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Carbon dioxide capture, transportation and geological storage — Carbon dioxide storage using enhanced oil recovery (CO_2-EOR)

Captage, transport et stockage géologique du dioxyde de carbone — Stockage du dioxyde de carbone au moyen de la récupération assistée du pétrole (RAP-CO_2)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 265, *Carbon dioxide capture, transportation, and geological storage*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This is the first edition of the standard entitled: *Carbon dioxide capture, transportation and geological storage — Carbon dioxide storage using enhanced oil recovery* (CO_2*-EOR).* The subject matter of this document is a new work product and does not cancel or replace any other documents in whole or in part related to the subject of CO_2-EOR.

Carbon dioxide enhanced oil recovery (CO_2-EOR) is a technique for increasing the recovery of hydrocarbons from an oil field.

The process involves using wells to inject volumes of CO_2 at pressures where the injected CO_2 usually mixes with the oil, changing the properties of the oil and enabling it to flow more freely to production wells. In most cases, a CO_2-EOR project is designed as a closed-loop system whereby some of the injected CO_2 is co-produced with the oil and then separated in above-ground recycling facilities prior to being reinjected into the oil reservoir. CO_2 that is injected into the project reservoir is contained as an inherent element of the injection and production operations, and this document requires that such containment be demonstrated. CO_2 that is injected and remains trapped in the project reservoir (or EOR complex) during and after oil production activities is not released to the atmosphere, and this trapping is referred to as "associated storage". Annex A provides a detailed description of the CO_2-EOR process as presently used (and potential "next generation" uses) and the associated storage that occurs as an intrinsic part of those operations. Although methane is often present in EOR project reservoirs, this document does not specifically address methane or other greenhouse gases. The demonstration requirements for safe, long-term containment, however, address assessment of trapping and potential leakage pathways that would likely assure containment of methane as well as CO_2. As detailed in Annex A, CO_2-EOR has been deployed internationally for several decades and has potential to expand. CO_2-EOR is commercially valuable today because it allows for the additional recovery of hydrocarbon resources while simultaneously trapping injected CO_2 for safe, long-term containment as a part of the process.

This document applies to quantifying and documenting the total CO_2 (and optionally the anthropogenic portion of the CO_2) that is stored in association with CO_2-EOR. The document recognizes that CO_2-EOR is principally an oil recovery operation. Associated with this oil recovery, however, safe and long-term CO_2 storage occurs. The absence of an accepted standard for demonstrating the safe, long-term containment of CO_2 in association with CO_2-EOR and documenting the quantity of associated stored CO_2 constitutes one of the barriers to the increased use of anthropogenic CO_2 in CO_2-EOR operations. The purpose of this document is to remove that barrier and thereby facilitate the exchange of goods and services related to the increased use and emissions reductions through associated storage by providing methods for demonstrating the safe, long-term containment of, and determining the quantity of CO_2 stored in association with CO_2-EOR. The document does not address the financial consequences that may or may not result from documenting storage of CO_2 in association with CO_2-EOR operations.

This document does not provide requirements for the selection, characterization or permitting of sites for CO_2-EOR projects because those sites are selected, characterized, and permitted pursuant to requirements and standards applicable to oil and gas exploration and production. Likewise, this document does not specify environment, health and safety protections or corrective action and mitigation requirements that are provided by the regulations and standards applicable to all hydrocarbon production operations. (A list of many of the existing standards applicable to CO_2 injection wells and oil and gas operations is presented in the Bibliography.) This document does provide requirements for demonstrating that the site in question is adequate to provide safe, long-term containment of CO_2, for demonstrating that the CO_2 flood is operated in a way to assure containment of the CO_2 in the EOR complex, and for quantifying associated storage.

