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

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Preface

This Standard was prepared by the Standards Australia Committee EE-002, Carbon dioxide capture, transportation, and geological storage.

The objective of this document is to specify requirements for the quantifying and documenting of 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).

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 AS ISO 27914:2019 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 AS ISO 27914:2019.

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.

This document does not include the following:

(i) 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.

(ii) Storage of CO_2 above ground.

(iii) Buffer and seasonal storage of CO_2 below ground (similar to natural gas storage).

(iv) Any technique or product that does not involve injection of CO_2 into the subsurface.

(v) Emissions of any GHGs other than CO_2.

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

This document is identical with, and has been reproduced from, ISO 27916:2019, *Carbon dioxide capture, transportation and geological storage — Carbon dioxide storage using enhanced oil recovery (CO_2-EOR)*.

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The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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.

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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

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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.

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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.

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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 *CO2-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 *CO2-EOR* (3.4), to regulate storage of CO_2 in association with a *CO2-EOR* (3.4) operation, or to regulate quantification of the storage of CO_2 in association with a *CO2-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)

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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 *CO2-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 *CO2-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 *CO2-EOR project* (3.5)

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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.

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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

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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;

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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.

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6.1.3 Operational containment assurance

The EOR operations management plan shall provide operational containment assurance during the quantification period, based on engineering data encompassing such items as the results of reservoir management practices, including injection-withdrawal ratio monitoring, well integrity monitoring, pressure monitoring, monitoring of CO_2 movement within leakage pathways identified in the initial containment assurance and monitoring of pressure response within the boundary of the EOR complex. The operational containment assurance may include results from other monitoring. These results shall be used in periodically providing evidence of containment, including the supporting rationale.

Containment assurance and reservoir management shall be reviewed, and the EOR operation management plan shall be revised as necessary if changes occur that have the potential to adversely affect containment, which may include:

a) unexpected changes in project performance that have potential to influence associated storage of CO_2;

b) addition or abandonment of injection zones;

c) change to the areal extent of the project reservoir;

d) addition or abandonment of wells;

e) anomalous change of injection-withdrawal ratio;

f) development of reservoirs which are located above or below the project reservoir; or

g) discovery of CO_2 beyond the boundary of the CO_2-EOR complex.

6.2 Monitoring program, methods, and implementation

6.2.1 Monitoring of potential leakage pathways

The monitoring program shall address the identified inventory of potential leakage pathways from the containment assurance plan [see 6.1.1 e)] to determine, for each potential leakage pathway, whether it is:

a) not active and thus excluded from the monitoring program;

b) not active, but might activate under operation of the CO_2-EOR project and is thus to be addressed by the monitoring program; or

c) active.

The operator shall conduct the potential leakage pathway assessment in accordance with the EOR operation management plan or as required by the authority. A final leakage pathway assessment shall be conducted prior to project termination.

NOTE It is likely that the monitoring program could require collection of data prior to start of the quantification period and during the operational life of the project (see 5.5).

6.2.2 Monitoring methods

The monitoring program shall describe tools, methods, applicability, and frequency for detecting and quantifying losses (see 8.4). Details of the monitoring program and data assessed (including relevant data prior to the quantification period) shall be provided in the initial documentation (see 4.3), along with the threshold beneath which there would be no detection. The method of quantification for quantities of CO_2 below the detection threshold shall be specified in the EOR operations management plan (see 8.6).

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6.2.3 Monitoring program implementation

The monitoring program shall be implemented to address facility and project losses in accordance with the EOR operations management plan (see 6.1) as applied to the inventory of potential leakage pathways (see 6.2.1). The monitoring program shall be reviewed and revised as EOR operational practices are modified.

7 Well construction

7.1 New well construction

A description of the new wells shall provide evidence that they are designed, constructed, and tested to provide safe, long-term containment of CO_2. Well materials, including metals, cements, and elastomers, shall be selected based on their ability to withstand the expected operational environment including the thermomechanical stress of operation and the geochemistry (including CO_2 where present) of the subsurface. At a minimum, wells that penetrate the EOR complex shall be cemented through each cap rock using cement that is suitable for the thermomechanical and geochemical environment for the safe, long-term containment of CO_2. To the extent not provided by other evidence of suitable construction (for example: reference to information that has been provided to the authority during permitting of CO_2-EOR operations), the following information shall be provided:

a) well name;

b) unique well identifier;

c) spud date, completion date;

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

e) surface or seabed location;

f) total and measured depth;

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

h) significant equipment remaining in the well.

