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CARBON CAPTURE, UTILIZATION & STORAGE CONFERENCE

USGS science for a changing world

A Probabilistic Assessment Methodology for Carbon Dioxide Enhanced Oil Recovery and Associated Carbon Dioxide Retention

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Outline for Presentation

- Energy Independence and Security Act
- Review of USGS Comprehensive Resource Database
- Review of USGS probabilistic assessment methodology for carbon dioxide enhanced oil recovery (CO_2-EOR) and associated CO_2 retention
- Summary and discussion

Energy Independence and Security Act 2007 Public Law 110–140 (U.S. Congress, 2007)

TITLE VII—CARBON CAPTURE AND SEQUESTRATION

Subtitle B—Carbon Capture and Sequestration Assessment and Framework

SEC. 711. CARBON DIOXIDE SEQUESTRATION CAPACITY ASSESSMENT.

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

(1) the geographical extent of all potential sequestration formations in all States;

(2) the capacity of the potential sequestration formations;

(3) the injectivity of the potential sequestration formations;

(4) **an estimate of potential volumes of oil and gas recoverable by injection and sequestration of industrial carbon dioxide in potential sequestration formations**

Methodology Development and Assessment of National CO_2 Enhanced Oil Recovery and Associated CO_2 Storage Potential

- Requested by Energy Independence and Security Act
- Goal is to develop a probabilistic assessment methodology and then estimate the technically recoverable (pre-economic) hydrocarbon potential using CO_2-EOR within the United States
- The recoverable hydrocarbon volume occupies potential pore space that may be available for sequestration of anthropogenically produced CO_2 in subsurface hydrocarbon reservoirs

USGS Methodology: Volumetric Approach

Step 1: Build a comprehensive resource database (CRD) for reservoirs within U.S. sedimentary basins:

Overview of a Comprehensive Resource Database for the Assessment of Recoverable Hydrocarbons Produced by Carbon Dioxide Enhanced Oil Recovery

By Marshall Carolus, Khosrow Biglarbigi, and Peter D. Warwick

Edited by Emil D. Attanasi, Philip A. Freeman, and Celeste D. Lohr

- (Report with USGS editors)

Step 1. Comprehensive Resource Database (cont.)

- Primary data sources: IHS Energy Group (2011); IHS Inc. (2012), and Nehring Associates Inc. (2012)
- State Geological Survey and other publicly available or donated proprietary data sets
- Populate database for missing data using:
  - Analogs
  - Algorithms
  - Simulations
- The CRD entries are by reservoir and are divided into regions, provinces and plays defined by the USGS 1995 National Oil and Gas Assessment (Beeman et al., 1996)

Step 2: Screening Criteria for Reservoirs in the CRD where CO_2 is either Miscible, Miscible Transitional, or Immiscible in the oil

Screening criteria (units)	Miscible	Miscible Transitional	Immiscible
API gravity (API)	>25*	22 ≥ API ≤ 25	13 ≤ API ≤ 22**
Viscosity (cP)			>10+
Depth (ft)			1,400++
Reservoir Pressure (psi)	Minimum miscibility pressure ≤ fracture pressure - 400	Minimum miscibility pressure ≤ fracture pressure - 400	

* National Petroleum Council (1984)
** Hite (2006)
\+ Taber et al. (1997)
++ Henline et al. (1985)

API = American petroleum Institute
cP = centipoise
ft = feet
psi = pounds per square inch

USGS Methodology: Volumetric Approach (cont.)

Step 3: The CO2-EOR volume for each reservoir is modeled by the original oil-in-place (OOIP) multiplied by a recovery factor (RF):

$$EOR = OOIP * RF$$

Step 3.1: The largest uncertainty of the OOIP depends on the uncertainties of two basic values: rock volume and richness of OOIP per acre foot.