This document provides for the quantification of the CO_2 that is stored in association with CO_2-EOR operations. The results of quantifications under this document could be used as input for calculations conducted in accordance with a number of other standards, protocols or programs for the quantification or reporting of greenhouse gas emissions, mitigation, or reductions, including those complying with ISO 14064-1, ISO 14064-2 and ISO 14064-3. Specifically, this document provides for the identification and quantification of CO_2 losses (including fugitive emissions) and quantification of the amount of CO_2

stored in association with CO_2-EOR projects. Such quantification could be used in a broader scheme for the quantification and verification of emissions and emission reductions over the entire carbon capture, transportation and storage chain. Specifically, using this document will provide quantification results that could be used as input to approaches described in ISO/TR 27915 for Quantification & Verification (Q&V). In addition, the quantification of CO_2 stored in association with a CO_2-EOR project pursuant to this document could be combined with the quantifications generated under ISO 27920, Carbon dioxide capture, transportation, and geological storage — Quantification and Verification, which is currently under development. The quantification of the storage associated with a CO_2-EOR project that occurs as part of a CCS project chain could be combined with the quantification of one or more capture, transportation and geological storage systems to produce a total quantification for the entire CCS project chain. Under some emissions quantification and reporting regimes, CO_2 quantities stored in association with CO_2-EOR are either treated as not emitted and excluded from calculations or subtracted as offsets.

Carbon dioxide capture, transportation and geological storage — Carbon dioxide storage using enhanced oil recovery (CO_2-EOR)

1 Scope

1.1 Applicability

This document applies to carbon dioxide (CO_2) that is injected in enhanced recovery operations for oil and other hydrocarbons (CO_2-EOR) for which quantification of CO_2 that is safely stored long-term in association with the CO_2-EOR project is sought. Recognizing that some CO_2-EOR projects use non-anthropogenic CO_2 in combination with anthropogenic CO_2, the document also shows how allocation ratios could be utilized for optional calculations of the anthropogenic portion of the associated stored CO_2 (see Annex B).

1.2 Non-applicability

This document does not apply to quantification of CO_2 injected into reservoirs where no hydrocarbon production is anticipated or occurring. Storage of CO_2 in geologic formations that do not contain hydrocarbons is covered by ISO 27914 even if located above or below hydrocarbon producing reservoirs. If storage of CO_2 is conducted in a reservoir from which hydrocarbons were previously produced but will no longer be produced in paying or commercial quantities, or where the intent of CO_2 injection is not to enhance hydrocarbon recovery, such storage would also be subject to the requirements of ISO 27914.

1.3 Standard boundary

1.3.1 Inclusions

The conceptual boundary of this document for CO_2 stored in association with CO_2-EOR includes:

a) safe, long-term containment of CO_2 within the EOR complex;

b) CO_2 leakage from the EOR complex through leakage pathways; and

c) on-site CO_2-EOR project loss of CO_2 from wells, equipment or other facilities.

1.3.2 Exclusions

This document does not include the following:

a) lifecycle emissions, including but not limited to CO_2 emissions from capture or transportation of CO_2, on-site emissions from combustion or power generation, and CO_2 emissions resulting from the combustion of produced hydrocarbons;

b) storage of CO_2 above ground;

c) buffer and seasonal storage of CO_2 below ground (similar to natural gas storage);

d) any technique or product that does not involve injection of CO_2 into the subsurface; and

e) emissions of any GHGs other than CO_2.

NOTE Some authorities might require other GHG components of the CO_2 stream to be quantified.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
anthropogenic carbon dioxide
carbon dioxide that is initially produced as a by-product of a combustion, chemical, or separation process (including separation of hydrocarbon-bearing fluids or gases) where it would otherwise be emitted to the atmosphere (excluding the recycling of non-anthropogenic CO_2)

Note 1 to entry: The chemical symbol "CO_2" is synonymous with "carbon dioxide". Accordingly, the two ways of writing out "carbon dioxide" and "CO_2" are used interchangeably in this document.

