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Carbon dioxide capture, transportation and geological storage — Quantification and verification

Capture du dioxyde de carbone, transport et stockage géologique — Quantification et vérification

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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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*.

Introduction

This document is intended to serve as a reference document for future development of any technical standards that could be approved by TC 265 for the quantification and verification (Q&V) of greenhouse gas (GHG) emissions and emission reductions from CCS projects. This document is a review of current practices and requirements, for the Q&V of carbon dioxide captured, transported and geologically stored; as well as for direct and indirect GHGs that can arise from integrated CCS project activities associated with injection of carbon dioxide into geological formations for the purposes of isolation from the atmosphere (and ocean) over the long term. While carbon dioxide (CO_2) is the primary target of the capture process, other GHGs (such as methane, CH_4) may be entrained in the capture stream, and emissions can include GHG's other than CO_2. This document includes limited discussion of other environmental impacts.

This document integrates the various aspects of Q&V adopted by other ISO/TC 265 Working Groups (WGs) into a comprehensive project framework.

The UNFCCC Paris Agreement (adopted on 12 December 2015) lays the foundation for countries to work cooperatively to limit the increase in global average temperature to between 1,5 °C and 2 °C above pre-industrial levels, by reducing emissions of greenhouse gases (GHGs) into the atmosphere and by increasing removals of GHGs from the atmosphere. Many of the climate models considered by the IPCC in their most recent assessment report (IPCC, 2014) suggest that keeping average global temperature rises to less than 2 °C will require large scale deployment of carbon dioxide capture, transportation and geological storage technologies (CCS) in order to reduce anthropogenic emissions from the electrical sector and from industries where there are no viable alternatives. The IPCC (2014) also suggest that CCS with bio-energy (BECCS) will be required to remove carbon dioxide from the atmosphere to meet medium term emission objectives. In the longer term (i.e. 70 to 100 years), it may be necessary, and viable, to further reduce harmful concentrations of CO_2 in the atmosphere by capturing CO_2 directly from the atmosphere for injection into geological formations (DACCS).

While many countries have existing domestic GHG emission reporting requirements, the Paris Agreement emphasizes "robust accounting" for all countries (UNFCCC, 2015, Article 6, paragraph 2), covering both anthropogenic emissions of greenhouse gases by sources and removals of greenhouse gases by sinks (Article 4, paragraph 2). The key principles for accounting and reporting identified in the Paris Agreement are transparency (to ensure that actions are shared and equitable, and that outcomes are real), accuracy, completeness, comparability and consistency, and the avoidance of double accounting (UNFCCC, 2015, Article 4, paragraph 13). Environmental integrity (i.e. no harm to ecosystems or biodiversity) is a fundamental principle for all activities, as are issues relating to the socioeconomic impacts of a project.

ISO/TC 265 was established to develop technical standards for the design, construction, operation, environmental planning and management, risk management, quantification, monitoring and verification, and related activities in the field of CCS. Six working groups (WGs) have been established. They all report through to the Technical Committee (TC) and are charged with focusing on particular aspects of the CCS technology chain.

WG1 – Capture

WG2 – Transport

WG3 – Storage

WG4 – Quantification and Verification

WG5 – Cross-cutting Issues

WG6 – CO_2 storage through Enhanced Oil Recovery (EOR)

This document established under WG4 is intended to provide a credible foundation for future standard approaches for the quantification and verification (Q&V) of GHGs associated with CCS projects (for geological storage or for EOR). Future standards developed in this area will improve understanding

and confidence in CCS related GHG mitigation by regulatory authorities, investors and civil society, as well as enhance validation processes underpinning project compliance obligations.

The development of this document complements the development of other CCS and non-CCS, but relevant, ISO standards and TRs, including in particular the whole ISO/TC 265 catalogue. Documents are referenced from the EU, UNFCCC, IPCC, and various government bodies. As CCS Q&V is an ever-evolving area of examination, this document has been based on the best available information at the time of its release.

The principal GHG considered within this document is carbon dioxide (CO_2), other GHG's (as listed in Chapter 5), are included in the Q&V of CCS projects, but are not usually significant. To some extent, GHG and CO_2 are used somewhat interchangeably and the reader is invited to consider the context of the terms. Most of the GHG captured through the CCS system will be a relatively pure stream of CO_2, perhaps mixed with other gases such as N_2, but in an Enhanced Oil Recovery (EOR) system the recycled CO_2 could also include methane (CH_4). Emissions from fossil-fired industrial activity could also contain some N_2O.

