were used to determine the potential status of SAUs in regard to the EPA underground source of drinking water (USDW) regulations (U.S. Environmental Protection Agency, 2008, 2009, 2010).

Assessment Process

Assessment Assumptions and Constraints

Several assumptions were implemented to complete the assessment within the timeframe specified by the Energy Independence and Security Act (Public Law 110–140; U.S. Congress, 2007). The methodology of Brennan and others (2010) and Blondes, Brennan, and others (2013) does not factor in engineering issues such as injection rate or time-dependent variables to determine the storage potential of SAUs. Additionally, the methodology does not identify locations within individual SAUs where the storage resources would be most accessible or favorable. Also, the resources were estimated without consideration either of accessibility due to land-management or regulatory restrictions or of economic viability. Thus, if storage of CO_2 within a formation is feasible with current technology, it was considered for this report. Because the legislation that mandated this assessment (Public Law 110–140) required that the assessment incorporate USDW regulations of the EPA (U.S. Environmental Protection Agency, 2008, 2009, 2010), a substantial percentage of a potential storage formation containing water with less than 10,000 milligrams per liter (mg/L) of total dissolved solids (TDS) (considered freshwater for the purpose of this assessment) would be disqualified as a protected underground source of potential drinking water. As discussed in Blondes, Brennan, and others (2013), if a potential SAU contains both saline water and freshwater, the area of the SAU considered for the estimate was reduced to account for the estimated fraction of freshwater thought to be present. A potential exception may be granted by the EPA (or by States to whom the EPA has delegated responsibilities) for areas of current petroleum production with freshwater and for areas where waivers may

be obtained for CO₂ storage. These areas were considered for buoyant storage (Blondes, Brennan, and others, 2013). Additionally, all CO₂ storage formations must be overlain by a low-permeability robust sealing formation having a minimum thickness of about 75 ft (23 m) depending on the seal lithology (Blondes, Brennan, and others, 2013). These constraints are illustrated in figure 4 and discussed further in Brennan and others (2010) and Blondes, Brennan, and others (2013). Federally owned offshore areas were not assessed because resource assessments in these areas are typically done by the Bureau of Ocean Energy Management (BOEM).

Besides the SAU depth constraints described by Brennan and others (2010), some additional assumptions were made to identify SFs technically feasible for geologic storage of CO₂. One major assumption was that increases in pressure within the reservoir during CO₂ injection could be mitigated by pressure management, for example by water production from the SF. Such pressure management should be used to avoid complications associated with reservoir or seal rock integrity, induced seismicity, or potential leakage from the storage formation. Therefore, failure of reservoir or seal rock integrity caused by injection site operations and the consequential potential for CO₂ leakage along faults and fractures, or by updip migration, were constraints not taken into account in this assessment.

Resource Calculations

The probabilistic methodology used in this assessment follows that described by Brennan and others (2010) and Blondes, Brennan, and others (2013). The calculation for the total technically accessible storage resource, TA_{SR} (see “Assessment Categories” section above), can be summarized with the following equation (Blondes, Brennan, and others, 2013), which adds the buoyant trapping storage resource to the sum of the residual trapping storage resources:

$$TA_{SR} = \rho_{CO_2} B_{PV} B_{SE} + \sum_{i=1}^3 \left[\rho_{CO_2} (A_{SF} T_{PI} \phi_{PI} - B_{PV}) R_W R_{iSE} R_i \right], \quad (1)$$

where

- The buoyant trapping storage resource, B_{SR} is equivalent to the first term on the right side of the equation ($B_{SR} = \rho_{CO_2} B_{PV} B_{SE}$).
- Each of the three terms in the summation is a residual trapping storage resource output: $R1_{SR}$, $R2_{SR}$, or $R3_{SR}$.
- ρ_{CO_2} is the density of CO₂ and is determined from subsurface geothermal and pressure gradient data for each basin, from comparisons with analog basins, or from published gradients.
- B_{PV} is the geologically determined pore volume that can store CO₂ by buoyant trapping. It is estimated on

the basis of hydrocarbon production, undiscovered resources, and volume calculations of geologic traps.

- B_{SE} and R_{iSE} are the buoyant and residual trapping storage efficiencies, respectively, defined as the fraction of accessible pore volume that will be occupied by injected CO₂. These are determined from estimates of subsurface geothermal and pressure gradients, multi-phase flow parameters, and fluid chemistry.
- A_{SF} is the area of the storage formation within the SAU and is constrained by using structure maps or data at the relevant depth ranges for the storage formation.
- T_{PI} is the thickness of the net porous interval and is generally calculated by using net thickness: gross thickness assumptions applied to the total SAU thickness.
- ϕ_{PI} is the porosity of the net porous interval, obtained from measurements of porosity in the interval or analog rock porosity data.
- R_W is the area fraction of the SAU available for storage after consideration of EPA water-quality guidelines or highly fractured seals.
- $i = 1, 2, \text{ or } 3$; the numbers refer to the names of the residual trapping injectivity classes.
- R_i can represent injectivity class fractions 1, 2, or 3, which are determined from a probabilistic distribution of rock permeability data.

Equation 1 sums the first five assessment results in the “Assessment Categories” section above. The sixth assessment result, KRR_{SR} , is nongeologic and was calculated separately by using known recovery production volumes, buoyant trapping storage efficiency factors, and ρ_{CO_2} . To help define the input parameters for TA_{SR} and KRR_{SR} , additional parameters were estimated by the assessment geologist or the assessment team. Formation volume factors (FVF) for oil, gas, and natural gas liquids were used to convert surface production volumes to equivalent volumes at depth. These were calculated from basin subsurface geothermal gradients and reservoir characteristics. The depth range was determined for each SAU and was important for the density, storage efficiency, and FVF calculations (Blondes, Brennan, and others, 2013).

During the assessment, the USGS geologist specified a minimum, most likely, and maximum estimate range about the mean of each input parameter. The three estimates for each parameter were used to define continuous distributions, such as a lognormal or a Beta-PERT distribution (Blondes, Brennan, and others, 2013). The calculation procedure is outlined in figure 5 and is described in detail in Blondes, Brennan, and others (2013). For simplicity, the storage formation pore volume (SF_{PV}) at the top of figure 5 is equivalent to the $A_{SF} T_{PI} \phi_{PI}$ term in equation 1, whereas all other equation 1 variables are shown. Storage resources were calculated with

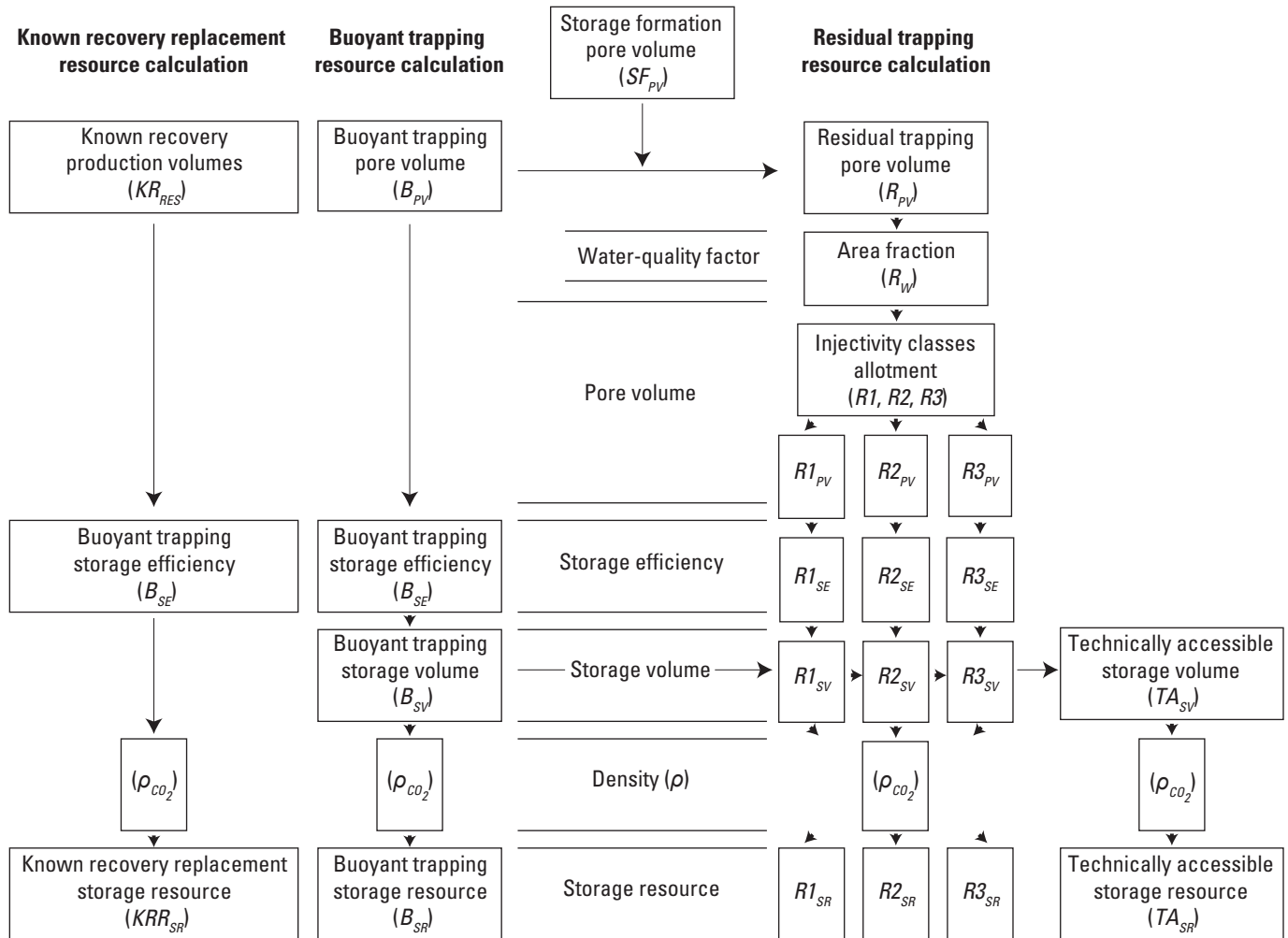


Figure 5. Flow diagram of the key steps for calculating known recovery replacement storage resources (KRR_{SR}), buoyant trapping storage resources (B_{SR}), residual trapping storage resources ($R1_{SR}$, $R2_{SR}$, $R3_{SR}$), and technically accessible storage resources (TA_{SR}). Residual trapping injectivity categories are

represented as class 1 ($R1$), class 2 ($R2$), and class 3 ($R3$). Also included are steps for calculating water quality, storage efficiency, and carbon dioxide density (ρ_{CO_2}). Modified from Brennan and others (2010) and Blondes, Brennan, and others (2013).

correctly propagated uncertainty (or propagation of error) by using a Monte Carlo method in which each input distribution was sampled 10,000 times. Assessment results for all SAUs include a mean, P_5 , P_{50} (median), and P_{95} for each of the six reported storage resource assessment categories (tables 1, 2, and 3). The terminology used in this report differs from that used by the petroleum industry and follows standard statistical practice (for example, Everitt and Skron dal, 2010) where a percentile represents the probability that the true storage resource is *less than* the value reported. For example, if the P_{95} for TA_{SR} is 1 Gt, there is a 95-percent probability that the true TA_{SR} value is less than 1 Gt. This is considered the high estimate.

An in-depth discussion and an explanation of the resource calculation methodology are in Blondes, Brennan, and others

(2013). Input data for each SAU are contained in the companion assessment data publication (U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013a).

Aggregation

The calculated CO_2 storage resources for each SAU are reported in the form of a probabilistic distribution, reported as the P_5 , P_{50} , P_{95} , and mean, although the modeling was done for the entire distribution. The assessment then combined the six resource results for an SAU (listed above) to basin, regional, and national scales using probabilistic aggregation to appropriately propagate uncertainty. Because USGS oil and

gas resource assessments have shown that geologic dependencies exist between assessment units, the aggregation procedure required estimating the dependencies, or correlations, between individual units (Schuenemeyer and Gautier, 2010). This aggregation procedure, which incorporated estimates of correlation among all SAUs (see U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013a, table 2), was necessary for the rigorous estimation of resource percentile at the basin, regional, and national scales. All assessments were conducted by USGS employees for process consistency. The aggregation procedure used in this study is discussed in detail in Blondes, Schuenemeyer, and others (2013).

Results of the Assessment of Technically Accessible Storage Resources

The results for the six CO₂ storage resource categories are summarized below and illustrated in tables 1–3. Table 1 summarizes the national results, and table 2 contains the assessment results aggregated by region and basin. Table 3 presents the results by basin and individual SAU. Most results are rounded to two significant figures.

Brennan and others (2010) suggested that existing technology, or that which is based on present-day geoscience knowledge and existing engineering capabilities, would be used to store CO₂; estimates made on that basis indicate that the technically accessible storage resource (TA_{SR}) beneath U.S. onshore areas and State waters ranges from approximately 2,300 Gt at the P_5 percentile to as much as 3,700 Gt at the P_{95} percentile, with a mean of 3,000 Gt (table 1). The estimated range of uncertainty about the mean for the TA_{SR} is illustrated in figure 6. A complete set of results for each SAU, along with plots of the empirical cumulative distribution functions (CDFs) for each SAU, is available in the companion data report (U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013a). The TA_{SR} was estimated for eight regions of the United States (figs. 1B and 2). The Coastal Plains Region accounts for 65 percent of the TA_{SR} (fig. 1B), and its U.S. Gulf Coast area accounts for the majority of the resources (59 percent). The Alaska, Rocky Mountains and Northern Great Plains, and Eastern Mid-Continent Regions contain the next largest storage resources, with each containing 9, 9, and 8 percent of the total, respectively. All other regions contain 5 percent or less of the total storage resources. The distributions of the TA_{SR} for regions with multiple basins are illustrated in figure 7A–F. The Pacific Northwest Region and Eastern Mesozoic Rift Basins Region contain only one assessment unit each, and so a distribution illustration is not presented for these regions.

Buoyant Trapping Storage

The mean technically accessible storage resource available for buoyant trapping storage of CO₂ in the United States is equivalent to approximately 44 Gt ($P_5 = 19$ Gt, and $P_{95} = 110$ Gt) of CO₂ (tables 1–3, figs. 1A and 8A). The national buoyant storage resource constitutes approximately 2 percent of the TA_{SR} (fig. 1A). The assessment regions that contain significant buoyant storage resources include the Coastal Plains (primarily U.S. Gulf Coast), Alaska, Western Mid-Continent, and Rocky Mountains and Northern Great Plains (fig. 8A).

