Helpful definitions related to geologic carbon dioxide (CO_2) sequestration

The following definitions are modified from the glossaries of Brennan and others (2010) and the U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team (2013). Refer to these reports for the complete citations of other sources mentioned below.

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 CO_2 is held in place by a top and lateral seal (either a sealing formation or a sealing fault), creating a column of CO_2 in communication across pore space.

buoyant trapping pore volume: A geologically determined, probabilistic distribution of the volume fraction of the storage formation (SF) that can store CO_2 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: 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 USGS assessment methodology (0.2 min, 0.3 most likely, and 0.4 max) are discussed in Blondes, Brennan, and others (2013).

buoyant trapping storage resource: The mass of CO_2 retained in the storage formation by buoyant trapping.

buoyant trapping storage volume: The volume of CO_2 retained in the storage formation by buoyant trapping.

U.S. Department of the Interior
U.S. Geological Survey
Energy Resources Program
http://energy.usgs.gov
February 2019

Project website
http://go.usa.gov/8X8

carbon sequestration: Both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediment), and subsurface geologic formations.

enhanced oil recovery (EOR): 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.

geologic storage of CO_2: 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 CO_2 injection rate data are generally limited to enhanced-oil-recovery operations using CO_2 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: 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.

permeability: 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: 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: For the USGS 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 CO_2 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 CO_2 is trapped as discrete droplets, blobs, or ganglia of CO_2 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 (SFPV) minus the buoyant trapping pore volume. The value represents the pore volume within the storage formation that can be used to store CO_2 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 CO_2 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 CO_2 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 CO_2.

storage assessment unit (SAU): A mappable volume of rock that includes two main components: (1) the storage formation (SF), which is the reservoir for CO_2 storage, and (2) a regional seal formation.

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 consists of sedimentary rock layers that are saturated with formation water having total dissolved solids (TDS) greater than 10,000 milligrams per liter (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: 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: 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: Defined in the methodology for the USGS 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).

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

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February 2019

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