This document aims to provide a transparent and non-prescriptive body of information relating to Q&V processes for CCS projects.

Carbon dioxide capture, transportation and geological storage — Quantification and verification

1 Scope

1.1 General

This document presents a review of publicly available literature identifying materially relevant issues and options relating to "good practices" for quantifying and verifying GHG emissions and reductions at the project level. Its scope covers all components of the CCS chain (e.g. capture, transport, storage) and includes a lifecycle assessment approach to estimating project level emissions and emission reductions from project assessment, construction and operations, through to completion and post-closure activities. This document considers the following at the project level:

— a variety of Q&V related boundaries applicable to all components of a CCS project;

— the composition of the CO_2 stream, including its purity, and requirements for measuring and verifying the physical and chemical state of the CO_2 stream in CCS projects;

— identification and quantification of GHG emissions and reductions across integrated CCS components;

— monitoring objectives, methodologies, and sampling strategies, including locations, periods, and frequencies;

— GHG data collection and reporting;

— verifying GHG expectations with agreed verification criteria;

— life cycle assessment (LCA) of CCS projects.

1.2 Limitations

Q&V approaches to measuring and verifying GHG emissions, reductions and removals for CCS projects continue to evolve. This document identifies the gaps and limitations in current levels of knowledge, of empirical methodologies and application of good practices for CCS Q&V.

This is a Technical Report and so does not seek to recommend technical standards for any specific Q&V method. This document cites existing ISO standards and other good-practice protocols that have been developed to quantify and verify GHGs from integrated CCS projects.

1.3 Stakeholders' requirements

This document aims to inform all stakeholders who influence, or are directly or indirectly involved in the reporting of emissions and emission reductions, or removals, for CCS projects. Stakeholders may include, for example, CCS project developers and operators, policy makers, regulators and other government oversight bodies, verifying entities, the financial community, equipment manufacturers, owners of other resources (e.g. water, coal, oil and gas), and members of the general public.

1.4 Review of the references

This document makes reference to a variety of sub-national, national and international laws applicable to CCS projects; current Q&V practices to measure GHG emissions and reductions, or removals, by CCS projects; existing ISO standards that are directly and/or indirectly relevant to CCS projects; identified stakeholder requirements; and the anticipated outcomes of other ISO/TC 265 WGs.

The discussion of Q&V is applicable to both onshore and offshore environments. At this stage, the offshore experience is from two Norwegian projects, Sleipner and Snohvit, while the onshore experience draws on an expanding range of storage, and CO_2 EOR projects, in North America and China; and from a cumulative body of research, pilot and demonstration projects, in Algeria, Australia, Canada, Europe, Japan and the USA.

References are cited throughout this document, including relevant standards and protocols. These references are listed in alphabetic order in the Bibliography.

1.5 Nomenclature

BECCS	Bio-energy with CCS
CCS	Carbon Capture and Storage (or Carbon dioxide Capture, transportation and geological Storage)
CDM	Clean Development Mechanism
CEMS	Continuous Emission Monitoring System
CMS	Continuous Measurement System
CO_2-e	Carbon dioxide equivalent
DACCS	Direct air carbon dioxide capture and (geological) storage
EIA	Environmental Impact Assessment
EOR	Enhanced Oil Recovery
EU ETS	European Union Emissions Trading Scheme
GHG	Greenhouse Gas
IEA GHG	International Energy Agency Greenhouse Gas R&D Programme
IPCC	Intergovernmental Panel on Climate Change
IPCC SR	IPCC Special Report on CCS (2005)
LCA	Life Cycle Assessment
MRR	Monitoring, Reporting Regulation (ref. EU)
Mt	1 million (metric) tonnes
Q&V	Quantification and Verification
tonne	1,000 kg
tCO_2-e	tonne CO_2 equivalent
TR	Technical Report
UNFCCC	United Nations Framework Convention on Climate Change

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 27917-1 and the following apply.

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

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

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

3.1
baseline
reference basis for comparison against which project status or performance is monitored or measured

Note 1 to entry: The IPCC (2014, Annex 1, Glossary, p.1253) defines baseline as "the state against which change is measured". In natural systems, a baseline represents the range of pre-existing natural variation of that system, which may include a complex range of diurnal, tidal, seasonal, annual, and climatically-driven natural fluctuations.

[SOURCE: ISO 21500:2012, 2.3, modified]

3.2
carbon capture and storage
CCS
process consisting of the separation of CO_2 from industrial and energy related sources, transportation and injection into a geological formation, resulting in its long-term isolation from the atmosphere

Note 1 to entry: CCS projects should also provide for the long-term isolation of CO_2 from oceans, potable water supplies and other resources.