Note 2 to entry: If CO_2 that meets the definition of anthropogenic CO_2 is not included in a supplemental quantification of associated storage of anthropogenic CO_2 (e.g., because it was received and injected by a CO_2-EOR project prior to the quantification period) it will generally be treated as non-anthropogenic CO_2 in that quantification.

3.2
associated storage
CO_2 stored in association with *CO_2-EOR* (3.4) that occurs as an inherent result of a dedicated hydrocarbon production operation

Note 1 to entry: The requirements of this document are intended to ensure that CO_2 stored in association with a CO_2-EOR operation is stored as effectively as CO_2 stored in a geologic storage operation that complies with ISO 27914.

3.3
authority
competent governmental entity or entities with legal power to regulate or permit *CO_2-EOR* (3.4), to regulate storage of CO_2 in association with a *CO_2-EOR* (3.4) operation, or to regulate quantification of the storage of CO_2 in association with a *CO_2-EOR* (3.4) operation

3.4
CO_2 enhanced oil recovery
CO_2-EOR
process designed to produce hydrocarbons from a reservoir using the injection of CO_2

Note 1 to entry: The process of CO_2 enhanced oil recovery is explained in detail in Annex A

3.5
CO_2 enhanced oil recovery project
CO_2-EOR project
EOR complex (3.10), underground equipment, wells, surface or above seabed equipment, activities and rights necessary to an enhanced oil recovery operation, including any necessary or required surface or subsurface rights regulated by the authority

3.6
CO_2 injection well
well used to inject CO_2 into a *project reservoir* (3.19)

3.7
CO_2 stream
stream consisting overwhelmingly of carbon dioxide

Note 1 to entry: The CO_2 stream typically includes impurities and may include substances added to the stream to improve performance of hydrocarbon recovery operation and/or to facilitate CO_2 detection.

[SOURCE: ISO 27917:2017, 3.2.10, modified — Note revised to added "to improve performance of hydrocarbon recovery operation".]

3.8
containment
status of CO_2 being confined within the *EOR complex* (3.10) by an effective *trap* (3.23) or combination of traps

3.9
containment assurance
demonstration that the features and geologic structure of the *CO_2-EOR project* (3.5) are adequate to provide *safe, long-term* (3.21) *containment* (3.8) of CO_2, and that the CO_2 flood is operated in a way to assure containment of the CO_2 in the *EOR complex* (3.10)

3.10
EOR complex
project reservoir (3.19), *trap* (3.23), and such additional surrounding volume in the subsurface as defined by the *operator* (3.16) within which injected CO_2 will remain in *safe, long-term* (3.21) *containment* (3.8)

3.11
injection-withdrawal ratio
ratio, during a defined period, of the volume of all fluids and gases injected into the *project reservoir* (3.19) to the volume of all fluids and gases produced from the project reservoir as determined using consistent temperature and pressure conditions

3.12
leakage
unintended release of CO_2 to the atmosphere or out of the *EOR complex* (3.10)

[SOURCE: ISO 27917:2017, 3.2.14, modified — Added to the atmosphere or out of the EOR complex.]

3.13
leakage pathway
geological or artificial conduit for *leakage* (3.12) of CO_2 out of the *EOR complex* (3.10)

3.14
loss
leakage (3.12), intended releases, and transfers of CO_2 from the *CO_2-EOR project* (3.5)

3.15
native CO_2
CO_2 present and indigenous within the *project reservoir* (3.19) prior to hydrocarbon production or any CO_2 injection

Note 1 to entry: Native CO_2 is also known as "in situ CO_2".

3.16
operator
entity responsible for the *CO_2-EOR project* (3.5)

3.17
plug & abandon
permanently close a well or wellbore to prevent inter-formational movement of fluids into strata, into freshwater aquifers, and out of the well

Note 1 to entry: In most cases, a series of cement plugs is set in the wellbore, with an inflow or integrity test made at each stage to confirm hydraulic isolation.