7.2 Well intervention

A description of the well modifications shall provide evidence that they are designed, constructed, and tested to provide safe, long-term containment of CO_2. Well materials, including metals, cements, and elastomers, shall be selected based on their ability to withstand the expected operational environment including the thermomechanical stress of operation and the geochemistry (including CO_2 where present) of the subsurface. To the extent not provided by other evidence that the well modifications performed are suitable (for example: reference to information that has been provided to the authority during permitting of well intervention), the following information shall be provided:

a) well name;

b) unique well identifier;

c) intervention type and date;

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

e) surface or seabed location;

f) total and measured depth;

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g) plugging and abandonment information (if applicable);

h) well intervention details; and

i) significant equipment remaining in the well.

8 Quantification

8.1 General

The quantification of associated storage [m_{stored}] (see 8.2) includes calculation of loss (see 8.4) and shall be conducted as specified in the EOR operations management plan (see 6.1.1) at least annually. All factors and variables defined in Clause 8 shall be quantified and documented.

Data collected from monitoring a CO_2-EOR project can be used in the quantification of associated storage. Any loss of CO_2 in association with a CO_2-EOR project shall be characterized and quantified.

NOTE 1 In some jurisdictions, an authority might require the operator to document information related to project CO_2 emissions such as (a) incremental emissions from the CO_2-EOR project from power or heat generation, (b) electricity and heat which are imported and the carbon intensity of generation of power (direct or average grid carbon intensity, if available), and (c) exported electricity. Such additional information could be included in the periodical documentation and utilized as appropriate for additional quantification procedures but would not change the quantity of anthropogenic CO_2 stored in association with the CO_2-EOR project. ISO/TR 27915 describes several mechanisms/protocols which utilize quantification of such additional CO_2 emissions.

NOTE 2 Some operators could also quantify the anthropogenic portion of m_{stored}. An example quantification calculation for the anthropogenic portion is shown in Annex B.

8.2 Quantification principles

Any method of quantification used by the operator shall follow these quantification principles:

a) The mass of CO_2 stored in association with CO_2-EOR [m_{stored}] shall be determined by subtracting loss from input [see Formula (1)].

b) The manner by which associated storage is quantified shall assure completeness and preclude double counting. The CO_2 that is recycled and reinjected into the EOR complex shall not be quantified as associated storage. Loss from the CO_2 recycling facilities shall be quantified.

c) Native CO_2 produced and captured in the CO_2-EOR project [m_{native}] should be quantified and documented and may be included in m_{input} if approved by the authority (see Note 2).

d) The operator shall quantify any CO_2 that is subsequently produced from the EOR complex and transferred offsite (see 8.4.5).

e) Quantification results shall be expressed either in units of mass or in volumetric units convertible to mass.

The method defined by Formula (1) should be used to document the associated storage of the mass of CO_2 [m_{stored}] within a defined period. m_{stored} should be calculated by quantifying the following variables:

$$m_{stored} = m_{input} - m_{loss\ operations} - m_{loss\ EOR\ complex} \quad (1)$$

— m_{input}; the total mass of CO_2 $m_{received}$ by the EOR project, approved m_{native}, (see 8.3);

— $m_{loss\ operations}$; the total mass of CO_2 loss from project operations (see 8.4.1 to 8.4.5); and

— $m_{loss\ EOR\ complex}$; the total mass of CO_2 loss from the EOR complex (see 8.4.6).

NOTE 1 In some jurisdictions $m_{loss\ operations}$ could be considered as fugitive emissions.

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NOTE 2 Typically native CO_2 present in the project reservoir prior to starting a CO_2-EOR project is separated from produced hydrocarbons during production and emitted to the atmosphere. When hydrocarbon production progresses to CO_2-EOR and if recycling facilities are installed, the native CO_2 is no longer emitted, but is captured and retained for direct use by the CO_2-EOR project (see Figure 1) and is combined with the CO_2 received from other sources.