[SOURCE: IPCC special report on CCS, 2005]

3.3
client
organization or person requesting validation or verification

Note 1 to entry: The client could be the responsible party or the GHG program administrator or other stakeholder.

[SOURCE: ISO 14064-1:2006, 2.25]

3.4
CO_2 (GHG) leakage
leakage
unintended release of CO_2 (or other GHGs) out of pre-defined containment

Note 1 to entry: Examples of containment are compressors, pipelines, trucks, ships, wells and geological formations. In the context of this document , leakage does not refer to the concept through which efforts to reduce emissions in one place shift emissions to another location or sector where they remain uncontrolled or not counted. Specific regulations at the national or sub-national level may further define leakage within specific contexts.

3.5
CO_2 stream
stream consisting overwhelmingly of carbon dioxide

Note 1 to entry: A CO_2 stream is likely to contain impurities such as other GHGs, and may also include substances added to the stream to improve the performance of the CCS stream or to enable detection of the CO_2. The minimum concentration of CO_2 in the CO_2 stream is usually subject to regulatory discretion and approval, but should be overwhelmingly CO_2.

[SOURCE: ISO 27917-1]

3.6
CO_2 stream composition
percentage by volume of each component of the *CO_2 stream* (3.5)

Note 1 to entry: The CO_2 stream composition is usually subject to regulatory discretion and approval. It is less common to report stream composition as a mass fraction.

3.7
CO_2 stream purity
percentage by volume of CO_2 as a component of the *CO_2 stream* (3.5)

3.8
detection limit
detection threshold
smallest value of a property of a substance that can be reliably detected by a specified measuring method in a specified context

3.9
emission factor
normalized measure of GHG emissions in terms of activity

Note 1 to entry: For example, tonnes of GHG emitted per tonne of fuel consumed. Valves and other such equipment might have typical leakage rates based on measurement from similar equipment. Emission factors can be applied based on experience for such equipment.

[SOURCE: Annex II of the IPCC special report on CCS, 2005]

3.10
GHG/CO_2 emission
emission
total mass of GHG (i.e. CO_2 or CO_2-e) released to the atmosphere, or surface water bodies, over a specified period of time

Note 1 to entry: Emissions from a geological storage complex occur at the interface between the ground and the atmosphere or at the interface between the seabed and ocean or lake. "GHG/CO_2 emission" is equivalent to the UNFCCC term "seepage" referred to in the CDM modalities and procedures for CCS project activities (see Reference [75]).

[SOURCE: ISO 14064-2:2006, 2.5, modified]

3.11
GHG/CO_2 emission reduction
calculated net decrease of GHG emissions between a *baseline* (3.1) scenario and the CCS project output

Note 1 to entry: A GHG emission reduction may also be referred to as "CO_2 avoided", although CO_2 avoided may also refer to CO_2 removals from the atmosphere.

[SOURCE: ISO 14064-2:2006, 2.7, modified]

3.12
GHG removal
total mass of GHG removed from the atmosphere over a specified period of time

Note 1 to entry: CCS projects could achieve GHG removals through BECCS (Bio-energy with CCS) or by DACCS (Direct air CO_2 capture and geological storage).

[SOURCE: ISO 14064-2:2006, 2.6]

3.13
fugitive emission
release of GHG from anthropogenic activities such as the processing or transportation of gas, petroleum or CO_2

Note 1 to entry: Fugitive emissions include unintentional releases such as leaks and spills, and intentional releases such as vents and flares for the purposes of safety, maintenance or to operate specific pieces of equipment (see Reference [91]).

[SOURCE: Annex II of the IPCC special report on CCS, 2005]

3.14
geological reservoir
subsurface body of rock with sufficient porosity and permeability to contain and transmit fluids (including super-critical phase GHGs) with an overlying impermeable seal (or caprock) which prevents escape of the fluids

[SOURCE: Annex II of the IPCC special report on CCS, 2005]

3.15
geological storage complex
subsurface geological system extending vertically to comprise storage units, and primary and secondary seals, extending laterally to the defined limits of the CO_2 storage project

Note 1 to entry: Limits can be defined by natural geological boundaries, regulation or legal rights.

3.16
greenhouse gas
GHG
gaseous constituent of the atmosphere, both natural and/or anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds

Note 1 to entry: The most common greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), nitrogen triflouride (NF_3) perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). Emissions from these gases are reported under the Kyoto Protocol, and aggregated into carbon dioxide equivalents (CO_2-e) using factors called global warming potentials (GWPs).