3.18
post-termination
period of time after *termination* (3.22)

3.19
project reservoir
geologic reservoir in to which CO_2 is injected for production of hydrocarbons in paying or commercial quantities

3.20
quantification period
period of time during which *associated storage* (3.2) is being quantified

3.21
safe, long-term
period necessary for *associated storage* (3.2) to be considered environmentally safe by the system under which the quantification is being implemented

3.22
termination
process beginning with the cessation of quantification of *associated storage* (3.2), and ending with both the termination of hydrocarbon production from the *project reservoir* (3.19), and the plugging & abandonment of wells unless otherwise required by the *authority* (3.3)

3.23
trap
any feature or mechanism that alone or in combination provides *safe, long-term* (3.21) *containment* (3.8) below a low-permeability confining geologic layer (cap rock or seal), including in the pore spaces of the *EOR complex* (3.10) (physical, stratigraphic, or structural trapping), by capillary pressure from the water in the pore spaces between the rock (residual trapping), by dissolution in the in situ formation fluids (solubility), by hydrodynamic trapping, by adsorption onto organic matter or by reacting in geologic formations to produce minerals (geochemical trapping)

4 Documentation

4.1 Purpose

The provisions of this clause are intended to facilitate documentation of the safe, long-term containment, and the quantification of associated storage.

4.2 Use of existing data

Documentation and demonstration requirements throughout this document may be satisfied by information that has already been required, is held, approved by, and available from the authority, because in many cases EOR operations are addressed by existing oil and gas regulations. To the extent that information fully satisfies the requirements, has already been provided and is available from the authority, such information is not required to be developed again for purposes of this document. References to information that is available do not include information held by another entity but not available to the operator.

4.3 Initial documentation

At the beginning of the quantification period, initial documentation shall be prepared and shall include:

a) a description of the EOR complex and engineered systems (see Clause 5);

b) the initial containment assurance (see 6.1.2);

c) the monitoring program (see 6.2);

d) the quantification method to be used (see Clause 8 and Annex B); and

e) the total mass of previously injected CO_2 within the EOR complex at the start of quantification period (see 8.5 and Annex B).

The initial documentation shall be offered to the authority.

4.4 Periodic documentation

Periodic documentation should be prepared at least annually and shall provide the following information:

a) the quantity of associated storage in specified units of CO_2 mass, or volumetric units convertible to mass, (see 8.2 m_{stored}) during the period covered by the documentation;

b) the cumulative quantity of associated storage in specified units of CO_2 mass, or volumetric units convertible to mass, (see 8.2 m_{stored}) since the beginning of the quantification period;

c) the formula and data used to quantify the mass of associated storage, including the mass of CO_2 delivered to the CO_2-EOR project and losses during the period covered by the documentation (see Clause 8 and Annex B);

d) the methods used to estimate missing data and the amounts estimated as described in 9.2;

e) the approach and method for quantification utilized by the operator, including accuracy, precision and uncertainties (see Clause 8 and Annex B);

f) a statement describing the nature of validation or verification of the statement including the date of review, process, findings, and responsible person or entity; and

g) source of each CO_2 stream quantified as associated storage (see 8.3).

The periodic documentation shall be offered to the authority.

NOTE The operator can determine that more frequent recordkeeping and documentation are required to meet the goals or requirements of the CO_2-EOR project.

5 EOR complex description, qualification, and construction

5.1 General

A general EOR operations management plan shall be prepared and periodically updated; shall provide a description of the EOR complex and engineered system [see 4.3 a)], shall establish that the EOR complex is adequate to provide safe, long-term containment of CO_2 and shall include site-specific and other information pertaining to:

a) geologic characterization of the EOR complex;

b) a description of the facilities within the CO_2-EOR project;

c) a description of all wells and other engineered features in the CO_2-EOR project; and

d) the operations history of the project reservoir.