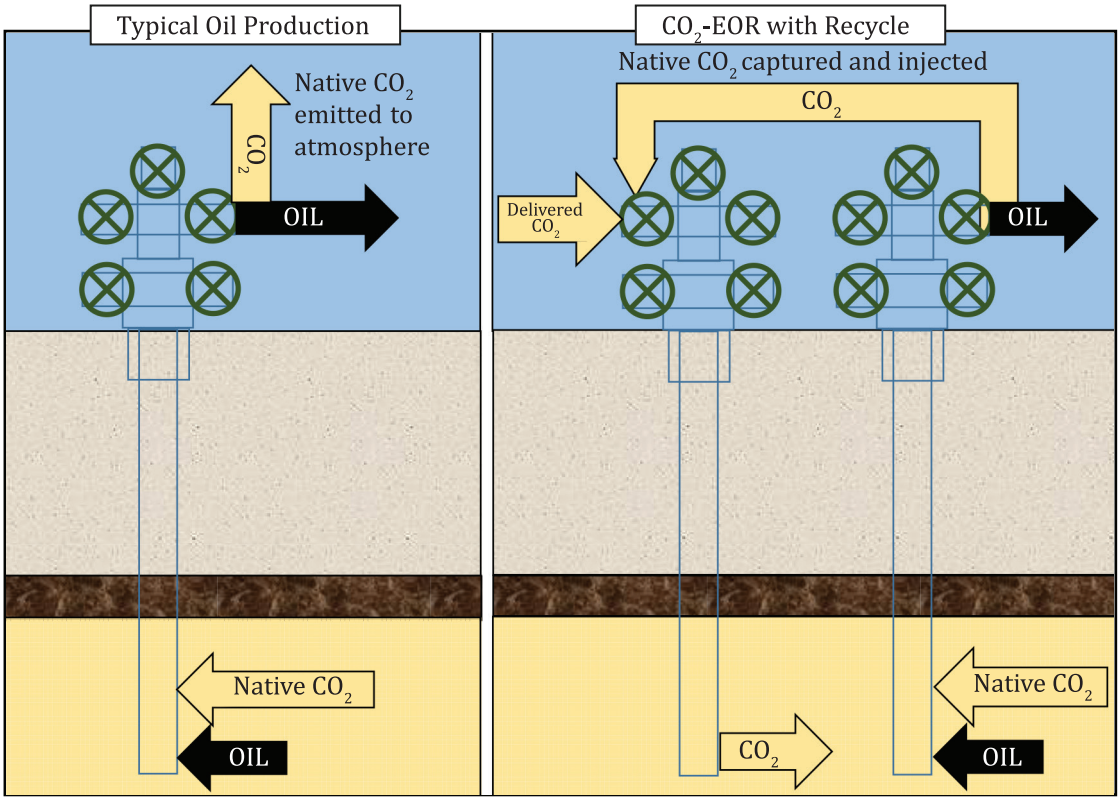

Figure 1 — Illustration of native CO_2, previously being emitted with typical production and now being captured and injected with CO_2-EOR (This diagram is to show movement of native CO_2 only and not meant to demonstrate production of other sources of CO_2)

8.3 Quantification of input [m_{input}]

The total CO_2 received at the custody transfer meter by the EOR project [$m_{received}$] shall be documented. The CO_2 stream received (including CO_2 transferred from another CO_2-EOR project) shall be metered. The native CO_2 recovered and included as m_{native} shall be documented.

CO_2 delivered to multiple CO_2-EOR projects shall be allocated among those CO_2-EOR projects. This allocation may be accomplished by contract. The sum of the quantities of allocated CO_2 shall not exceed the total quantities of CO_2 received.

NOTE Some operators could also quantify the anthropogenic portion of m_{input} (see 8.5).

8.4 Quantification of loss

8.4.1 Quantification of operational loss [$m_{loss\ operations}$]

The operator shall quantify the total mass of CO_2 loss from project operations within a defined period.

The $m_{loss\ operations}$ is composed of the following variables:

a) Loss of CO_2 due to leakage from production, handling and recycling CO_2-EOR facilities (infrastructure including wellheads) [$m_{loss\ leakage\ facilities}$];

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