[SOURCE: ISO 14064-2:2006, 2.1]

3.17
greenhouse gas activity data
quantitative measure of activity that results in a GHG emission or removal

Note 1 to entry: Examples of GHG activity data include the amount of energy, fuels or electricity consumed, material produced, service provided or area of land affected.

3.18
greenhouse gas emission or removal factor
conversion factor relating activity data to GHG emissions or removals

3.19
greenhouse gas information system
policies, processes and procedures to establish, manage and maintain GHG information

3.20
greenhouse gas report
stand-alone document intended to communicate an organization's or project's GHG-related information to its *intended users* (3.23)

[SOURCE: ISO 14064-2:2006, 2.15]

3.21
greenhouse gas source
process, activity or mechanism that releases a GHG into the atmosphere

[SOURCE: ISO 14064-2:2006, 2.2, modified; Annex II, IPCC CCS report 2005, modified]

3.22
integrated CCS project
project that involves capturing CO_2 from large point sources, transporting it to a storage site, injecting it into deep geologic formations (storage complex), and *monitoring* (3.28) to verify that it remains isolated from the atmosphere

3.23
intended user
individual or organization identified by those reporting GHG related information as being the one who relies on that information to make decisions

Note 1 to entry: The intended user could be the client, the responsible party, GHG program administrators, regulators, the financial community or other affected stakeholders, such as local communities, government departments or non-governmental organizations

[SOURCE: ISO 14064-2:2006, 2.22]

3.24
level of assurance
degree of assurance that the *intended user* (3.23) requires for verification

Note 1 to entry: The level of assurance is used to determine the depth of detail that a verifier designs into their verification plan to determine if there are any material errors, omissions or misrepresentations.

Note 2 to entry: There are two levels of assurance, reasonable or limited, which result in differently worded verification statements.

[SOURCE: ISO 14064-2:2006, 2.24, modified]

3.25
materiality
concept that individual, or the aggregation of, errors, omissions and misrepresentations could affect the GHG assertion and could influence the intended users' decisions

Note 1 to entry: The concept of materiality is used when designing the validation or verification and sampling plans to determine the type of substantive processes used to minimize the risk that the validator or verifier will not detect a material discrepancy (detection risk).

Note 2 to entry: The concept of materiality is used to identify information that, if omitted or misstated, would significantly misrepresent a GHG assertion to intended users, thereby influencing their conclusions. Acceptable materiality is determined by the validator, verifier or GHG program based on the agreed level of assurance.

[SOURCE: ISO 14064-2:2006, 2.28]

3.26
measurement
determination of quantities through physical devices

Note 1 to entry: Examples of measurements are temperature, flow, concentrations, length, distance, etc. Measurement may be direct (e.g. length with a meter) or indirect. Indirect measurements may require two steps, firstly sampling and then analysis. Indirect measures may also use a model to convert the measurement of a given quantity into the measurement of another one, for example, from velocity to flow rate, taking into account the pipe and fluid characteristics.

3.27
uncertainty (of measurement)
parameter associated with the result of a measurement that characterizes the dispersion of values that could reasonably be attributed to the measurement property

3.28
monitoring
continuous or repeated checking, supervising, critically observing, measuring, or determining the status of a system to identify variance from an expected performance level or *baseline* (3.1)

3.29
GHG quantification
act of measuring and/or estimating and/or predicting the amount of GHG emissions, reductions and removals associated with a CCS project

3.30
reporting scope
physical and temporal boundaries of information reported

3.31
responsible party
person or persons responsible for the provision of the *GHG quantification* (3.29) assertion and the supporting GHG information

[SOURCE: ISO 14064-1:2006, 2.23, modified]

3.32
sampling
selection of a subset from a population to estimate characteristics of the whole population

3.33
sampling strategy
set of technical principles or steps that aim to establish, depending on the objectives and the site considered, the sampling density, distribution, locations, and frequency for each sampling area

3.34
venting
intended release of GHG from pre-defined containment

3.35
verification of GHG assertion
systematic, independent and documented process for the evaluation of a GHG assertion against agreed verification criteria

Note 1 to entry: A GHG assertion is a factual and objective statement of performance related to GHGs made by an organization or project.

[SOURCE: ISO 14064-2:2006, 2.26, modified]

3.36
verifier
competent and independent person, or persons, with responsibility for performing and reporting on the verification process

Note 1 to entry: This term can be used to refer to a verification body.

[SOURCE: ISO 14064-1:2006, 2.36]