Residual Trapping Storage

The mean estimated storage capacities for the three residual trapping storage classes are summarized here: residual trapping class 1 has 140 Gt ($P_5 = 97$ Gt, and $P_{95} = 200$ Gt), or approximately 5 percent of the mean TA_{SR} ; residual trapping class 2 has 2,700 Gt ($P_5 = 2,100$ Gt, and $P_{95} = 3,300$ Gt), or approximately 89 percent of the mean TA_{SR} ; and residual trapping class 3 has 130 Gt ($P_5 = 58$ Gt, and $P_{95} = 230$ Gt), or approximately 4 percent of the mean TA_{SR} (table 1; fig. 1A). Residual trapping class 2 contains the most significant resources of the three residual storage classes and of the TA_{SR} (fig. 1A). The regional distribution of residual trapping class 2 storage resources is illustrated in figure 8B, with the primary regions being the Coastal Plains (especially the U.S. Gulf Coast area), Alaska, Eastern Mid-Continent, and Rocky Mountains and Northern Great Plains.

Petroleum Reservoirs

Known hydrocarbon recovery volumes indicate that the CO₂ storage resources (KRR_{SR}) available in petroleum reservoirs within the assessed areas range from approximately 11 Gt at the P_5 probability percentile to as much as 15 Gt at the P_{95} probability percentile, with a mean of 13 Gt. This value indicates that approximately 30 percent of the mean buoyant storage resources reported above is in petroleum reservoirs.

Discussion of Results

The numerical results of the assessment reveal important aspects of the distribution of potential CO₂ storage resources in the United States. The following list has some of the key findings of this assessment.

1. Most (89 percent) of the TA_{SR} is in the residual trapping class 2 storage resource category (mean estimate of 2,700 Gt; fig. 1A). Residual trapping classes 1 and 3 account for 5 and 4 percent of the TA_{SR} , respectively (fig. 1A). These resources occur in all assessed basins and need to be better defined by site characterization studies prior to their utilization for CO₂ storage.

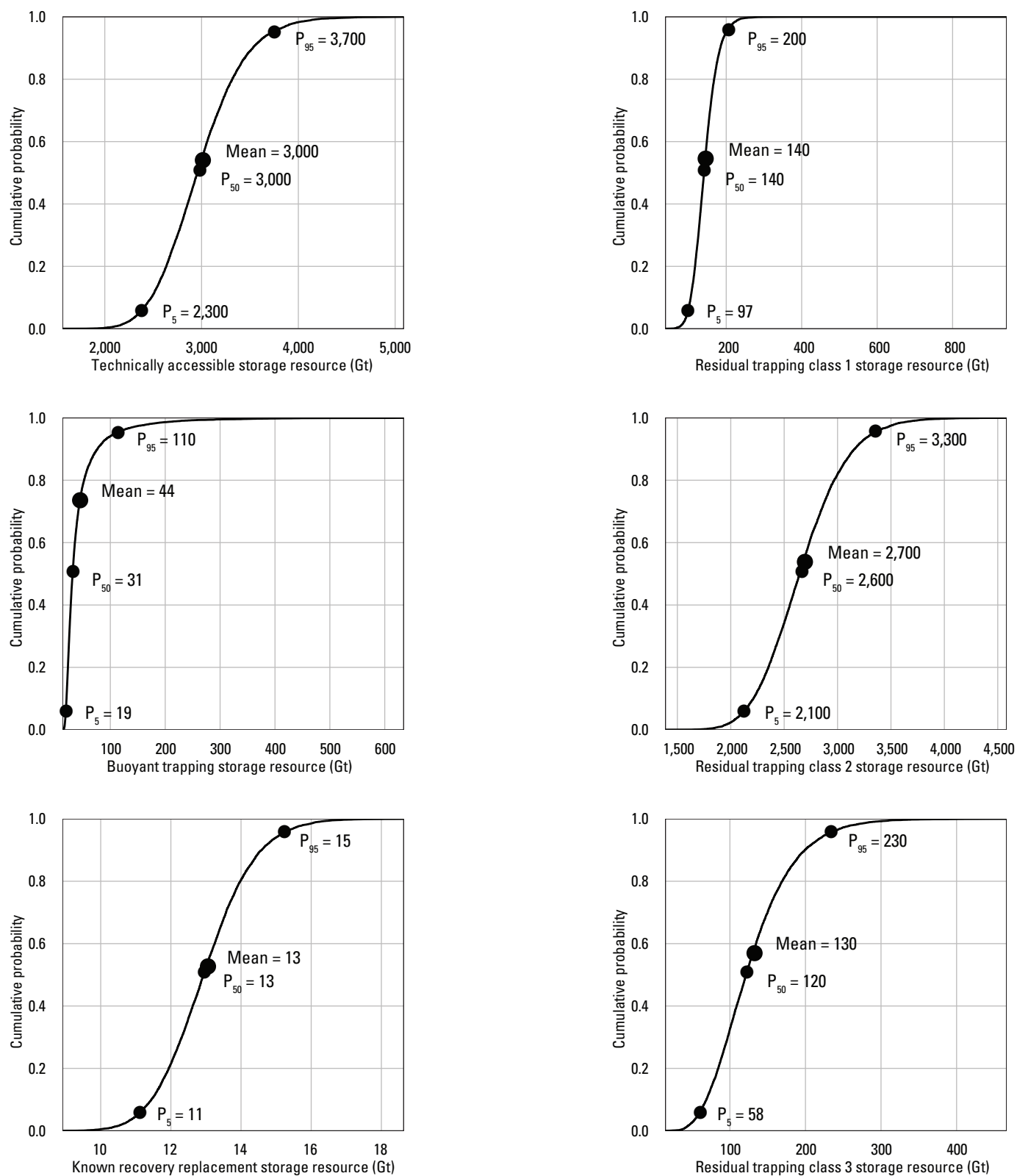
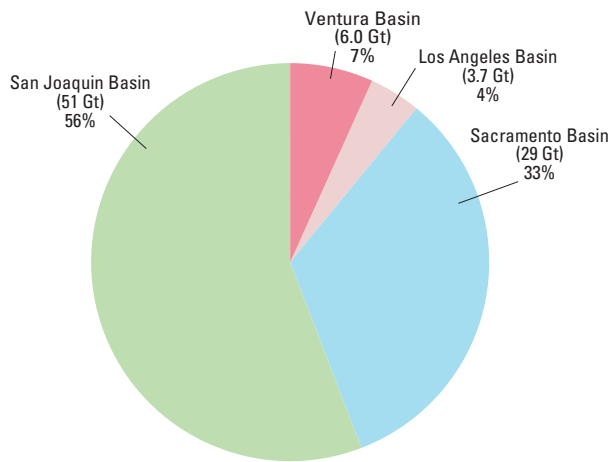


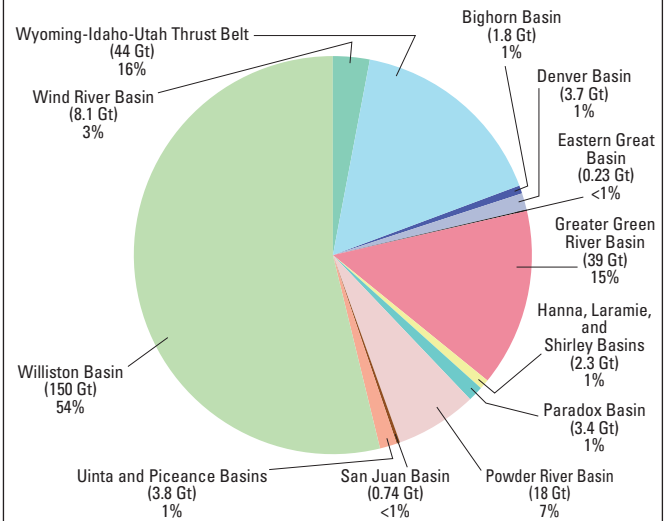
Figure 6. Graphs showing empirical cumulative distribution function (CDF) plots of all six categories of technically accessible storage resources (TA_{SR}) for carbon dioxide in the United States, exclusive of federally owned offshore areas. The cumulative probability for a given percentile represents the probability that the true storage

resource is *less than* the value shown. All values are rounded to two significant figures. Data are listed in table 1 and are given in billions of metric tons (gigatons, Gt). Where the mean and P_{50} values are the same within rounding to two significant figures, their respective dots on the curve may be slightly offset and reflect the unrounded values.

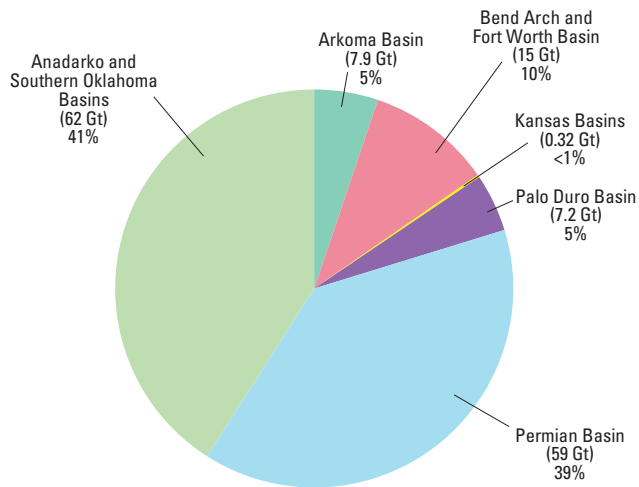
A. California Region, $TA_{SR} = 90$ Gt



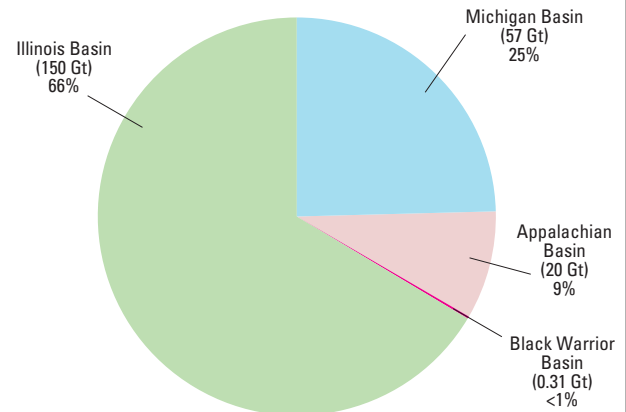
B. Rocky Mountains and Northern Great Plains Region, $TA_{SR} = 270$ Gt



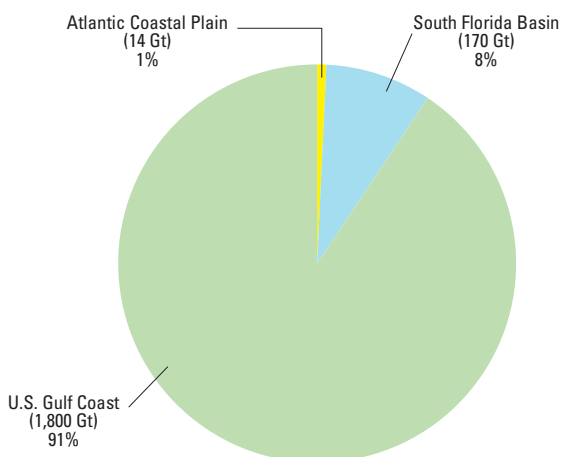
C. Western Mid-Continent Region, $TA_{SR} = 150$ Gt



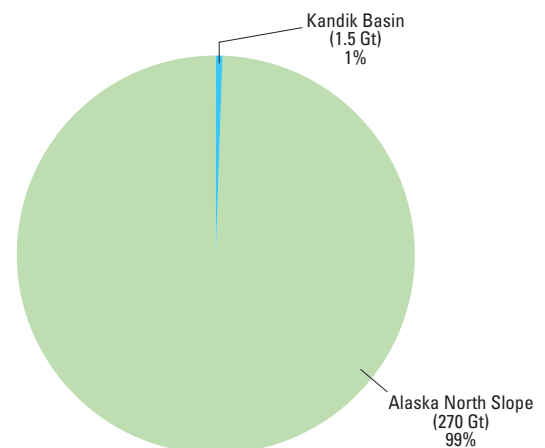
D. Eastern Mid-Continent Region, $TA_{SR} = 230$ Gt



