DET NORSKE VERITAS

CO2QUALSTORE
Guidance for users of the guideline

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For: CO2QUALSTORE partners and users of the guideline	DET NORSKE VERITAS AS P.O.Box 300 1322 Høvik, Norway Tel: +47 67 57 99 00 Fax: +47 67 57 99 11 http://www.dnv.com Org. No: NO 945 748 931 MVA

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Summary:

The main purpose of this document is to provide an easy-to-read manual for potential users of the CO2QUALSTORE guideline. In addition, the current report will map the relation between the guideline and related documents, including emerging directives and regulations for CO_2 Geological Storage (CGS). The current summary report will also provide reference to relevant standards, including an ISO standard that may be consulted for guidance on risk management.

	Name and Position	Signature
Prepared by:	Jørg Aarnes Principal Consultant	Jørg Aarnes
Verified by	Mike Carpenter Senior Consultant	M.E. Carpenter
Approved by:	Ståle Selmer-Olsen Associate Director	Ståle Selmer-Olsen

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1 OBJECTIVE AND OUTLINE

The main purpose of this document is to provide an easy-to-read manual for potential users of the CO2QUALSTORE guideline [1] (henceforth referred to as the guideline). To this end, the main application areas of the guideline for various users are described.

In addition, the current report will map the relation between the guideline and related documents, including emerging directives and regulations for CO_2 Geological Storage (CGS) [1-9]. The purpose of the mapping is help future users of the guideline

1. to assure compliance with relevant conventions, regulations, directives; and
2. to support development and harmonised implementation of legal and regulatory frameworks aligned with current best practise guidelines and standards for CGS.

The current report also provides reference to a relevant ISO standard on risk management [15] and lists some other relevant standards.

2 BRIEF SUMMARY OF GUIDELINE

The objective of the guideline is to provide a systematic approach to selection and qualification of sites and projects for CO_2 Geological Storage (CGS). A key intention is to harmonize implementation of CGS in compliance with regulations, international standards and directives (cf. Figure 1) while avoiding additional documentation and reporting requirements that may incur project delays and additional expense. To this end, the guideline introduces a generic workflow (Figure 2) for CGS project development relating activities and key project deliverables to associated milestones. To each of the stages Screen, Assess & Select, Operate and Close, a more detailed sub-workflow is presented with specific associated activities and deliverables. Finally, the purpose and scope of the different steps in the workflows for each stage is described. This description serves two primary purposes: to drive towards a consensus on the objectives of each step, and provide a basis for the discussion that a project developer may have with stakeholders on how the objectives should be met.

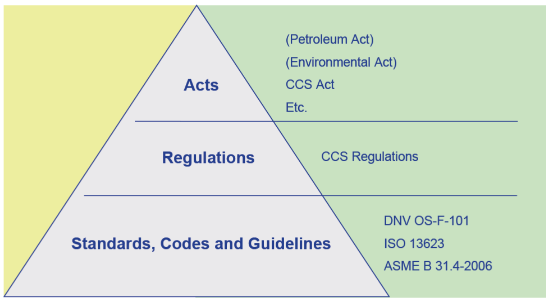

Figure 1: Acts, directives, conventions and regulations are commonly supported by standards, codes and guidelines that help facilitate efficient, safe and responsible implementation of industry best practice in compliance with regulatory frameworks.