$$\text{OOIP per acre-foot} = 7{,}758((Ø)(Soi))/FVFo$$

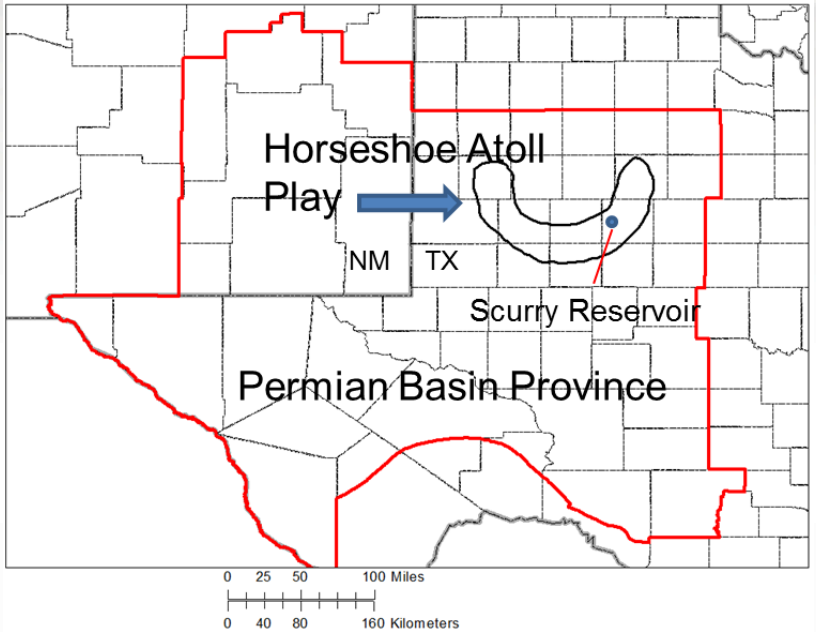
where OOIP is expressed in terms of barrels per acre-foot, Ø is porosity in fraction, Soi is initial oil saturation in fraction, and FVFo is the oil formation volume factor in barrels per stock tank barrel (STB).

USGS Methodology: Volumetric Approach (cont.)

Step 3.2: Estimate the variability of the OOIP

A representative reservoir in each play, usually with the largest OOIP, will be evaluated by the assessment geologist to determine the minimum and maximum average values for Ø and Soi. The most likely values will be from the CRD.

The range of values for the representative reservoirs in the play will be scaled and used to model the probability distribution of the OOIPs for the other reservoirs in the play.



For example, in the Horseshoe Atoll Play in the Permian Basin Province, the Scurry Reservoir (SACROC) was used as the representative Reservoir to model OOIP distributions for the other reservoirs in the play.

USGS Methodology: Volumetric Approach (cont.)

Step 3.3: The uncertainty of RF will be based on:

- Reservoir simulations using CO_2-Prophet (publicly available CO_2-EOR modeling software)
- Decline curve analysis and recoverable hydrocarbon volume (Jahediesfanjani, written commun., 2015)
- Recovery factors reported in the literature (Olea, written commun., 2015)

USGS Methodology: Volumetric Approach (cont.)

Step 3.4 Variability of RF

- Sensitivity analysis using reservoir models by CO_2-Prophet, show the Dykstra Parsons coefficient (VDP), HCPV CO_2 injected, and residual oil saturation after water flooding (Sorw) have the most impact on RFs.
- The assessment geologist will determine the minimum and maximum average values for VDP, HCPV, and Sorw. The most likely values will be from the CRD.

Step 3.5: Associated CO_2 storage resulting from CO_2-EOR will be based on:

- Reservoir simulations using CO_2-Prophet
- CO_2 storage (loss) reported in the literature (Olea, 2015)

VDP = measure of reservoir heterogeneity of the vertical permeability
HCPV = hydrocarbon pore volume

USGS Methodology: Volumetric Approach (cont.)

Step 4: The assessment procedure will generate a numerical probability distribution using a Monte Carlo simulator for each reservoir within a play.

Step 5.1: The numerical distributions will be aggregated at the play, basin, region, and national levels by a process that closely follows that of the USGS national CO_2 storage assessment (U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team, 2013) as it is described in Blondes and others (2013).

Step 5.2. Final probability distributions can be used to extract information about uncertainty in the results, such as means, 5th percentiles, medians, or 95th percentiles.

Summary

- The USGS has developed a comprehensive resource database (CRD) and a probabilistic assessment methodology to estimate the technically recoverable hydrocarbon potential using CO_2-EOR within all qualifying reservoirs in the United States.
- The assessment results will include pre-economic estimates of the technically recoverable oil potential and resulting CO_2 retention by using CO_2-EOR.
- The methodology has been peer-reviewed and is in final stages of the USGS approval process. Subsequent reviews will include a review by the American Association of Petroleum Geologists Committee on Resource Evaluation (CORE).
- The assessment is planned for completion by 2018.

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