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



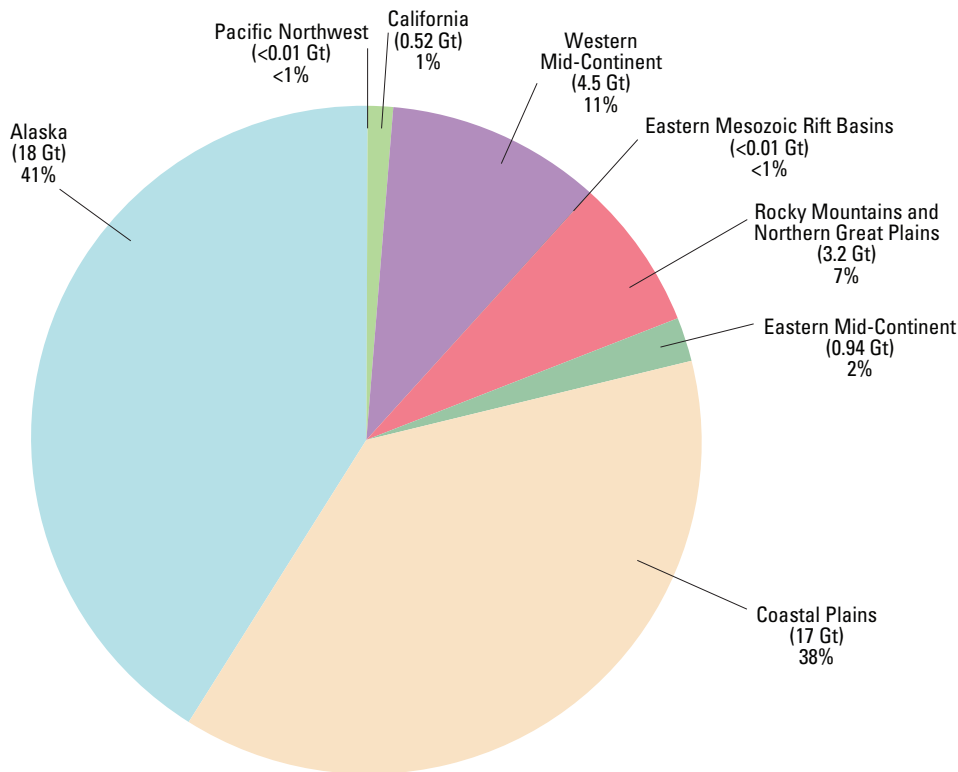
F. Alaska Region, $TA_{SR} = 270$ Gt



2. 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. Existing oil in hydrocarbon reservoirs may be produced in the near future by using enhanced-oil-recovery technology that utilizes anthropogenic CO₂, and then the reservoirs could be used for CO₂ storage. Because of the depth of knowledge about the hydrocarbon reservoirs, buoyant trapping storage resources in these reservoirs may be more attractive for storage of CO₂ than residual trapping storage resources.
3. The regions with the largest technically accessible storage resources (fig. 7A–F) are the Coastal Plains Region (mean estimate of 1,900 Gt, of which about 1,800 Gt, or 91 percent, is in the U.S. Gulf Coast) and the Alaska Region (mean estimate of 270 Gt), where the resource is almost entirely in the Alaska North Slope (tables 2 and 3). Storage resources in the U.S. Gulf Coast are near major population centers and industrial CO₂ sources and will likely be utilized for CO₂ storage in subsurface formations in the near future. The CO₂ storage resources in Alaska are in remote areas in the northern part of the State and may not be readily utilized for anthropogenic CO₂ storage. However, the Alaska North Slope petroleum industry may utilize these subsurface reservoirs for storage of CO₂ that is coproduced with hydrocarbons or stored during the enhanced-oil-recovery process using CO₂.
4. Available water-quality databases indicate that many basins in the Western United States contain variable amounts of freshwater (<10,000 mg/L TDS), which, according to EPA regulations incorporated in the Energy Independence and Security Act of 2007, will restrict the use of the CO₂ storage resource capacity in these basins. Among the basins in the Rocky Mountains and Northern Great Plains Region (fig. 2), the Williston Basin, which contains predominantly saline water, has the most available storage resource (mean estimate of 150 Gt; fig. 7B). Please refer to Blondes, Brennan, and others (2013) and U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team (2013a) for a detailed accounting of how water quality affected the delineation of the SAU areas within individual basins.
5. Forty-six deep SAUs (at depths greater than 13,000 ft; 3,962 m) in 13 basins were quantitatively assessed (tables 3 and 4). The deep SAUs account for 470 Gt, or 16 percent of the total TA_{SR} . In addition, deep SAUs account for 6 percent of the total B_{SR} . Any potential developer of the deep SAUs has to consider the increased operational pressures needed to inject CO₂ at depths greater than 13,000 ft (3,962 m).
6. Of the 10 SAUs having the largest storage capacity (table 3), 8 are near population centers and may be utilized for geologic storage of anthropogenic CO₂; the two exceptions are in the Alaska North Slope and the Williston Basin. These 10 SAUs, ranked in decreasing order of mean estimates of TA_{SR} , are listed below:
 1. Sligo and Hosston Formations and Cotton Valley Group (610 Gt), U.S. Gulf Coast
 2. Sligo and Hosston Formations and Cotton Valley Group Deep (220 Gt), U.S. Gulf Coast
 3. Carrizo Sand and Wilcox Group (220 Gt), U.S. Gulf Coast
 4. Frio and Vicksburg Formations (170 Gt), U.S. Gulf Coast
 5. Lower Torok Formation (140 Gt), Alaska North Slope
 6. Pre-Punta Gorda (110 Gt), South Florida Basin
 7. Mount Simon Sandstone (94 Gt), Illinois Basin
 8. Tuscaloosa and Woodbine Formations (85 Gt), U.S. Gulf Coast
 9. Yegua and Cockfield Formations (62 Gt), U.S. Gulf Coast
 10. Winnipegosis Formation, Interlake Formation, and Bighorn Group (61 Gt), Williston Basin
7. The total geologic storage resources for CO₂ in the United States are large, and both types will probably be needed. 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. The B_{SR} estimate indicates 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.

Figure 7 (facing page). Pie charts showing mean estimates of technically accessible storage resources (TA_{SR}) for carbon dioxide (CO₂) in selected regions of the United States. Resources in federally owned offshore areas were not assessed. Resource estimates are illustrated for six of the eight regions shown in figure 2: A, California Region; B, Rocky Mountains and Northern Great Plains Region; C, Western Mid-Continent Region; D, Eastern Mid-Continent Region; E, Coastal Plains Region; and F, Alaska Region. The Pacific Northwest Region and Eastern Mesozoic Rift Basins Region contain only one quantitatively assessed storage assessment unit each and are therefore not presented in this figure. Mean values sum to totals but are reported to only two significant figures. Gt, gigatons.

A. Buoyant trapping storage resource by region, total = 44 Gt



B. Residual trapping class 2 storage resource by region, total = 2,700 Gt

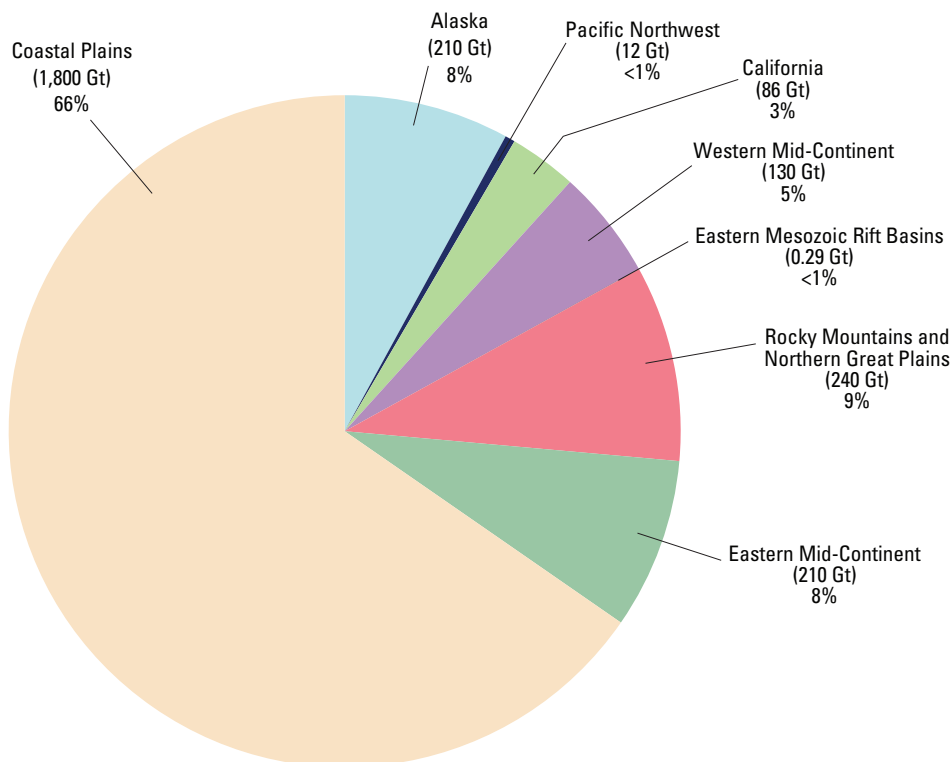


Figure 8. Pie charts showing mean estimates of (A) buoyant trapping storage resources and (B) residual trapping class 2 storage resources for carbon dioxide (CO₂) in the United States, by region. Resources in federally owned offshore areas were not assessed. Mean values sum to totals but are reported to only two significant figures. Gt, gigatons.

Table 4. Mean estimates by the U.S. Geological Survey in 2012 for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in deep storage assessment units (SAUs) in the United States.

[Estimates are in millions of metric tons (megatons, Mt). Mean values sum to totals but are reported to only two significant figures. Deep SAUs are at depths greater than 13,000 feet (3,962 meters). The 46 deep SAUs are in 13 basins]

Basin name	TA_{SR} in deep SAUs (Mt)	Percent of basin TA_{SR}	Percent of national TA_{SR}
Alaska North Slope	56,000	21	2
Anadarko and Southern Oklahoma Basins	25,000	40	1
Bighorn Basin	350	20	0
Greater Green River Basin	20,000	52	1
Hanna, Laramie, and Shirley Basins	730	32	0
Los Angeles Basin	740	20	0
Permian Basin	19,000	31	1
San Joaquin Basin	1,400	3	0
Uinta and Piceance Basins	710	19	0
U.S. Gulf Coast	310,000	18	11
Williston Basin	11,000	7	0
Wind River Basin	1,400	17	0
Wyoming-Idaho-Utah Thrust Belt	24,000	54	1
Total	470,000		16

Comparison of Results with Findings from Previous Assessments

These USGS basin-scale assessment results are comparable with findings from other assessments of geologic CO_2 storage capacities of the United States and North America. Most notable are the DOE NETL Regional Carbon Sequestration Partnerships assessments and carbon sequestration atlases of the U.S. Department of Energy, National Energy Technology Laboratory (2008, 2010, 2012) and the North American Carbon Atlas Partnership (2012). For a review of the USGS, DOE NETL, and other CO_2 storage assessment methodologies, see Spencer and others (2011), Popova and others (2012), Prelicz and others (2012), and U.S. Department of Energy, National Energy Technology Laboratory (2012). The USGS assessment methodology (Brennan and others, 2010; Blondes, Brennan, and others, 2013) and assessment results are unique among the various assessments mentioned above, because the USGS methodology is fully probabilistic and better accounts for the range of uncertainties found in geologic settings. Another key difference between the USGS and previous assessments is that the USGS assessment reports resources for individual SAUs located within defined basins of the United States. In addition, unlike the other assessments, the USGS only assessed buoyant traps that meet the minimum depth criteria of 3,000 ft (914 m) and that have an overlying regional seal as described in Brennan and others (2010) and Blondes, Brennan, and others (2013). Also, the USGS assessment results are statistically

aggregated at the basin, region, and national scales. Results reported by the previous U.S. Department of Energy, National Energy Technology Laboratory (2008, 2010, 2012) assessments are regional and include regional results from areas within Canada. The North American Carbon Atlas Partnership (2012) reports CO_2 storage resources for Canada, Mexico, and the United States. Although the USGS and DOE NETL assessment methodologies and implementations are different, both USGS and DOE assessment efforts have identified geologic storage resources on the order of thousands of gigatons of CO_2 within the United States.

Conclusions

The U.S. Geological Survey recently 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 TA_{SR} is an estimate of the geologic storage resource that may be available for CO_2 injection and storage and is based on current geologic and hydrologic knowledge of the subsurface and current engineering practices. Following the assessment methodology of Brennan and others (2010) and Blondes, Brennan, and others (2013), the assessment team members obtained a mean estimate of approximately 3,000 gigatons (Gt) of subsurface CO_2 storage capacity that is technically accessible in onshore areas and State waters; this amount is more than 500 times the 2011 annual U.S. energy-related CO_2 emissions of 5.5 Gt (U.S. Energy Information Administration, 2012b).

The estimate of the TA_{SR} includes buoyant trapping storage and three classes of residual trapping storage. Buoyant trapping storage of CO_2 can occur in structural or stratigraphic closures, for which the USGS team obtained a mean estimate of 44 Gt of storage; that amount is approximately eight times the annual energy-related CO_2 emissions that were estimated by the U.S. Energy Information Administration (2012b), and this assessment indicates that the use of residual trapping storage resources for CO_2 will be required to significantly reduce anthropogenic CO_2 emissions into the atmosphere during the next few decades. Known hydrocarbon recovery volumes indicate that the CO_2 storage resources (KRR_{SR}) available in petroleum reservoirs within the assessed areas range from approximately 11 Gt at the P_5 probability percentile to as much as 15 Gt at the P_{95} probability percentile, with a mean of 13 Gt. For CO_2 that is held in place by capillary pore pressures (residual trapping) in areas outside of buoyant traps, three injectivity classes were defined on the basis of reservoir permeability. These classes include (1) residual trapping class 1 for rocks with very high permeability, defined as permeability greater than 1 D; (2) residual trapping class 2 for rocks with moderate permeability, defined as permeability between 1 mD and 1 D; and (3) residual trapping class 3 for the remainder of rocks in the storage formation that have low permeability, defined as permeability less than 1 mD. The mean estimated storage capacities for the three residual storage classes follow: residual trapping class 1 has 140 Gt; residual trapping class 2 has 2,700 Gt; and residual trapping class 3 has 130 Gt.