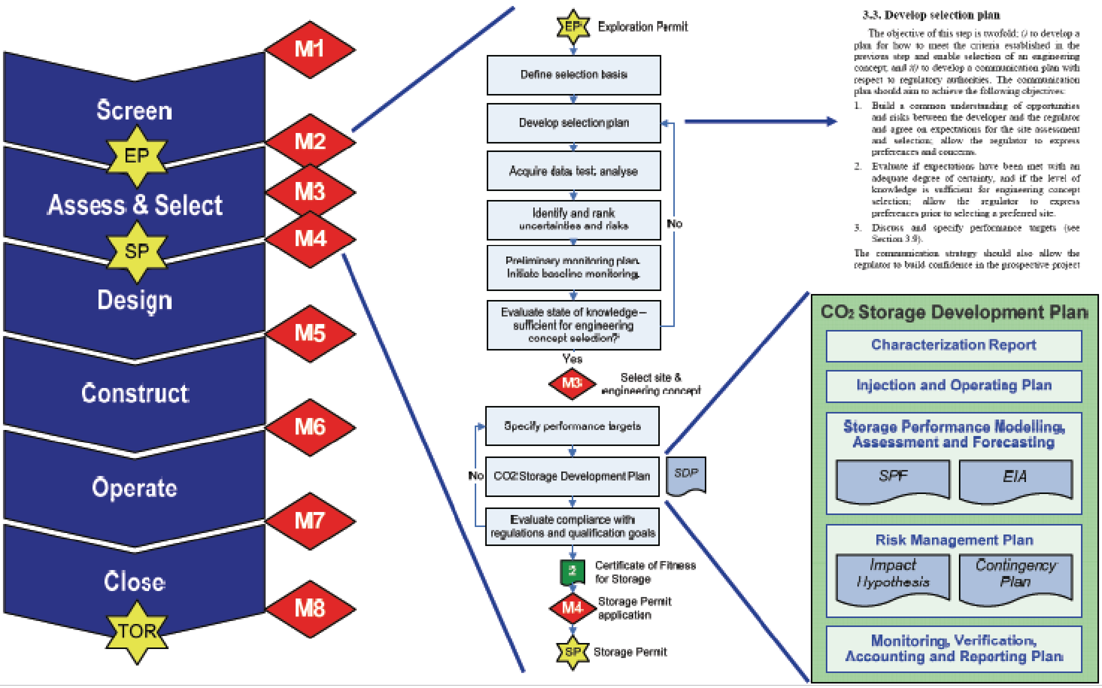

Figure 2: Generic workflow for a CGS project development (left) and the associated qualification workflow for the Assess and Select stage. Red diamonds refer to project milestones and yellow stars refer to permits or licenses that may be required. EP denotes Exploration Permit, SP denotes Storage Permit and TOR refers to Transfer Of Responsibility. Milestones M2, M3 and M4 represent the short-listing of sites for further characterization, site and engineering concept selection, and the submission of storage permit application respectively.

Figure 2 shows the workflow proposed for the Assess & Select stage. Note the guideline recognizes that the steps in the workflows may be performed in a different order, or with more iterations, in a real project, but the intention of the workflows is to provide a common reference that may serve as a guide for checking compliance. Moreover, if followed, it is envisioned that these workflows contribute to enhanced traceability and streamlined implementation across projects, both regionally and internationally. Note that the Design and Construct stages are not covered in the guideline.

The term qualification means the process of providing the evidence that the CGS site will function reliably within specified operational limits with an acceptable level of confidence. This includes demonstrating sufficient capacity and injectivity for the intended volumes of CO_2, geological characteristics providing good containment of injected CO_2 streams, and adequate monitoring potential to ensure environmentally safe CGS in compliance with applicable regulations.

Selection and qualification of sites and projects for CGS is regarded as an iterative process, involving a dialogue between the prospective project developer and the relevant regulator(s). A key objective of this dialogue is to agree on appropriate performance targets, and to reach consensus on the documentation necessary to provide confidence that the agreed performance targets will be met subject to a planned project development and operational strategy.

In the guideline it is proposed that the performance targets shall be tailored to the unique characteristics of each site. The performance targets should include a specification of which risk and/or uncertainty reducing measures shall be implemented to reduce the risk level down to an acceptable level. Such project specific performance targets can provide a valuable instrument that may be applied to reach consensus on conditions for granting of relevant permits.

The guideline is the result of a collaborative effort within the CO2QUALSTORE consortium, and feedback and comments from representatives from national authorities and CCS interest organizations. The guideline has also been subject to review by a large group of external stakeholders and regulators. In particular, as part of the CO2QUALSTORE project, meetings have been organized with representatives form national authorities in the UK, Norway, Denmark and Germany. In addition, the guideline has been presented to and discussed by the EU Commission Information Exchange Group on CCS and the North Sea Basin Task-Force, consisting of regulators from Norway, UK, The Netherlands and Germany. Finally, the guideline has been presented to and discussed with selected stakeholders.