5.2 Geological characterization and containment assessment of the EOR complex

The general geologic characterization of the EOR complex shall be based on subsurface and other data collected at the site (augmented where appropriate with data from analogous fields), including any features that may affect safe, long-term containment of CO_2 and evidence of the integrity of the reservoirs and traps. The operator shall define the EOR complex in the geologic description to contain all likely subsurface locations to which the CO_2 could reasonably move beyond the project reservoir. For projects desiring to quantify associated storage, the geological characterization and engineering description shall provide evidence of the integrity of the reservoirs and traps that supports a conclusion that the EOR complex is suitable for safe, long-term containment. The description of the EOR complex should include, but not necessarily be limited to:

a) general lithologic description of the stratigraphic column above the EOR complex;

b) depth to the top of the EOR complex;

c) thickness of the defined stratigraphy within the EOR complex;

d) structural and geophysical properties;

e) lateral boundaries and any spill points relevant to containment;

f) hydraulic/petrophysical/geochemical/geomechanical properties;

g) associated storage capacity of CO_2 in the project reservoir, recognizing that EOR operations are typically designed for maximum economic hydrocarbon production; and

h) engineering data as described in 6.1.3.

5.3 Description of the facilities within the CO_2-EOR project

The description of the facilities within the CO_2-EOR project shall provide an overview of the equipment, downstream of the CO_2 custody transfer meter, used to handle CO_2 and production, including design specifications. This should typically include piping, separators, processing and dehydration equipment, pumps, compressors, and any other equipment relevant to CO_2 handling and production. It should specifically address vent, release, sampling, and metering points, including a description of metering accuracy and estimation techniques.

5.4 Existing wells within the EOR complex

The description of wells shall identify each well penetrating the EOR complex and shall provide evidence it has been constructed and/or plugged & abandoned in such a manner as to provide safe, long-term containment of CO_2. Such wells include injection, production, monitoring, temporarily abandoned, shut-in, and plugged & abandoned wells. The following information shall be provided where available:

a) well name;

b) unique well identifier;

c) spud and completion dates;

d) well status (e.g. injection, production, monitoring, temporarily abandoned, shut-in, plugged & abandoned);

e) surface or seabed location;

f) total and measured depth;

g) plugging & abandonment information;

h) well construction, completion, and well integrity technical details;

i) significant equipment remaining in the well; and

j) well intervention details and history.

In some cases, remote sensing methods or field or aerial surveys to locate old wells may be necessary.

5.5 Operations history of the project reservoir

The operations history of the CO_2-EOR complex should include:

a) production and injection data for the project reservoir;

b) temperature and pressure history, including current distribution;

c) interaction with adjacent reservoirs;

d) any known leakage incidents; and

e) history of seismic activity.

6 Containment assurance and monitoring within the EOR complex

6.1 Containment assurance and EOR operation management plan

6.1.1 EOR operations management plan

The EOR operations management plan (see 5.1) shall specify the procedures for field management, including:

a) project data as described in Clause 5, to be used for monitoring and quantification;

b) engineering controls for injection and production;

c) periodic assessment of reservoir performance as compared with expected behaviour in accordance with 6.1.3;

d) assessment of containment by geologic features and engineering systems in accordance with 6.1.3;

e) assessment and management of potential leakage pathway risks and monitoring technologies and procedures (see 6.1.3), including definition of detection thresholds, that are sufficient to meet the requirements of 8.6;

f) method of quantification of CO_2 below the detection threshold in accordance with 8.6;

g) corrective measures for potential leakage or unexpected events;

h) providing data for associated storage quantification; and

i) developing a termination plan for the CO_2-EOR project that specifies criteria for termination and outlines the termination qualification process sufficient to meet the requirements of Clause 10.

6.1.2 Initial containment assurance

The EOR operations management plan shall provide an initial containment assurance plan to identify and assess potential geologic, engineered, and engineering-affected leakage pathways that might lead to loss of CO_2 from the EOR complex.