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Glossary

The following definitions are modified from Brennan and others (2010) and other sources indicated.

barrels of oil equivalent (BOE) A unit of petroleum volume in which the gas part is expressed in terms of its energy equivalent in barrels of oil. For this assessment, the energy equivalent (not the volume equivalent) of 6,000 cubic feet of natural gas equals 1 barrel of oil equivalent (Klett and others, 2005).

buoyancy Upward force on one phase (for example, a fluid) produced by the surrounding fluid (for example, a liquid or a gas) in which it is fully or partially immersed, caused by differences in density.

buoyant trapping A trapping mechanism by which CO₂ is held in place by a top and lateral seal (either a sealing formation or a sealing fault), creating a column of CO₂ in communication across pore space.

buoyant trapping pore volume (B_{pv}) A geologically determined, probabilistic distribution of the volume fraction of the storage formation (SF) that can store CO₂ by buoyant trapping. This distribution minimum is typically defined by existing plus forecast undiscovered oil and gas production volumes. The maximum is probabilistically calculated from distributions of geologic parameters describing the known trapping structures within the storage formation.

buoyant trapping storage efficiency (B_{se}) A distribution of efficiency values that describe the fraction of buoyant trapping that can occur within a volume of porous media. The values used in the methodology for this assessment (0.2 min, 0.3 most likely, and 0.4 max) are discussed in Blondes, Brennan, and others (2013).

buoyant trapping storage resource (B_{sr}) The mass of CO₂ retained in the storage formation by buoyant trapping.

buoyant trapping storage volume (B_{sv}) The volume of CO₂ retained in the storage formation by buoyant trapping.

carbon sequestration Both natural and deliberate processes by which CO₂ is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediment), and geologic formations.

enhanced oil recovery Injection of steam, gas, or other chemical compounds into hydrocarbon reservoirs to stimulate the production of usable oil beyond what is possible through natural pressure, water injection, and pumping at the wellhead.

federally owned offshore areas Federal jurisdiction begins at 3 geographic (nautical) miles from the established baseline

for the coast and extends to an outer limit of 200 nautical miles. However, there are special cases. Because of claims existing at the dates of statehood, Texas and the Gulf Coast of Florida have proprietary interest in a submerged belt of land, 9 geographic miles wide, extending seaward along the coast (Thormahlen, 1999). Resource assessments in federally owned offshore areas are typically done by the Bureau of Ocean Energy Management (BOEM).

gas:oil ratio (GOR) Ratio of gas to oil (in cubic feet per barrel) in a hydrocarbon accumulation. GOR is calculated by using volumes of gas and oil at surface conditions.

gas reservoir A subsurface accumulation of hydrocarbons primarily in the gas phase that is contained in porous or fractured rock formations. A gas accumulation is defined by the USGS (Klett and others, 2005) as having a gas:oil ratio of 20,000 cubic feet per barrel or greater.

geologic storage of CO₂ A type of carbon sequestration that utilizes the long-term retention of carbon dioxide in subsurface geologic formations.

injectivity The “Schlumberger Oilfield Glossary” (Schlumberger, 2011) defines an injectivity test as a procedure that is used to determine “the rate and pressure at which fluids can be pumped into the treatment target without fracturing the formation.” Although injectivity is typically reported as a rate, the methodology used in this assessment addresses this requirement by using permeability values to divide the residual storage component of the storage formation into three classes; *see* residual trapping classes 1, 2, and 3. The permeability is a proxy for injectivity because actual CO₂ injection rate data are generally limited to enhanced-oil-recovery operations using CO₂ and are not available for various reservoir types.

known recovery production volumes The cumulative petroleum production and proved reserves for a given reservoir.

known recovery replacement storage resource (KRR_{sr}) The storage resource calculated from known recovery production volumes.

minimum size The lower limit for inclusion of oil and gas field information in assessment calculations. Following USGS oil and gas assessment methodology (Schmoker and Klett, 2005), volumetric data from accumulations with less than 0.5 million barrels of oil equivalent total production were not included in any of the calculations in the methodology used for this assessment.

National Oil and Gas Assessment (NOGA) U.S. Geological Survey National Oil and Gas Assessment, described at <http://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment.aspx>.

oil reservoir A subsurface accumulation of hydrocarbons composed primarily of oil that is contained in porous or fractured rock formations. An oil accumulation is defined by the USGS (Klett and others, 2005) as having a gas:oil ratio less than 20,000 cubic feet per barrel.

percentile In values sorted by increasing magnitude, any of the 99 dividers that produce exactly 100 groups with equal number of values (Everitt and Skron dal, 2010). The dividers are used to denote the proportion of values above and below them. The dividers are sequential integer numbers starting from the one between the two groups with the lowest values. For example, in the modeling of sequestration capacity, a 95th percentile of 10 Gt denotes that 10 Gt divides all likely values into 95 percent of them below 10 Gt and 5 percent above it.

permeability (k) A measure of the ability of a rock to permit fluids to be transmitted through it; it is controlled by pore size, pore throat geometry, and pore connectivity. Permeability is typically reported in darcies.

porosity (ϕ) The part of a rock that is occupied by voids or pores. Pores can be connected by passages called pore throats, which allow for fluid flow, or pores can be isolated and inaccessible to fluid flow. Porosity is typically reported as a volume, fraction, or percentage of the rock.

porosity of the net porous interval (ϕ_{pi}) For this assessment, three values (minimum, most likely, and maximum) were estimated for the mean porosity of each net porous interval. The determination by the assessment geologist of how much porosity was sufficient to allow storage of CO₂ was dependent on the geology of the storage formation, and this dependence did not allow for a fixed threshold.

pressure gradient The change in pore pressure per unit depth, typically in units of pound-force per square inch per foot (psi/ft), kilopascals per meter (kPa/m), or bars per meter (bar/m).

residual trapping A mechanism by which CO₂ is trapped as discrete droplets, blobs, or ganglia of CO₂ as a nonwetting phase, essentially immiscible with the wetting fluid, within individual pores where the capillary forces overcome the buoyant forces.

residual trapping class 1 ($R1$) Storage formation rock with permeability greater than 1 darcy that is available for residual trapping.

residual trapping class 2 ($R2$) Storage formation rock with permeability ranging from 1 millidarcy to 1 darcy that is available for residual trapping.

residual trapping class 3 ($R3$) Storage formation rock with permeability less than 1 millidarcy that is available for residual trapping.

residual trapping pore volume (R_{pv}) A calculated value equal to the storage formation pore volume (SF_{pv}) minus the buoyant trapping pore volume (B_{pv}). The value represents the pore volume within the storage formation that can be used to store CO₂ by residual trapping; it is calculated during iterations of

the Monte Carlo simulator after a value from the buoyant trapping pore volume distribution is randomly chosen by the simulator program (@RISK; version 5.7 is commercially available from Palisade Corporation: <http://www.palisade.com/risk/>). Calculations were made for the three residual trapping classes $R1$, $R2$, and $R3$ to obtain $R1_{pv}$, $R2_{pv}$, and $R3_{pv}$.

residual trapping storage efficiency (R_{se}) A distribution of efficiency values that describes the fraction of residual trapping that can occur within a volume of porous media. The values used in the methodology for this assessment to define the distribution were calculated for each storage assessment unit by using equations from MacMinn and others (2010) and regional pressure and temperature data (Blondes, Brennan, and others, 2013). Calculations were made for the three residual trapping classes $R1$, $R2$, and $R3$ to obtain $R1_{se}$, $R2_{se}$, and $R3_{se}$.

residual trapping storage resource (R_{sr}) The mass of CO₂ retained in the storage formation by residual trapping. Calculations were made for the three residual trapping classes $R1$, $R2$, and $R3$ to obtain $R1_{sr}$, $R2_{sr}$, and $R3_{sr}$.

residual trapping storage volume (R_{sv}) The volume of CO₂ retained in the storage formation by residual trapping. Calculations were made for the three residual trapping classes $R1$, $R2$, and $R3$ to obtain $R1_{sv}$, $R2_{sv}$, and $R3_{sv}$.

seal A geologic feature that inhibits the mixing or migration of fluids and gases between adjacent geologic units. A seal is typically a rock unit or a fault; it can be a top seal, inhibiting upward flow of buoyant fluids, or a lateral seal, inhibiting the lateral flow of buoyant fluids.

seal formation The confining rock unit within the storage assessment unit. The seal formation is a rock unit that sufficiently overlies the storage formation and where managed properly has a capillary entrance pressure low enough to effectively inhibit the upward buoyant flow of CO₂.

State waters State jurisdiction begins at the established baseline for the coast and extends 3 geographic (nautical) miles. However, there are special cases. Because of claims existing at the dates of statehood, Texas and the Gulf Coast of Florida have proprietary interest in a submerged belt of land, 9 geographic miles wide, extending seaward along the coast (Thormahlen, 1999).

storage assessment unit (SAU) A mappable volume of rock that includes two main components: (1) the storage formation (SF), which is a reservoir for CO₂ storage, and (2) a regional seal formation.

storage assessment unit code For each storage assessment unit, the nine-digit code (shown in table 3) identifies the USGS-specific storage assessment unit. The preceding letter “C” refers to a carbon dioxide storage assessment unit and distinguishes it from USGS National Oil and Gas Assessment (NOGA) Project assessment units that may have similar numbers. The first digit after “C” of the code denotes the world region number (5), the following three digits (034) denote the North America NOGA province number, the following two

digits (C5034xx) denote the basin number (always 01 unless there is more than one basin in each province). The last two digits (C503401xx) denote the storage assessment unit number of that particular basin. In this report, the NOGA province and basin names are the same.

storage efficiency factor (B_{SE} and R_{SE}) Values representing the fraction of the total available pore space that will be occupied by free-phase CO_2 . Ranges of storage efficiency are specific to trapping types. The two used in this assessment were buoyant trapping storage efficiency (B_{SE}) and residual trapping storage efficiency (R_{SE}).

storage formation (SF) The reservoir of the storage assessment unit. The storage formation consist of sedimentary rock layers that are saturated with formation water having total dissolved solids (TDS) greater than 10,000 mg/L. In the CO_2 assessment methodology, the storage formation resource calculation is the main resource calculation and consists of two parts: a buoyant trapping resource and a residual trapping resource.

storage formation pore volume (SF_{pv}) The available pore space in the storage formation calculated from the area of the storage formation within the SAU and the thickness and porosity of the net porous interval. This value was used in the calculation of the residual trapping pore volume (R_{pv}).

technically accessible storage resource (TA_{SR}) The mass of CO_2 that may be injected and stored using present-day

geologic and hydrologic knowledge of the subsurface and engineering practices. This term is analogous to the term “technically recoverable resource” used in USGS oil and gas assessments.

technically accessible storage volume (TA_{sv}) The volume of CO_2 that may be injected and stored using present-day geologic and hydrologic knowledge of the subsurface and engineering practices.

thickness of the net porous interval (T_{pi}) Defined in the methodology for this assessment as the mean net stratigraphic thickness of the portion of the storage formation that the assessment geologist determined contained an appropriate lithology with sufficient porosity to store CO_2 . Three values (minimum, most likely, and maximum) were estimated for the mean thickness of each net porous interval.

total dissolved solids (TDS) The quantity of dissolved material in a sample of water, usually expressed in milligrams per liter (mg/L).

total petroleum system (TPS) A total petroleum system consists of all genetically related petroleum generated by a pod or closely related pods of mature source rocks. Particular emphasis is placed on similarities of the fluids of petroleum accumulations (Schmoker and Klett, 2005).

trapping The physical and geochemical processes by which injected CO_2 is retained in the subsurface.

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States

Estimates are in millions of metric tons (megatons, Mt). P_5 , P_{50} , and P_{95} are probability percentiles and represent the 5-, 50-, and 95-percent probabilities, respectively, that the true storage resource is less than the value shown. The percentiles were calculated by using the aggregation method described in the “Aggregation” section of this report and in Blondes, Schuenemeyer, and others (2013). Percentile values do not sum to totals because the aggregation procedure used partial dependencies between storage assessment units. Mean values sum to totals but are reported to only two significant figures if the value is greater than 1 Mt and are rounded to the nearest 0.1 Mt if the value is less than 1 Mt. For each storage assessment unit, the nine-digit code identifies the USGS-specific SAU. Components of the code are explained in the “Glossary.” A complete set of input parameters and results for each SAU, along with plots of the probability distributions for each SAU, is available in the companion assessment data publication (U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013a). Basins are listed alphabetically. NQ, nonquantitative SAU.

26 National Assessment of Geologic Carbon Dioxide Storage Resources—Results

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.

SAU code	SAU name	KRR_{SR}				B_{SR}				$R1_{SR}$			
		Known recovery replacement storage resource				Buoyant trapping storage resource				Residual trapping class 1 storage resource			
		P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
Alaska North Slope (C5001)													
C50010101	Endicott Group - LCU Truncation	16	20	25	20	17	23	52	28	33	45	58	45
C50010102	Endicott Group - Kayak Shale	9.4	12	15	12	10	14	37	18	2.2	5.0	7.3	4.9
C50010103	Lower Ellesmerian	0.0	0.0	0.0	0.0	0.6	21	720	180	0.0	0.0	0.0	0.0
C50010104	Lower Ellesmerian Deep	13	16	20	16	23	150	2,800	680	0.0	0.0	0.0	0.0
C50010105	Lower Ellesmerian - LCU Truncation	0.0	0.0	0.0	0.0	0.1	1.8	47	11	0.0	0.0	0.0	0.0
C50010106	Beaufortian and Upper Ellesmerian	660	860	1,100	860	910	1,200	2,400	1,400	0.0	0.0	0.0	0.0
C50010107	Lower Torok Formation	0.1	0.1	0.2	0.1	550	4,600	52,000	13,000	0.0	0.0	0.0	0.0
C50010108	Upper Torok Formation	0.0	0.0	0.0	0.0	110	430	4,400	1,100	0.0	0.0	0.0	0.0
C50010109	Nanushuk Formation	0.0	0.0	0.0	0.0	33	140	2,000	510	0.0	0.0	0.0	0.0
C50010110	Tuluvak Formation	0.0	0.0	0.0	0.0	21	71	430	130	0.0	0.0	0.0	0.0
C50010111	Lower Seabee Formation	0.0	0.0	0.0	0.0	9.1	27	110	40	0.0	0.0	0.0	0.0
C50010112	Middle Schrader Bluff Formation	0.0	0.0	0.0	0.0	8.8	31	160	51	19	32	48	32
C50010113	Canning Formation	0.0	0.0	0.0	0.0	25	34	46	35	0.0	0.0	0.0	0.0
C50010114	Staines Tongue	0.0	0.0	0.0	0.0	14	160	1,800	460	440	690	1,000	700
Aggregated totals		700	910	1,100	910	2,400	8,600	62,000	18,000	510	770	1,100	760
Anadarko and Southern Oklahoma Basins (C5058)													
C50580101	Lower Paleozoic Composite	21	30	41	30	25	38	230	79	450	920	1,700	990
C50580102	Lower Paleozoic Composite Deep	3.1	4.4	6.0	4.4	4.0	7.2	48	15	0.0	0.0	0.0	0.0
C50580103	Hunton Group and Misener Sandstone	8.0	12	17	12	10	16	57	23	0.0	0.0	0.0	0.0
C50580104	Hunton Group and Misener Sandstone Deep	27	38	50	38	31	42	100	53	0.0	0.0	0.0	0.0
C50580105	Mississippian Composite	110	180	270	180	730	1,000	2,200	1,300	0.0	0.0	0.0	0.0
C50580106	Mississippian Composite Deep	18	24	30	24	140	210	530	260	0.0	0.0	0.0	0.0
C50580107	Lower Virgilian	0.0	0.0	0.0	0.0	0.0	0.5	24	6.4	0.0	0.0	0.0	0.0
C50580108	Chase and Council Grove Groups	12	16	21	16	13	18	110	45	0.0	0.0	0.0	0.0
Aggregated totals		220	300	420	310	1,000	1,400	3,300	1,700	450	920	1,700	990
Appalachian Basin (C5067)													
C50670101	Ordovician and Cambrian Composite	12	17	24	18	17	28	150	50	160	270	440	280
C50670102	Clinton, Medina, and Tuscarora Formations	0.7	1.0	1.5	1.1	2.6	15	110	31	0.0	0.0	0.0	0.0
C50670103	McKenzie, Lockport, and Newburg Formations	0.2	0.2	0.3	0.2	0.4	2.1	17	4.6	0.0	0.0	0.0	0.0
C50670104	Oriskany Sandstone	6.4	8.9	12	9.1	11	18	130	40	0.0	0.0	0.0	0.0
Aggregated totals		21	28	37	28	38	79	370	130	160	270	440	280
Arkoma Basin (C5062)													
C50620101	Ordovician Composite	3.7	5.2	7.3	5.3	4.4	6.4	26	11	0.0	0.0	0.0	0.0
C50620102	Hunton Group	0.0	0.0	0.0	0.0	3.0	9.8	32	13	0.0	0.0	0.0	0.0
C50620103	Batesville Sandstone and Wedington Sandstone Member	0.0	0.0	0.0	0.0	4.1	7.8	15	8.3	0.0	0.0	0.0	0.0
Aggregated totals		3.7	5.2	7.3	5.3	14	25	66	31	0.0	0.0	0.0	0.0