2.1 Interface with guidelines for capture and transport

This guideline only covers CO_2 geological storage, i.e., does not include CO_2 capture, transportation or injection wells. These parts of the CCS value chain are addressed in three other Joint Industry Projects (JIPs) developing guidelines for qualification of CO_2 capture technology, safe reliable and cost-effective transmission of CO_2 in pipelines, and re-qualification of wells for CO_2 injection (see Figure 3). The guidelines developed in CO_2CAPTURE and the first phase of the CO_2PIPETRANS are completed [12,13]. DNV Recommended Practices (RPs) based on these guidelines are to be issued spring 2010.

The scope of the CO_2PIPETRANS only covers the pipeline part of the CO_2 transport, i.e., does not cover compression or booster stations, and does not include wells to be used for CO_2 injection. The CO_2WELLS guideline will cover active, temporarily abandoned and permanently abandoned wells (the latter will not be considered as candidates for re-qualification for CO_2 injection). Also note that CO_2WELLS does not cover design of new wells. The re-qualification procedure aims to develop a recognized procedure for evaluating the suitability of existing wells (from oil and gas exploration and production activities) that should enable cost effective re-use of existing infrastructure.

In addition to developing a guideline for re-qualification of wells for CO_2 injection, CO_2WELLS also aims to develop a common industry framework for risk evaluation of wells at CO_2 storage sites. This objective is not covered at a sufficient level of detail in CO2QUALSTORE. Indeed, the guideline considers wells to be an element in the risk-

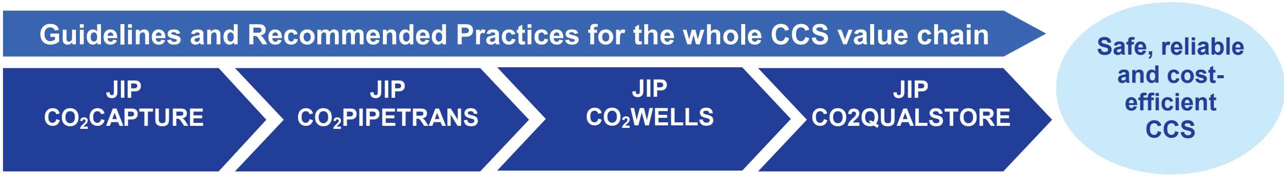

Figure 3: Four Joint Industry Projects (JIPs) developing guidelines for different parts of the CCS value chain. CO_2CAPTURE describes a procedure for qualification of CO_2 capture technology [12], CO_2PIPETRANS provides procedures for safe, reliable and cost-effective transmission of CO_2 in pipelines [13], and this guideline aims to provide procedures for selection and qualification of sites and projects for CO_2 geological storage. Wells are not specifically addressed in CO2QUALSTORE or CO_2PIPETRANS. CO_2WELLS aims to develop a common industry framework for risk evaluation of wells at CO_2 storage sites and a risk-based procedure for re-qualification of wells for CO_2 injection.

assessment of storage sites, but do not detail any procedures for the risk analysis of wells. The scope of CO_2WELLS is therefore complementary and supplementary to the scope of CO2QUALSTORE.

2.2 CO2QUALSTORE Workbook

Adopting a risk-based approach to site selection and management gives project developers more flexibility in the project design and operation, and regulators more influence on project management as it gives an incentive to reduce risks beyond minimal thresholds. By adopting a risk-based approach the guideline provides guidance on how site-specific performance targets can be defined. However, as this approach focuses on the performance goals and the work process to achieve these, it is gives less prescriptive and specific advice. To compensate for this and to make the guideline more practical in use, a workbook [10] with practical examples of the guideline and its various steps may be followed/interpreted.