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.—Continued

$R2_{SR}$ Residual trapping class 2 storage resource				$R3_{SR}$ Residual trapping class 3 storage resource				TA_{SR} Technically accessible storage resource			
P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
Alaska North Slope (C5001)—Continued											
160	210	260	210	0.1	1.6	5.8	2.1	210	280	370	280
350	480	650	490	0.8	9.5	35	13	370	510	710	520
7,700	13,000	21,000	13,000	210	2,600	10,000	3,500	9,300	16,000	28,000	17,000
25,000	39,000	57,000	40,000	900	12,000	44,000	16,000	30,000	52,000	93,000	56,000
1,900	2,800	4,000	2,900	0.8	13	51	18	1,900	2,800	4,100	2,900
13,000	21,000	33,000	22,000	12	160	620	220	15,000	23,000	35,000	24,000
65,000	100,000	150,000	100,000	1,300	17,000	65,000	23,000	77,000	130,000	240,000	140,000
5,700	9,200	14,000	9,400	120	1,500	5,700	2,000	6,800	12,000	21,000	13,000
1,100	1,800	2,800	1,900	6.2	82	310	110	1,200	2,200	4,600	2,500
460	640	860	650	7.9	100	370	130	560	860	1,500	910
120	150	180	150	2.5	31	110	41	150	220	350	230
280	450	660	460	0.6	7.2	27	9.6	330	530	850	550
81	110	150	110	1.8	24	87	31	120	170	250	180
6,900	10,000	14,000	10,000	11	150	550	200	7,600	11,000	17,000	12,000
150,000	200,000	280,000	210,000	7,600	38,000	110,000	45,000	170,000	260,000	400,000	270,000
Anadarko and Southern Oklahoma Basins (C5058)—Continued											
2,500	5,300	9,800	5,600	0.0	0.0	0.0	0.0	3,200	6,300	11,000	6,600
8,400	15,000	25,000	15,000	16	220	860	300	8,600	15,000	26,000	16,000
760	1,700	3,500	1,900	0.8	11	42	15	780	1,800	3,600	1,900
2,800	4,400	6,800	4,500	53	670	2,500	890	3,300	5,300	8,400	5,500
7,200	18,000	42,000	21,000	23	300	1,200	420	8,400	20,000	44,000	22,000
2,100	3,100	4,500	3,100	36	470	1,700	620	2,500	3,900	6,100	4,000
1,600	2,900	4,800	3,000	0.0	0.0	0.0	0.0	1,600	2,900	4,800	3,000
1,900	2,600	3,600	2,700	33	430	1,600	570	2,200	3,200	4,700	3,300
34,000	55,000	88,000	57,000	670	2,500	6,100	2,800	38,000	60,000	96,000	62,000
Appalachian Basin (C5067)—Continued											
3,000	4,800	7,700	5,000	38	490	1,900	660	3,500	5,700	9,300	6,000
7,200	11,000	18,000	12,000	14	190	700	250	7,300	12,000	18,000	12,000
1,000	1,600	2,400	1,600	0.0	0.2	0.9	0.3	1,000	1,600	2,400	1,600
250	550	1,000	580	6.4	87	360	120	300	680	1,400	740
13,000	18,000	27,000	19,000	180	840	2,500	1,000	14,000	20,000	29,000	20,000
Arkoma Basin (C5062)—Continued											
3,100	6,500	12,000	6,900	25	330	1,200	440	3,400	6,900	13,000	7,400
190	400	730	420	1.9	24	89	32	220	440	800	460
30	66	130	71	0.1	1.1	4.2	1.5	37	75	140	80
3,500	7,000	13,000	7,400	39	360	1,300	480	3,800	7,500	13,000	7,900

28 National Assessment of Geologic Carbon Dioxide Storage Resources—Results

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.

SAU code	SAU name	<i>KRR_{SR}</i> Known recovery replacement storage resource				<i>B_{SR}</i> Buoyant trapping storage resource				<i>R1_{SR}</i> Residual trapping class 1 storage resource			
		P ₅	P ₅₀	P ₉₅	Mean	P ₅	P ₅₀	P ₉₅	Mean	P ₅	P ₅₀	P ₉₅	Mean
Atlantic Coastal Plain (C5070)													
C50700101	Lower Cretaceous Composite	0.0	0.0	0.0	0.0	39	100	270	120	1,800	2,900	4,500	3,000
C50700102	Upper Cretaceous Composite	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	130	180	240	190
Aggregated totals		0.0	0.0	0.0	0.0	39	100	270	120	2,000	3,100	4,700	3,200
Bend Arch and Fort Worth Basin (C5045)													
C50450101	Chappel Limestone and Ellenburger Group	3.2	4.3	5.8	4.4	4.4	8.2	43	14	0.0	0.0	0.0	0.0
C50450102	Bend Group and Comyn Formation	210	280	370	280	220	290	460	330	330	660	1,100	680
Aggregated totals		210	290	370	290	230	310	500	340	330	660	1,100	680
Bighorn Basin (C5034)													
C50340101	Tensleep Sandstone	30	40	53	41	34	44	56	45	0.0	0.0	0.0	0.0
C50340102	Tensleep Sandstone Deep	0.0	0.0	0.0	0.0	0.2	0.6	1.7	0.7	0.0	0.0	0.0	0.0
C50340103	Ervay Member	17	23	31	24	20	26	50	30	0.0	0.0	0.0	0.0
C50340104	Ervay Member Deep	0.0	0.0	0.0	0.0	0.1	0.8	9.0	2.2	0.0	0.0	0.0	0.0
C50340105	Crow Mountain Sandstone	0.0	0.0	0.0	0.0	0.3	2.0	12	3.6	0.0	0.0	0.0	0.0
C50340106	Crow Mountain Sandstone Deep	0.0	0.0	0.0	0.0	0.1	0.8	4.2	1.3	0.0	0.0	0.0	0.0
C50340107	Cloverly Formation	0.4	0.6	0.8	0.6	0.5	1.1	52	17	0.0	0.0	0.0	0.0
C50340108	Cloverly Formation Deep	0.0	0.0	0.0	0.0	0.0	0.1	6.6	1.8	0.0	0.0	0.0	0.0
C50340109	Muddy Sandstone	6.3	8.9	12	9.0	7.4	9.8	23	12	0.0	0.0	0.0	0.0
C50340110	Muddy Sandstone Deep	0.1	0.1	0.1	0.1	0.1	0.2	1.3	0.4	0.0	0.0	0.0	0.0
C50340111	Frontier Sandstone	14	19	25	19	16	23	71	32	0.0	0.0	0.0	0.0
C50340112	Frontier Sandstone Deep	0.0	0.0	0.0	0.0	0.2	1.6	14	3.6	0.0	0.0	0.0	0.0
Aggregated totals		75	93	110	93	89	120	290	150	0.0	0.0	0.0	0.0
Black Warrior Basin (C5065)													
C50650101	Lewis Sandstone	0.0	0.1	0.1	0.1	0.1	0.3	1.4	0.5	0.0	0.0	0.0	0.0
C50650102	Parkwood Formation	14	22	32	23	13	17	29	19	0.0	0.0	0.0	0.0
Aggregated totals		14	23	32	23	13	17	30	19	0.0	0.0	0.0	0.0
Central California Coast Basins (C5011)													
C50110101	Vaqueros Sandstone (NQ)	--	--	--	--	--	--	--	--	--	--	--	--
Aggregated totals		--	--	--	--	--	--	--	--	--	--	--	--
Columbia Basin of Oregon, Washington, and Idaho (C5005)													
C50050101	Eocene-Oligocene Composite (NQ)	--	--	--	--	--	--	--	--	--	--	--	--
C50050102	Eocene-Oligocene Composite Deep (NQ)	--	--	--	--	--	--	--	--	--	--	--	--
Aggregated totals		--	--	--	--	--	--	--	--	--	--	--	--
Denver Basin (C5039)													
C50390101	Plainview and Lytle Formations	0.2	0.3	0.4	0.3	1.9	29	480	120	0.0	0.0	0.0	0.0
C50390102	Muddy Sandstone	68	91	120	93	73	98	230	130	35	100	250	120
C50390103	Greenhorn Limestone	0.0	0.0	0.0	0.0	0.0	0.3	5.2	1.3	0.0	0.0	0.0	0.0
C50390104	Niobrara Formation and Codell Sandstone	0.1	0.1	0.1	0.1	16	26	87	36	0.0	0.0	0.0	0.0
C50390105	Terry and Hygiene Sandstone Members	6.4	8.5	11	8.6	7.1	9.6	21	11	0.0	0.0	0.0	0.0
Aggregated totals		76	100	130	100	110	170	850	300	35	100	250	120

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.—Continued

$R2_{SR}$ Residual trapping class 2 storage resource				$R3_{SR}$ Residual trapping class 3 storage resource				TA_{SR} Technically accessible storage resource			
P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
Atlantic Coastal Plain (C5070)—Continued											
6,600	10,000	16,000	11,000	0.0	0.1	4.7	1.1	8,800	13,000	20,000	14,000
200	270	340	270	0.0	0.0	0.0	0.0	350	450	570	450
6,900	11,000	16,000	11,000	0.0	0.1	4.7	1.1	9,200	14,000	20,000	14,000
Bend Arch and Fort Worth Basin (C5045)—Continued											
1,200	2,700	5,800	3,000	50	650	2,600	900	1,500	3,500	7,500	3,900
5,300	9,700	16,000	10,000	30	400	1,500	540	6,500	11,000	18,000	12,000
7,000	13,000	20,000	13,000	170	1,100	3,800	1,400	8,600	15,000	24,000	15,000
Bighorn Basin (C5034)—Continued											
1.7	23	93	32	0.0	0.1	0.7	0.2	43	68	140	77
0.1	1.3	5.2	1.8	0.0	1.2	10	2.6	0.7	3.5	16	5.2
94	170	290	180	0.2	2.6	11	3.6	120	200	340	210
29	52	93	56	0.6	8.0	32	11	34	64	120	69
160	250	360	250	0.4	4.7	17	6.2	160	260	380	260
27	45	72	47	0.6	7.4	28	10	32	56	94	58
39	260	860	330	0.1	1.5	10	2.8	44	270	910	350
2.2	29	100	37	0.2	7.1	54	15	3.5	40	150	54
8.2	42	120	50	0.0	0.4	2.6	0.8	18	54	140	63
0.1	1.8	6.7	2.4	0.0	0.9	7.1	1.8	0.4	3.3	14	4.6
240	410	710	440	0.2	3.3	13	4.7	260	450	770	470
76	110	160	110	2.5	32	120	43	92	150	260	160
890	1,500	2,400	1,500	21	86	230	100	1,100	1,700	2,800	1,800
Black Warrior Basin (C5065)—Continued											
43	76	120	79	0.0	0.6	2.3	0.8	43	77	130	80
120	200	340	210	0.1	1.4	5.4	1.9	130	220	370	230
170	280	450	290	0.2	2.1	7.2	2.7	180	300	480	310
Central California Coast Basins (C5011)—Continued											
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Columbia Basin of Oregon, Washington, and Idaho (C5005)—Continued											
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Denver Basin (C5039)—Continued											
180	510	1,100	570	12	160	740	240	280	790	2,000	930
730	2,100	4,900	2,300	0.5	6.8	32	10	880	2,300	5,300	2,600
3.3	7.8	17	8.6	0.9	11	48	16	6.8	21	63	26
5.0	12	26	13	1.2	16	67	23	29	59	150	72
16	33	63	35	0.3	4.6	18	6.4	27	49	90	53
1,000	2,700	5,900	3,000	37	210	830	300	1,400	3,300	7,200	3,700

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.