The examples cover the following issues:

- Screening of prospective storage sites
- Characterization and selection of storage sites
- Risk assessment techniques and processes
- Evaluation of well integrity of abandoned wells
- Development of Monitoring, Verification, Accounting and Reporting (MVAR) plans
- Development and updating of a risk database
- Specification of operational performance targets
- Description of performance targets for site closure to support demonstration of compliance with regulatory conditions for transfer of responsibility
- The use of industrial analogues in constraining the risk assessments
- Coupling of the guideline with an accounting framework to form the basis for a CDM methodology
- Comparison with other relevant guidelines.
- Overview of some relevant R&D and demo projects providing input to the guideline development.

The workbook is currently project specific, i.e., only available to the CO2QUALSTORE partners. Several of the examples in the workbook are taken from sub-projects and satellite projects run by the CO2QUALSTORE partners [11].

3 GUIDANCE FOR USERS

The guideline should provide a reference document that guides implementation of CGS projects, informs of industry practice, and supports implementation of national and state regulations. The guideline should also provide a basis for verification. Verification refers to the comparison and evaluation of predicted and measured performance of a project in terms of safety and environment and/or emission reduction. Verification is done by the operator, competent authority and/or an independent third party.

Table 1 shows the intended value of the guideline for a range of different users. The general public is not identified as a direct user of the guideline. However, implementation in compliance with this guideline should help provide assurance to the general public and other potential interested parties that a CGS site is selected based on a transparent and recognised process, will be safely and responsibly managed according to industry practice, and is in compliance with regulations and relevant directives.

The following subsections attempt to describe how and when various users may apply the guideline.

Table 1: Applicability matrix showing the intended value of the guideline for various users.

	Developer	Regulator	Third
Guide implementation	X		
Inform of industry practice	X	X	X
Support implementation of regulations	X	X	
Reference for verification	X	X	X
Support stakeholder communication	X	X	X

3.1 Guidance for project developers

Table 1 indicates five areas of application of the guideline for project developers. The purpose of this section is to explain how it is intended that the guideline may support a project developer in these areas. "Guidance for verification" is discussed separately in Section 3.3 below. In particular, Section 3.3 highlights milestones where project developers or regulators may consider initiating verification activities to validate results of associated deliverables.

3.1.1 Guide implementation and inform of industry practice

The main value of the guideline for project developers is probably as a template for structuring of the site and project development, and as a reference document that indicates documentation that regulators should request from project developers at given milestones. In particular, the guideline aims to drive towards consistent implementation of CGS projects, and consequently help regulators evaluate if a project is developed in accordance with industry practice.

Workflows: The guideline suggests tasks that should be considered included in the Screen, Assess & Select, Operate and Close stages of a CGS project. These workflows provide a starting point for planning of studies to be performed as part of the site development, and as a basis for the discussion that project developers may have with regulators aiming to demonstrate that the work performed meets general expectations and is consistent with industry practice.

Note that it is emphasized that the different steps in the workflows are not necessarily mandated by regulations, and do not need to be performed in the order they appear. However, documenting that steps in the relevant workflows have been executed may build trust and confidence in the project developer's ability to responsibly select and operate a site for CGS, and contribute to enhanced traceability of the site development and management.

Documentation: The documents that the guideline suggests that regulators should request from project developers at key project milestones, and the key principles for development of these documents, are described in Appendix B of the guideline. The main objectives of these documents are described below.

1. *Screening Report (SR):* Review the activities and findings of the site screening and document the basis for the decision to commit budget and resources for further site assessment of one or more sites shortlisted for further characterization.
2. *Characterization Report (CR):* Document the site characterization activities that have been executed and how these activities have built understanding of the storage characteristics by iteratively addressing risks and reducing associated uncertainties. The initial CR should also describe how the characterization results support the site and engineering concept selection.
3. *Injection and Operating Plan (IOP):* Define a developer's ambitions for a storage site and the technical means for achieving these aims.
4. *Storage Performance Forecast (SPF):* Document the results of modeling and simulation studies performed to assess the significance of each identified risk element, and the effect of each associated safeguard.
5. *Environmental Impact Assessment (EIA):* Clarify the positive and negative effects that a project's activities may have on the environment, economy, natural resources and society.
6. *Impact Hypothesis (IH):* Give a concise statement of the expected consequences – both positive and negative – of the CGS project. In particular, the IH should assess the residual risk contingent upon implementation of all safeguards implied by the performance targets.
7. *Contingency Plan (CP):* Prioritize and rank contingency measures according to the assessed cost-effectiveness of their risk/uncertainty reducing effect, document that conceivable but unexpected site performance scenarios can be adequately controlled, and express the project developer's commitment to implement appropriate contingency measures if necessary.
8. *Monitoring, Verification, Accounting and Reporting (MVAR) plan:* Describe how the risk profile of a storage site will be reduced over its lifetime, building assurance that the performance targets will be achieved, and verifying that the CGS site is performing as expected within agreed and acceptable limits, as well as to address known or perceived risks. Furthermore, the MVAR plan should document and report how the goals of the projects are being met in terms of emissions avoided and storage containment.
9. *Project Review:* Review and assess consistency, traceability and transparency of modeling and performance predictions, risk and uncertainty assessments, the SPF and EIA, performance targets, the IH and CP, and the MVAR plan.

The SR is only prepared once, or until it meets the expectations of the regulator. All other reports will be updated throughout the project life. Documents 2-8 form the CO_2 Storage Development Plan (SDP) which will be updated, as appropriate, as part of permit review processes. To facilitate this process, it is proposed to include an extra report, the Project Review, which primarily aims to document that the SDP, as well as studies that form the basis for the SDP, has been executed, maintained and updated in a consistent, traceable and transparent way.

3.1.2 Support implementation of regulations

The guideline aims to be consistent with emerging regulations, although additional requirements may apply in local regulations. Thus, following the guideline may not necessarily be sufficient to demonstrate compliance with regulations, but it is intended that the guideline may serve as a basis for tuning project development to the requirements of applicable regulations and directives. In particular, the guideline aims to drive towards an industry practice that is supportive of a risk based approach with sufficient flexibility to adapt to local regulations and site specific conditions.

Because emerging regulatory frameworks for CGS differ in scope and format, some of which are linked to existing regulations for petroleum activities, it is difficult to define a generic approach for how to tune the guideline to applicable regulations. Instead we provide some examples showing how the guideline relates to three documents that attempt to define a regulatory framework for CGS in Europe [1], the USA [3] and Australia [4] in Section 4 below.

3.1.3 Support stakeholder communication

The guideline indicates when and how during the life-cycle of a CGS project that it is advised that the project developer should communicate with, or disseminate information to, regulators, stakeholders and potentially also the public. This topic is broadly covered in Appendix C of the guideline, which distinguishes between permit application/review processes, public outreach programs, and communication triggered by significant irregularities.

Appendix C of the guideline does not provide guidance on how to manage public outreach programs, but gives some very generic principles that may help guide the communication process in such programs. The aims and purposes of communication processes that are proposed to take place as part of permit application/review processes are described in Section 3.2 below. The primary aim of these communication processes is to drive towards a consensus on conditions for project approval and granting of storage permits, including consensus on acceptable levels of risk and uncertainty.

The public will frequently have less knowledge about CCS, and associated opportunities and risks, than regulators and stakeholders involved in project approval processes. But opposition to CCS from the public may nevertheless be an obstacle that may cause project delays. The guideline therefore highlights the need for good communication with the public, where the communication strategy is tuned to the intended recipients. This strategy should reflect that perception and acceptance of risks involves a subjective balancing of benefits with risks.

For communication triggered by significant irregularities, a workflow is provided in order to help streamline the communication process. The guideline indicates that essential objectives for good communication and management of significant irregularities include the following:

- Trust that significant irregularities are promptly and openly communicated to relevant authorities, and if appropriate, to stakeholders and the public.
- Confidence that the developer comprehensively assesses the scale and origin of the problem, and how to prevent similar events in the future.
- Confidence that continued storage operation will only be permitted if it is assessed by a transparent and recognized procedure that the future site performance will be in compliance with applicable regulations and qualification goals.
- Trust that the conclusions of the analysis performed are openly communicated to relevant authorities, and, if required, any other appropriate audiences.