SAU code	SAU name	KRR_{SR}				B_{SR}				$R1_{SR}$			
		Known recovery replacement storage resource				Buoyant trapping storage resource				Residual trapping class 1 storage resource			
		P ₅	P ₅₀	P ₉₅	Mean	P ₅	P ₅₀	P ₉₅	Mean	P ₅	P ₅₀	P ₉₅	Mean
Eastern Great Basin (C5019)													
C50190101	Joana Limestone (NQ)	--	--	--	--	--	--	--	--	--	--	--	--
C50190102	Navajo Sandstone	0.9	1.2	1.6	1.2	1.2	2.2	23	6.6	0.0	0.0	0.0	0.0
Aggregated totals		0.9	1.2	1.6	1.2	1.2	2.2	23	6.6	0.0	0.0	0.0	0.0
Eastern Mesozoic Rift Basins (C5068)													
C50680101	Stockton Formation	0.0	0.0	0.0	0.0	1.3	2.0	19	5.9	0.0	0.0	0.0	0.0
C50680201	New Oxford Formation (NQ)	--	--	--	--	--	--	--	--	--	--	--	--
C50680301	Manassas Sandstone (NQ)	--	--	--	--	--	--	--	--	--	--	--	--
Aggregated totals		0.0	0.0	0.0	0.0	1.3	2.0	19	5.9	0.0	0.0	0.0	0.0
Greater Green River Basin (C5037)													
C50370101	Paleozoic Composite	12	16	21	16	14	21	51	25	0.0	0.0	0.0	0.0
C50370102	Paleozoic Composite Deep	9.1	12	15	12	11	24	450	120	0.0	0.0	0.0	0.0
C50370103	Nugget Sandstone	0.4	0.7	0.9	0.7	1.1	3.1	13	4.6	0.0	0.0	0.0	0.0
C50370104	Nugget Sandstone Deep	1.4	1.8	2.3	1.8	2.1	8.2	170	42	0.0	0.0	0.0	0.0
C50370105	Muddy Sandstone and Cloverly Formation	81	120	160	120	93	120	160	120	0.0	0.0	0.0	0.0
C50370106	Muddy Sandstone and Cloverly Formation Deep	4.6	6.0	7.4	6.0	5.2	7.1	21	9.7	0.0	0.0	0.0	0.0
C50370107	Frontier Sandstone	190	260	380	270	210	270	380	290	0.0	0.0	0.0	0.0
C50370108	Frontier Sandstone Deep	0.3	0.4	0.5	0.4	0.5	2.2	27	6.8	0.0	0.0	0.0	0.0
C50370109	Hilliard, Baxter, and Mancos Shales	2.2	3.2	4.6	3.3	2.6	3.8	28	9.9	0.0	0.0	0.0	0.0
C50370110	Hilliard, Baxter, and Mancos Shales Deep	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.6	0.0	0.0	0.0	0.0
C50370111	Mesaverde Group	21	30	42	30	23	31	89	47	0.0	0.0	0.0	0.0
C50370112	Mesaverde Group Deep	0.0	0.0	0.0	0.0	0.0	0.7	28	7.1	0.0	0.0	0.0	0.0
C50370113	Dad Member	31	44	64	45	35	47	75	50	0.0	0.0	0.0	0.0
C50370114	Dad Member Deep	0.1	0.1	0.1	0.1	0.1	0.2	2.1	0.6	0.0	0.0	0.0	0.0
Aggregated totals		380	500	650	500	440	580	1,500	740	0.0	0.0	0.0	0.0
Hanna, Laramie, and Shirley Basins (C5030)													
C50300101	Paleozoic Composite	0.4	0.6	0.8	0.6	0.7	2.2	23	6.1	5.2	12	23	12
C50300102	Paleozoic Composite Deep	0.0	0.0	0.0	0.0	0.0	0.3	3.2	0.8	0.0	0.0	0.0	0.0
C50300103	Muddy Sandstone and Cloverly Formation	0.4	0.5	0.7	0.5	0.4	0.6	17	5.8	0.0	0.0	0.0	0.0
C50300104	Muddy Sandstone and Cloverly Formation Deep	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.7	0.0	0.0	0.0	0.0
C50300105	Frontier Sandstone	0.0	0.0	0.0	0.0	0.0	0.1	0.7	0.2	0.0	0.0	0.0	0.0
C50300106	Frontier Sandstone Deep	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0
C50300107	Shannon Sandstone Member	0.0	0.0	0.0	0.0	0.1	0.3	1.3	0.5	0.0	0.0	0.0	0.0
C50300108	Shannon Sandstone Member Deep	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.2	0.0	0.0	0.0	0.0
C50300109	Mesaverde Formation	0.0	0.0	0.0	0.0	4.6	34	240	68	0.0	0.0	0.0	0.0
C50300110	Mesaverde Formation Deep	0.0	0.0	0.0	0.0	0.3	3.4	35	9.0	0.0	0.0	0.0	0.0
C50300111	Dad Member	0.0	0.0	0.0	0.0	3.0	15	79	25	0.0	0.0	0.0	0.0
C50300112	Dad Member Deep	0.0	0.0	0.0	0.0	0.3	1.7	12	3.3	0.0	0.0	0.0	0.0
Aggregated totals		0.9	1.1	1.4	1.1	17	74	370	120	5.2	12	23	12

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.—Continued

$R2_{SR}$ Residual trapping class 2 storage resource				$R3_{SR}$ Residual trapping class 3 storage resource				TA_{SR} Technically accessible storage resource			
P₅	P₅₀	P₉₅	Mean	P₅	P₅₀	P₉₅	Mean	P₅	P₅₀	P₉₅	Mean
Eastern Great Basin (C5019)—Continued											
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80	170	360	190	1.9	24	97	34	98	210	430	230
80	170	360	190	1.9	24	97	34	98	210	430	230
Eastern Mesozoic Rift Basins (C5068)—Continued											
130	280	510	290	7.6	100	410	140	180	400	830	440
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130	280	510	290	7.6	100	410	140	180	400	830	440
Greater Green River Basin (C5037)—Continued											
760	1,500	2,900	1,600	17	230	890	310	930	1,800	3,400	1,900
3,700	7,000	12,000	7,400	180	2,300	9,500	3,300	4,900	9,900	20,000	11,000
200	420	770	440	0.7	9.5	37	13	210	440	790	460
4,300	6,000	8,500	6,200	71	910	3,300	1,200	4,800	7,200	11,000	7,400
170	740	1,800	820	1.7	28	150	45	300	900	2,000	990
330	720	1,500	790	0.5	6.7	30	9.8	340	740	1,500	810
110	280	670	320	3.3	45	210	68	380	620	1,200	680
0.0	0.0	0.0	0.0	6.3	92	470	150	9.4	98	490	150
2,400	4,300	7,300	4,500	51	650	2,500	870	2,900	5,200	8,700	5,400
140	280	440	290	16	210	840	290	220	500	1,200	580
4,200	7,100	11,000	7,300	45	580	2,200	780	4,700	7,900	12,000	8,100
170	280	430	290	13	170	660	230	230	470	1,000	530
460	920	1,700	970	4.7	62	250	86	550	1,000	1,900	1,100
17	58	120	62	2.0	30	150	47	25	95	250	110
21,000	30,000	43,000	31,000	1,700	6,200	17,000	7,400	26,000	38,000	57,000	39,000
Hanna, Laramie, and Shirley Basins (C5030)—Continued											
180	370	710	400	0.1	0.9	3.6	1.2	190	390	750	420
16	79	200	90	0.6	11	60	18	20	95	250	110
5.3	70	270	95	0.0	0.6	4.5	1.2	6.9	75	290	100
0.7	8.6	32	12	0.1	2.0	16	4.2	1.0	12	47	16
65	130	230	130	0.1	1.8	7.3	2.5	67	130	230	140
10	16	23	16	0.8	10	37	14	14	27	56	30
16	77	200	89	0.3	4.4	25	7.5	17	84	220	97
4.0	14	30	15	0.5	7.9	39	12	6.6	24	63	28
170	560	1,200	610	0.3	4.9	23	7.4	210	630	1,400	690
290	480	680	480	1.6	21	77	28	310	510	740	520
27	89	190	96	0.1	0.8	3.6	1.2	40	110	240	120
12	21	32	21	0.5	7.0	27	9.5	16	31	60	34
1,100	2,000	3,200	2,100	25	91	240	110	1,300	2,200	3,600	2,300

32 National Assessment of Geologic Carbon Dioxide Storage Resources—Results

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.

SAU code	SAU name	KRR_{SR}				B_{SR}				$R1_{SR}$			
		Known recovery replacement storage resource				Buoyant trapping storage resource				Residual trapping class 1 storage resource			
		P ₅	P ₅₀	P ₉₅	Mean	P ₅	P ₅₀	P ₉₅	Mean	P ₅	P ₅₀	P ₉₅	Mean
Illinois Basin (C5064)													
C50640101	Mount Simon Sandstone	0.0	0.0	0.0	0.0	53	230	1,100	370	840	1,400	2,200	1,400
C50640102	Ordovician Composite	26	33	41	33	27	37	120	55	0.0	0.0	0.0	0.0
C50640103	Devonian and Silurian Composite	41	52	65	52	5.0	6.9	15	8.0	37	72	110	72
Aggregated totals		69	85	100	85	94	290	1,300	440	900	1,400	2,300	1,500
Kandik Basin (C5002)													
C50020101	Nation River Formation	0.0	0.0	0.0	0.0	0.3	4.3	59	14	0.0	0.0	0.0	0.0
C50020102	Step Conglomerate and Tahkandit Limestone	0.0	0.0	0.0	0.0	0.3	5.3	97	23	0.0	0.0	0.0	0.0
Aggregated totals		0.0	0.0	0.0	0.0	1.1	13	150	38	0.0	0.0	0.0	0.0
Kansas Basins (C5056)													
C50560101	Lower Paleozoic Composite	3.8	4.9	6.0	4.9	3.9	5.2	8.2	5.5	0.0	0.0	0.0	0.0
C50560102	Hunton Group	0.6	0.8	1.0	0.8	0.7	0.9	1.4	0.9	0.0	0.0	0.0	0.0
Aggregated totals		4.5	5.6	6.9	5.7	4.8	6.1	9.2	6.5	0.0	0.0	0.0	0.0
Los Angeles Basin (C5014)													
C50140101	Repetto and Puente Formations	9.7	13	16	13	42	73	130	79	66	130	230	130
C50140102	Repetto and Puente Formations Deep	0.0	0.0	0.0	0.0	0.5	1.6	5.1	2.0	0.0	0.0	0.0	0.0
Aggregated totals		10	13	16	13	43	75	140	81	66	130	230	130
Michigan Basin (C5063)													
C50630101	Ordovician and Cambrian Composite	41	55	71	55	55	95	420	150	2,700	4,500	6,800	4,600
C50630102	Salina Group and Middle Silurian Composite	83	110	140	110	110	150	410	190	0.0	0.0	0.0	0.0
C50630103	Sylvania and Bois Blanc Formations and Bass Islands Dolomite (NQ)	--	--	--	--	--	--	--	--	--	--	--	--
C50630104	Dundee Formation	9.8	12	15	12	10	13	29	16	29	38	51	39
Aggregated totals		140	180	220	180	190	280	790	360	2,800	4,500	6,800	4,600
Palo Duro Basin (C5043)													
C50430101	Basin Center Paleozoic Composite	1.0	1.4	1.7	1.4	1.2	1.8	9.9	3.6	29	55	95	57
C50430102	Basin Flank Paleozoic Composite	58	77	99	78	0.1	0.8	8.5	2.2	38	57	80	58
C50430103	Basin Center Permian	56	74	96	75	0.0	0.5	15	3.6	0.0	0.0	0.0	0.0
Aggregated totals		120	150	190	150	1.6	4.1	32	9.3	72	110	170	120
Paradox Basin (C5021)													
C50210101	Paleozoic Composite	36	51	71	52	45	63	160	78	0.0	0.0	0.0	0.0
Aggregated totals		36	51	71	52	45	63	160	78	0.0	0.0	0.0	0.0
Permian Basin (C5044)													
C50440101	Lower Paleozoic Composite	470	680	960	690	640	860	1,800	1,100	1,400	2,800	5,300	3,000
C50440102	Lower Paleozoic Composite Deep	330	430	550	440	440	570	860	620	610	1,000	1,600	1,000
C50440103	Permian Composite	160	210	270	210	420	560	1,200	680	39	75	130	77
Aggregated totals		1,000	1,300	1,700	1,300	1,600	2,000	4,000	2,400	2,200	3,900	6,700	4,100

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.—Continued

$R2_{SR}$ Residual trapping class 2 storage resource				$R3_{SR}$ Residual trapping class 3 storage resource				TA_{SR} Technically accessible storage resource			
P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
Illinois Basin (C5064)—Continued											
59,000	86,000	130,000	88,000	190	2,500	8,900	3,200	62,000	91,000	130,000	94,000
37,000	53,000	74,000	53,000	150	1,900	7,000	2,500	38,000	55,000	77,000	56,000
2,300	3,600	5,200	3,600	16	210	790	280	2,500	3,900	5,800	4,000
110,000	140,000	200,000	150,000	1,000	5,100	14,000	6,100	110,000	150,000	210,000	150,000
Kandik Basin (C5002)—Continued											
200	580	1,200	620	5.0	74	350	110	240	690	1,400	740
180	530	1,200	580	5.4	77	350	120	220	660	1,500	720
480	1,100	2,200	1,200	22	170	630	230	570	1,400	2,700	1,500
Kansas Basins (C5056)—Continued											
130	240	420	250	0.9	11	47	16	140	260	450	270
25	44	75	46	0.1	0.7	2.9	1.0	26	46	77	48
160	280	480	300	1.5	12	48	17	180	300	510	320
Los Angeles Basin (C5014)—Continued											
1,400	2,600	4,700	2,800	0.0	0.1	0.7	0.2	1,600	2,800	5,000	3,000
580	730	910	740	0.1	1.4	5.6	2.0	580	740	920	740
2,000	3,300	5,600	3,500	0.1	1.6	6.2	2.2	2,200	3,500	5,800	3,700
Michigan Basin (C5063)—Continued											
19,000	29,000	43,000	30,000	210	2,600	9,500	3,400	24,000	37,000	54,000	38,000
11,000	17,000	26,000	17,000	40	520	1,900	700	12,000	18,000	27,000	18,000
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360	480	620	480	2.6	34	120	44	430	570	760	580
33,000	47,000	66,000	48,000	560	3,300	11,000	4,200	40,000	56,000	78,000	57,000
Palo Duro Basin (C5043)—Continued											
1,000	1,800	3,100	1,900	0.4	6.1	24	8.4	1,000	1,900	3,200	2,000
1,200	1,700	2,200	1,700	0.6	8.6	31	11	1,300	1,700	2,300	1,800
2,200	3,300	4,800	3,400	2.7	35	130	48	2,200	3,300	4,900	3,400
4,900	6,900	9,400	7,000	9.0	56	170	67	5,100	7,100	9,600	7,200
Paradox Basin (C5021)—Continued											
1,000	2,500	5,300	2,800	28	380	1,600	530	1,300	3,100	6,300	3,400
1,000	2,500	5,300	2,800	28	380	1,600	530	1,300	3,100	6,300	3,400
Permian Basin (C5044)—Continued											
12,000	24,000	45,000	26,000	63	850	3,400	1,200	16,000	29,000	53,000	31,000
10,000	16,000	23,000	16,000	53	690	2,500	910	12,000	18,000	27,000	19,000
4,700	8,000	13,000	8,300	30	400	1,600	550	5,500	9,200	15,000	9,600
31,000	48,000	75,000	50,000	460	2,200	6,400	2,600	37,000	57,000	89,000	59,000

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.

SAU code	SAU name	KRR_{SR}				B_{SR}				$R1_{SR}$			
		Known recovery replacement storage resource				Buoyant trapping storage resource				Residual trapping class 1 storage resource			
		P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
Powder River Basin (C5033)													
C50330101	Minnelusa and Tensleep Sandstones	32	43	57	43	35	48	130	64	0.0	0.0	0.0	0.0
C50330102	Crow Mountain Sandstone	0.0	0.0	0.0	0.0	0.0	0.3	3.1	0.8	0.0	0.0	0.0	0.0
C50330103	Lower Sundance Formation	1.2	1.6	2.1	1.6	1.3	1.7	5.0	2.5	0.0	0.0	0.0	0.0
C50330104	Fall River and Lakota Formations	7.8	11	14	11	13	33	170	56	0.0	0.0	0.0	0.0
C50330105	Muddy Sandstone	27	37	50	38	33	48	220	81	0.3	1.8	4.1	2.0
C50330106	Frontier Sandstone and Turner Sandy Member	6.4	8.8	12	8.9	7.2	10	37	16	0.0	0.0	0.0	0.0
C50330107	Sussex and Shannon Sandstone Members	8.6	11	15	11	9.0	12	30	16	0.0	0.0	0.0	0.0
C50330108	Parkman Sandstone Member	2.2	2.9	3.6	2.9	2.4	3.2	32	19	0.0	0.0	0.0	0.0
C50330109	Teapot Sandstone Member	1.2	1.6	2.0	1.6	1.3	1.8	18	10	0.0	0.0	0.0	0.0
C50330110	Teckla Sandstone Member	1.1	1.4	1.8	1.4	1.2	1.6	21	12	0.0	0.0	0.0	0.0
Aggregated totals		96	120	150	120	120	180	710	280	0.3	1.8	4.1	2.0
Raton Basin (C5041)													
C50410101	Dakota Sandstone (NQ)	--	--	--	--	--	--	--	--	--	--	--	--
Aggregated totals		--	--	--	--	--	--	--	--	--	--	--	--
Sacramento Basin (C5009)													
C50090101	Kione Sands of Forbes Formation	0.0	0.0	0.0	0.0	0.1	0.6	7.0	1.8	0.0	0.0	0.0	0.0
C50090102	Winters Formation	16	26	39	26	20	28	67	36	340	570	890	590
C50090103	Starkey Sands of the Moreno Formation	2.2	3.4	5.1	3.5	3.1	4.8	45	14	0.0	0.0	0.0	0.0
C50090104	Mokelumne River Formation	11	16	22	16	13	18	44	23	96	160	260	170
C50090105	Domengine Formation	2.2	3.0	3.9	3.0	2.7	3.7	9.9	4.7	0.0	0.0	0.0	0.0
Aggregated totals		34	48	67	49	42	57	180	80	460	740	1,100	760
San Joaquin Basin (C5010)													
C50100101	Lathrop Sand of the Panoche Formation	0.6	0.9	1.4	1.0	0.8	1.2	11	3.5	410	720	1,100	730
C50100102	Moreno Formation Sands	1.4	2.2	3.4	2.3	1.8	2.6	12	4.5	300	520	800	530
C50100103	Domengine Formation	0.1	0.2	0.2	0.2	1.0	6.3	43	12	0.0	0.0	0.0	0.0
C50100104	Temblor Formation	14	20	26	20	19	42	530	140	320	630	1,100	650
C50100105	Temblor Formation Deep	0.0	0.0	0.0	0.0	0.1	1.7	23	5.6	0.0	0.0	0.0	0.0
C50100106	Stevens Sand of the Monterey Formation	0.4	0.6	0.7	0.6	0.9	12	400	97	320	560	850	570
C50100107	Stevens Sand of the Monterey Formation Deep	0.6	0.7	0.9	0.8	0.7	1.3	14	3.8	0.0	0.0	0.0	0.0
Aggregated totals		18	24	32	25	31	98	980	270	1,600	2,400	3,400	2,500
San Juan Basin (C5022)													
C50220101	Entrada Sandstone	0.2	0.2	0.3	0.2	0.2	0.4	1.5	0.6	3.8	8.4	17	9.1
C50220102	Dakota Sandstone	0.5	0.6	0.9	0.7	0.6	0.9	4.8	1.6	0.0	0.0	0.0	0.0
C50220103	Gallup Sandstone	8.6	11	15	11	9.1	12	26	15	0.0	0.0	0.0	0.0
C50220104	Lewis Shale and Mesaverde Group	0.0	0.0	0.0	0.0	0.8	1.1	3.5	1.8	0.0	0.0	0.0	0.0
Aggregated totals		9.4	12	16	12	11	15	37	19	3.8	8.4	17	9.1

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.—Continued

<i>R2_{SR}</i> Residual trapping class 2 storage resource				<i>R3_{SR}</i> Residual trapping class 3 storage resource				<i>TA_{SR}</i> Technically accessible storage resource			
P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
Powder River Basin (C5033)—Continued											
2,900	4,800	7,600	5,000	0.2	3.4	14	4.8	2,900	4,900	7,700	5,100
15	41	92	45	0.1	0.8	3.8	1.2	15	42	96	47
610	1,400	2,600	1,500	0.0	0.0	0.3	0.1	610	1,400	2,600	1,500
1,500	2,600	4,300	2,700	0.0	0.0	0.3	0.0	1,500	2,600	4,400	2,700
340	740	1,500	800	0.3	4.9	21	7.1	390	810	1,700	890
1,000	1,900	3,400	2,000	3.3	43	180	60	1,100	1,900	3,500	2,100
430	880	1,800	970	3.8	50	220	72	470	970	1,900	1,100
1,100	3,000	5,800	3,200	1.8	28	130	41	1,200	3,000	5,900	3,200
420	1,100	2,100	1,200	0.8	11	50	16	430	1,100	2,200	1,200
15	200	750	260	0.1	1.7	13	3.6	18	210	790	280
11,000	17,000	25,000	18,000	39	170	510	210	11,000	18,000	26,000	18,000
Raton Basin (C5041)—Continued											
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Sacramento Basin (C5009)—Continued											
930	1,300	2,000	1,400	0.0	0.0	0.0	0.0	930	1,300	2,000	1,400
5,900	9,900	15,000	10,000	0.0	0.0	1.5	0.3	6,400	10,000	16,000	11,000
7,400	12,000	17,000	12,000	0.0	2.0	9.2	2.9	7,400	12,000	17,000	12,000
1,900	3,000	4,500	3,100	0.0	0.0	0.0	0.0	2,100	3,200	4,800	3,300
1,500	2,200	3,200	2,200	0.0	0.0	0.0	0.0	1,500	2,200	3,200	2,200
19,000	28,000	39,000	29,000	0.0	2.3	10	3.2	20,000	29,000	40,000	29,000
San Joaquin Basin (C5010)—Continued											
9,600	16,000	23,000	16,000	0.0	0.0	0.0	0.0	10,000	17,000	24,000	17,000
6,900	11,000	17,000	12,000	0.0	0.0	0.0	0.0	7,400	12,000	17,000	12,000
200	400	730	420	1.2	16	60	21	210	430	780	450
7,300	13,000	21,000	13,000	0.0	0.0	0.0	0.0	7,900	14,000	22,000	14,000
800	1,100	1,400	1,100	3.3	44	150	56	840	1,100	1,500	1,100
3,200	5,300	7,800	5,400	0.1	2.2	11	3.4	3,700	5,900	8,700	6,000
160	250	340	250	3.0	39	150	52	190	290	460	300
33,000	48,000	65,000	48,000	25	120	300	130	36,000	51,000	69,000	51,000
San Juan Basin (C5022)—Continued											
140	290	550	310	0.0	0.0	0.0	0.0	150	300	570	320
33	62	110	66	1.4	18	70	25	43	86	170	93
82	190	410	210	0.0	0.1	0.5	0.2	93	210	430	230
46	82	140	85	0.7	9.2	36	13	53	95	160	100
380	640	1,100	670	5.2	30	94	37	430	710	1,200	740

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.

SAU code	SAU name	KRR_{SR}				B_{SR}				$R1_{SR}$			
		Known recovery replacement storage resource				Buoyant trapping storage resource				Residual trapping class 1 storage resource			
		P ₅	P ₅₀	P ₉₅	Mean	P ₅	P ₅₀	P ₉₅	Mean	P ₅	P ₅₀	P ₉₅	Mean
South Florida Basin (C5050)													
C50500101	Pre-Punta Gorda	0.0	0.0	0.0	0.0	3.7	51	710	170	0.0	0.0	0.0	0.0
C50500102	Sunniland Formation	6.7	8.5	10	8.5	8.9	21	95	32	0.0	0.0	0.0	0.0
C50500103	Gordon Pass and Marco Junction Formations	0.0	0.0	0.0	0.0	0.1	2.5	68	17	0.0	0.0	0.0	0.0
C50500104	Dollar Bay Formation	0.0	0.0	0.0	0.0	0.2	2.5	38	9.2	0.0	0.0	0.0	0.0
C50500105	Cedar Keys and Lawson Formations	0.0	0.0	0.0	0.0	0.0	0.0	13	8.0	0.0	0.0	0.0	0.0
Aggregated totals		6.7	8.5	10	8.5	21	97	900	240	0.0	0.0	0.0	0.0
Uinta and Piceance Basins (C5020)													
C50200101	Paleozoic Composite	31	42	56	43	35	48	98	56	0.0	0.0	0.0	0.0
C50200102	Paleozoic Composite Deep	0.0	0.0	0.0	0.0	0.0	0.3	6.7	1.6	0.0	0.0	0.0	0.0
C50200103	Lower Cretaceous Composite	4.3	6.1	8.4	6.2	5.2	7.4	21	9.7	0.0	0.0	0.0	0.0
C50200104	Lower Cretaceous Composite Deep	0.7	1.0	1.3	1.0	1.0	1.5	3.8	1.9	0.0	0.0	0.0	0.0
C50200105	Green River Formation	6.9	9.2	12	9.2	1.3	9.0	160	40	0.0	0.0	0.0	0.0
Aggregated totals		46	58	75	59	47	73	280	110	0.0	0.0	0.0	0.0
U.S. Gulf Coast (C5047 and C5049)													
C50490101	Norphlet Formation	0.1	0.1	0.1	0.1	35	48	63	48	0.0	0.0	0.0	0.0
C50490102	Norphlet Formation Deep	63	82	100	83	81	130	560	210	0.0	0.0	0.0	0.0
C50490103	Smackover Formation	70	97	130	99	82	120	550	210	0.0	0.0	0.0	0.0
C50490104	Smackover Formation Deep	140	180	240	190	160	220	630	290	0.0	0.0	0.0	0.0
C50490105	Haynesville Formation	180	250	340	250	200	260	370	270	0.0	0.0	0.0	0.0
C50490106	Haynesville Formation Deep	44	57	71	57	48	61	76	62	0.0	0.0	0.0	0.0
C50490107	Sligo and Hosston Formations and Cotton Valley Group	1,300	1,800	2,600	1,900	1,400	2,000	6,600	3,200	23,000	42,000	70,000	44,000
C50490108	Sligo and Hosston Formations and Cotton Valley Group Deep	46	60	75	60	56	90	520	170	0.0	0.0	0.0	0.0
C50490109	Knowles and Winn Limestones and Calvin Sandstone (NQ)	--	--	--	--	--	--	--	--	--	--	--	--
C50490110	Rodessa Formation and James Limestone	160	220	310	230	180	240	390	260	150	320	670	350
C50490111	Rodessa Formation and James Limestone Deep	8.3	11	13	11	9.3	13	43	19	0.0	0.0	0.0	0.0
C50490112	Fredericksburg Group and Rusk Formation	43	59	81	60	50	70	180	89	470	900	1,800	990
C50490113	Edwards, Glen Rose, and James Limestones	10	15	21	15	13	18	31	19	0.0	0.0	0.0	0.0
C50490114	Washita and Fredericksburg Groups, Rusk Formation, and James Limestone	56	81	110	83	66	92	390	160	0.0	0.0	0.0	0.0

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.—Continued

$R2_{SR}$ Residual trapping class 2 storage resource				$R3_{SR}$ Residual trapping class 3 storage resource				TA_{SR} Technically accessible storage resource			
P₅	P₅₀	P₉₅	Mean	P₅	P₅₀	P₉₅	Mean	P₅	P₅₀	P₉₅	Mean
South Florida Basin (C5050)—Continued											
66,000	100,000	140,000	100,000	300	3,800	14,000	5,100	69,000	100,000	150,000	110,000
1,100	1,200	1,400	1,200	0.0	0.0	0.2	0.0	1,100	1,300	1,500	1,300
19,000	27,000	36,000	27,000	180	2,400	8,600	3,100	21,000	30,000	41,000	30,000
4,200	6,400	9,000	6,400	46	600	2,200	790	4,600	7,100	10,000	7,200
18,000	21,000	24,000	21,000	0.0	0.0	0.0	0.0	18,000	21,000	24,000	21,000
120,000	160,000	200,000	160,000	1,400	7,600	21,000	9,000	120,000	160,000	210,000	170,000
Uinta and Piceance Basins (C5020)—Continued											
590	1,100	1,900	1,100	14	180	690	240	750	1,400	2,400	1,400
0.0	0.0	0.0	0.0	32	420	1,600	560	34	430	1,600	560
250	470	790	490	13	180	670	240	340	680	1,300	730
33	62	110	65	4.5	60	240	83	53	130	320	150
260	490	910	530	17	220	900	310	360	780	1,700	880
1,300	2,200	3,300	2,200	290	1,200	3,300	1,400	2,000	3,500	6,300	3,800
U.S. Gulf Coast (C5047 and C5049)—Continued											
31,000	50,000	76,000	51,000	0.0	0.0	0.0	0.0	31,000	50,000	76,000	52,000
25,000	43,000	68,000	44,000	0.0	0.0	0.0	0.0	25,000	43,000	68,000	45,000
7,900	15,000	27,000	16,000	40	520	2,100	720	8,500	16,000	29,000	17,000
21,000	31,000	47,000	32,000	94	1,200	4,500	1,600	22,000	33,000	50,000	34,000
2,800	4,600	7,200	4,700	66	850	3,200	1,100	3,600	5,900	9,500	6,100
2,200	3,800	5,900	3,900	75	970	3,700	1,300	2,800	5,000	8,700	5,200
310,000	520,000	820,000	540,000	1,100	14,000	50,000	18,000	370,000	590,000	910,000	610,000
160,000	210,000	280,000	210,000	590	7,600	27,000	9,900	170,000	220,000	300,000	220,000
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3,700	6,900	13,000	7,500	2.8	43	170	59	4,200	7,600	14,000	8,200
2,000	3,300	5,500	3,400	3.9	52	200	71	2,100	3,300	5,600	3,500
5,800	9,800	17,000	10,000	5.6	75	290	100	6,600	11,000	19,000	12,000
290	520	890	550	2.8	37	140	50	340	590	990	610
2,000	4,100	8,000	4,500	13	170	690	240	2,200	4,500	8,800	4,900

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SAU code	SAU name	KRR_{SR}				B_{SR}				$R1_{SR}$			
		Known recovery replacement storage resource				Buoyant trapping storage resource				Residual trapping class 1 storage resource			
		P ₅	P ₅₀	P ₉₅	Mean	P ₅	P ₅₀	P ₉₅	Mean	P ₅	P ₅₀	P ₉₅	Mean
U.S. Gulf Coast (C5047 and C5049)—Continued													
C50490115	Washita and Fredericksburg Groups, Rusk Formation, and James Limestone Deep	37	48	58	48	39	52	77	54	0.0	0.0	0.0	0.0
C50490116	Tuscaloosa and Woodbine Formations	290	400	530	400	350	520	1,500	680	5,000	9,700	19,000	11,000
C50490117	Navarro, Taylor, and Austin Groups	120	170	240	180	150	200	480	250	0.0	0.0	0.0	0.0
C50470118	Carrizo Sand and Wilcox Group	860	1,200	1,700	1,300	1,100	1,600	6,500	2,500	1,200	2,300	4,900	2,600
C50470119	Queen City Sand	28	40	55	40	37	58	200	80	13	39	95	44
C50470120	Sparta Sand	2.7	3.6	4.5	3.6	1.2	9.8	230	57	180	350	680	380
C50470121	Yegua and Cockfield Formations	400	540	720	550	420	580	2,400	1,000	2,900	5,200	9,700	5,600
C50470122	Frio and Vicksburg Formations	1,100	1,600	2,200	1,600	1,400	2,100	15,000	4,900	7,000	15,000	30,000	17,000
C50470123	Lower Miocene I	100	150	200	150	150	250	830	340	6,500	13,000	22,000	13,000
C50470124	Lower Miocene II	180	250	350	260	230	350	1,100	460	7,000	13,000	21,000	13,000
C50470125	Middle Miocene	130	180	250	180	210	350	810	410	2,300	4,200	7,000	4,400
C50470126	Upper Miocene	230	310	410	310	250	330	500	350	3,900	7,100	12,000	7,300
C50470127	Tertiary Slope and Basin Floor (NQ)	--	--	--	--	--	--	--	--	--	--	--	--
Aggregated totals		6,400	8,000	9,800	8,000	7,800	11,000	39,000	16,000	75,000	120,000	170,000	120,000
Ventura Basin (C5013)													
C50130101	Vaqueros Sandstone and Sespe Formation	23	32	43	32	29	52	290	93	76	160	300	170
Aggregated totals		23	32	43	32	29	52	290	93	76	160	300	170
Western Oregon and Washington Basins (C5004)													
C50040101	Eocene Composite	0.0	0.0	0.0	0.0	0.1	1.5	35	8.2	860	1,600	2,700	1,700
Aggregated totals		0.0	0.0	0.0	0.0	0.1	1.5	35	8.2	860	1,600	2,700	1,700
Williston Basin (C5031)													
C50310101	Deadwood and Black Island Formations	0.3	0.4	0.5	0.4	0.6	4.4	64	15	910	1,800	3,400	1,900
C50310102	Deadwood and Black Island Formations Deep	2.9	3.8	4.6	3.8	3.2	4.8	22	7.9	0.0	0.0	0.0	0.0
C50310103	Winnipegosis Formation, Interlake Formation, and Bighorn Group	25	33	45	34	27	37	190	76	0.0	0.0	0.0	0.0
C50310104	Three Forks Formation and Jefferson Group	5.6	7.6	10	7.7	7.3	11	56	20	0.0	0.0	0.0	0.0
C50310105	Kibbey Formation and Madison Group	110	140	170	140	110	140	230	160	220	470	820	490
C50310106	Minnelusa Group	0.9	1.1	1.4	1.1	1.0	1.6	18	5.4	0.0	0.0	0.0	0.0
C50310107	Lower Swift Formation	0.0	0.0	0.0	0.0	39	150	540	200	0.0	0.0	0.0	0.0
C50310108	Inyan Kara Group	0.0	0.0	0.0	0.0	31	150	700	230	240	410	610	410
C50310109	Newcastle Formation	0.0	0.0	0.0	0.0	39	130	450	170	0.0	0.0	0.0	0.0
Aggregated totals		150	180	230	180	340	710	2,000	880	1,600	2,700	4,400	2,800

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.—Continued

$R2_{SR}$ Residual trapping class 2 storage resource				$R3_{SR}$ Residual trapping class 3 storage resource				TA_{SR} Technically accessible storage resource			
P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
U.S. Gulf Coast (C5047 and C5049)—Continued											
410	740	1,300	780	9.0	120	460	160	520	940	1,600	990
41,000	69,000	120,000	73,000	9.2	140	550	190	49,000	80,000	140,000	85,000
15,000	26,000	46,000	28,000	0.0	0.0	0.0	0.0	15,000	26,000	47,000	28,000
120,000	200,000	350,000	210,000	49	660	2,500	880	120,000	210,000	360,000	220,000
1,600	3,800	8,300	4,200	1.0	13	56	19	1,700	3,900	8,500	4,300
6,600	11,000	18,000	11,000	0.0	0.0	2.4	0.4	6,800	11,000	19,000	12,000
33,000	53,000	85,000	55,000	1.8	39	160	55	37,000	59,000	94,000	62,000
75,000	140,000	260,000	150,000	0.5	100	420	140	87,000	160,000	290,000	170,000
24,000	41,000	67,000	42,000	0.0	0.0	0.0	0.0	33,000	54,000	85,000	56,000
26,000	43,000	68,000	44,000	0.0	0.0	0.0	0.0	36,000	56,000	85,000	58,000
8,900	14,000	22,000	15,000	0.0	0.0	0.0	0.0	13,000	19,000	28,000	20,000
15,000	24,000	37,000	25,000	0.0	0.0	0.0	0.0	21,000	32,000	46,000	32,000
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1,100,000	1,600,000	2,200,000	1,600,000	6,600	30,000	83,000	35,000	1,300,000	1,700,000	2,400,000	1,800,000
Ventura Basin (C5013)—Continued											
3,100	5,500	9,200	5,700	0.5	9.0	35	12	3,200	5,700	9,600	6,000
3,100	5,500	9,200	5,700	0.5	9.0	35	12	3,200	5,700	9,600	6,000
Western Oregon and Washington Basins (C5004)—Continued											
6,600	12,000	20,000	12,000	0.6	9.5	43	14	7,500	14,000	22,000	14,000
6,600	12,000	20,000	12,000	0.6	9.5	43	14	7,500	14,000	22,000	14,000
Williston Basin (C5031)—Continued											
8,600	16,000	29,000	17,000	86	1,200	4,500	1,600	11,000	20,000	34,000	21,000
8,200	11,000	14,000	11,000	0.0	2.2	9.8	3.2	8,200	11,000	14,000	11,000
38,000	58,000	81,000	59,000	140	1,800	6,700	2,400	40,000	60,000	85,000	61,000
6,500	9,900	14,000	10,000	0.0	0.0	0.0	0.0	6,600	9,900	14,000	10,000
8,500	15,000	24,000	15,000	110	1,500	5,700	2,000	10,000	17,000	28,000	18,000
6,600	9,700	13,000	9,800	0.0	2.8	12	4.1	6,600	9,700	13,000	9,800
3,800	5,800	8,800	6,000	0.0	0.0	0.6	0.1	3,900	6,000	9,100	6,200
4,000	6,800	10,000	6,900	1.8	26	99	34	4,400	7,400	11,000	7,600
830	1,500	2,500	1,600	0.0	0.0	0.0	0.0	920	1,700	2,800	1,700
99,000	140,000	180,000	140,000	1,100	5,200	14,000	6,000	110,000	140,000	190,000	150,000

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.

SAU code	SAU name	KRR_{SR} Known recovery replacement storage resource				B_{SR} Buoyant trapping storage resource				$R1_{SR}$ Residual trapping class 1 storage resource			
		P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
Wind River Basin (C5035)													
C50350101	Tensleep Sandstone	6.0	7.9	10	8.0	7.8	12	41	17	0.6	1.4	3.3	1.6
C50350102	Tensleep Sandstone Deep	0.0	0.0	0.0	0.0	0.3	2.6	24	6.2	0.0	0.0	0.0	0.0
C50350103	Nugget and Crow Mountain Sandstones	0.5	0.7	0.9	0.7	0.8	1.8	9.5	3.1	0.0	0.0	0.0	0.0
C50350104	Nugget and Crow Mountain Sandstones Deep	0.0	0.0	0.0	0.0	0.0	0.3	3.8	0.9	0.0	0.0	0.0	0.0
C50350105	Cloverly Formation	2.5	3.6	5.1	3.7	3.1	4.1	22	9.0	0.0	0.0	0.0	0.0
C50350106	Cloverly Formation Deep	0.1	0.2	0.2	0.2	0.1	0.3	12	3.8	0.0	0.0	0.0	0.0
C50350107	Muddy Sandstone	3.0	4.1	5.4	4.1	3.4	4.4	12	6.2	0.0	0.0	0.0	0.0
C50350108	Muddy Sandstone Deep	0.8	1.0	1.4	1.1	0.9	1.1	4.3	2.1	0.0	0.0	0.0	0.0
C50350109	Frontier Sandstone	6.0	8.7	12	8.8	7.2	9.4	15	10	0.0	0.0	0.0	0.0
C50350110	Frontier Sandstone Deep	1.4	1.9	2.5	1.9	1.6	2.0	2.8	2.1	0.0	0.0	0.0	0.0
C50350111	Sussex and Shannon Sandstone Members	0.4	0.5	0.6	0.5	0.4	0.7	11	3.1	0.0	0.0	0.0	0.0
C50350112	Sussex and Shannon Sandstone Members Deep	6.6	8.8	11	8.9	7.1	9.5	31	15	0.0	0.0	0.0	0.0
C50350113	Fort Union and Lance Formations	19	28	38	28	23	30	85	48	0.0	0.0	0.0	0.0
Aggregated totals		52	66	81	66	63	86	280	130	0.6	1.4	3.3	1.6
Wyoming-Idaho-Utah Thrust Belt (C5036)													
C50360101	Paleozoic Composite	73	100	140	110	84	110	200	120	0.0	0.0	0.0	0.0
C50360102	Paleozoic Composite Deep	68	88	110	88	72	94	150	100	0.0	0.0	0.0	0.0
C50360103	Nugget Sandstone	82	110	150	110	89	110	140	110	0.0	0.0	0.0	0.0
C50360104	Nugget Sandstone Deep	2.4	3.1	4.0	3.2	2.8	4.0	10	5.0	0.0	0.0	0.0	0.0
C50360105	Bear River Formation	0.0	0.0	0.0	0.0	14	33	79	38	0.0	0.0	0.0	0.0
C50360106	Bear River Formation Deep	0.0	0.0	0.0	0.0	0.3	1.8	13	3.6	0.0	0.0	0.0	0.0
C50360107	Frontier Sandstone	1.7	2.4	3.4	2.4	1.9	2.7	19	7.7	0.0	0.0	0.0	0.0
C50360108	Frontier Sandstone Deep	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Aggregated totals		240	310	390	310	290	370	600	400	0.0	0.0	0.0	0.0

Table 3. Estimates by the U.S. Geological Survey in 2012 of basin and storage assessment unit (SAU) totals for technically accessible storage resources (TA_{SR}) for carbon dioxide (CO_2) in the United States.—Continued

$R2_{SR}$ Residual trapping class 2 storage resource				$R3_{SR}$ Residual trapping class 3 storage resource				TA_{SR} Technically accessible storage resource			
P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean	P_5	P_{50}	P_{95}	Mean
Wind River Basin (C5035)—Continued											
48	110	240	120	0.0	0.0	0.0	0.0	60	130	270	140
6.3	20	56	24	0.8	12	63	19	12	40	120	50
130	220	370	230	0.0	0.0	0.0	0.0	130	220	370	230
120	200	320	210	2.5	31	120	42	140	240	400	250
91	320	740	350	0.1	1.9	9.4	2.9	97	330	770	370
210	350	520	350	7.5	100	370	130	260	470	810	490
37	120	250	130	0.1	1.1	5.4	1.7	42	130	270	140
23	62	110	64	1.1	16	70	23	30	82	170	89
69	160	350	180	0.1	1.2	5.3	1.7	80	170	370	190
23	62	150	71	2.6	36	180	57	37	110	310	130
400	880	1,600	910	0.0	0.2	0.8	0.2	400	880	1,600	920
81	190	320	200	7.8	110	450	150	130	320	730	360
2,100	4,200	7,500	4,400	13	170	670	240	2,300	4,500	7,900	4,700
4,100	7,100	11,000	7,300	150	580	1,500	670	4,600	7,800	12,000	8,100
Wyoming-Idaho-Utah Thrust Belt (C5036)—Continued											
4,400	7,800	12,000	8,000	72	930	3,600	1,300	5,100	9,000	15,000	9,400
5,500	11,000	18,000	11,000	140	1,900	7,600	2,600	6,600	13,000	23,000	14,000
5,700	9,500	14,000	9,600	16	210	790	280	6,000	9,800	15,000	10,000
5,500	9,400	15,000	9,600	4.9	73	290	100	5,600	9,500	15,000	9,700
210	410	690	430	9.8	130	500	180	300	600	1,100	640
190	340	510	350	11	140	530	190	260	500	950	540
45	130	330	150	1.4	19	99	31	56	160	410	190
55	120	210	130	4.7	65	270	92	79	190	440	220
26,000	39,000	55,000	39,000	780	3,800	12,000	4,700	28,000	43,000	63,000	44,000

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