How communication of significant irregularities is managed may ultimately have a strong impact on the future reputation of CCS. One ill managed project can outweigh the track record of many well managed projects. Hence, to enhance credibility, the guideline suggests that an independent third party should be involved in the process of evaluating and communicating the implications of significant irregularities for human health and the environment.

Finally, when communicating or discussing risk it may be helpful to make use of metrics or analogues which allow comparison of different risks, e.g., by comparing CCS to health, safety and environmental risks arising from other large-scale public/private infrastructure developments (dams, railways, airports, etc.), and relevant analogues for CGS (e.g., oil and gas exploration, natural gas storage, acid gas disposal, etc.). A description of some relevant analogues that may be used to compare and communicate risks related to CGS is provided in [10].

3.2 Guidance for regulators

The guideline identifies several points of contact between a project developer and the relevant regulator or entity acting on behalf of the regulator (hereafter referred to simply as ‘the regulator’). The purpose of this section is to describe or suggest the following for the associated communication processes:

i) what the communication process should aim to achieve, i.e., the main deliverables;

ii) what the regulator may expect in terms of documentation/input from the project developer;

iii) what the role of the regulator/entity acting on behalf of regulator is anticipated to be.

3.2.1 Screening / Exploration permit application

Deliverables:

- Shared understanding of the opportunities and risks associated with implementing CGS in the targeted region and the screening process performed to identify the well suited sites.
- If applicable, conditions for granting of exploration permit.

Documentation/input: Screening Report (SR).

Role of regulator: The role of the regulator in this process may comprise of verification of the SR (see Section 3.3.2 below) and, if applicable, assessing if the screening performed has been adequate to grant an exploration permit to the project developer for one or more of the sites considered well suited for CGS. If the issue of an exploration permit is relevant, the regulator should discuss with the project developer any conditions that are attached to this permit.

3.2.2 Site and concept selection

Deliverables:

- Shared understanding of the basis for site and engineering concept selection, and a common perception that the "state of knowledge" is sufficient for this decision.
- Consensus that the permit application process can be initiated for selected site(s).

Documentation/input: Characterization Report (CR).

Role of regulator: Review data collected and the results of the site characterization, and evaluate if the "state of knowledge" is sufficient for site and engineering concept selection.

- No: Concerns considered not properly addressed should be expressed to project developer.
- Yes: Form an opinion of site(s) and engineering concept(s) recommended or preferred by project developer and assess if the reasons for choosing the preferred site(s) and engineering concept(s) are relevant, appropriate and properly justified.
    - Yes: Communicate position and agree on permit application process.
    - No: Communicate position and explain why a different solution is preferred.

3.2.3 Storage permit application

Deliverables:

- Performance targets (for site approval/operation and provisional targets for site closure)
- Storage permit

Documentation/input: Project risk database and CO_2 Storage Development Plan (SDP).

Role of regulator: There are two main tasks for the regulator in the so-called permit application process. The first task is to contribute actively to reach consensus on performance targets, e.g., in a workshop (with the participation from the project developer, the regulator, representatives from a competent entity acting on behalf the regulator, and potentially also competent third-party assigned with the task of facilitating the workshop). The second task is the more formal task of evaluating the storage permit application, and, in particular, the SDP. If the storage permit application is rejected, the project developer should be informed of the reasons for this decision.

3.2.4 Storage permit review

Deliverables:

- Updated performance targets, if required.
- Renewal/withdrawal of storage permit, possibly with updated operating conditions.

Documentation/input: Report from documentation review (Section 4.3 in guideline), previously specified performance targets and updated risk database.

Role of regulator: Contribute to reach consensus on updated performance targets, if required, and evaluate if the project has performed, and may be anticipated to continue to perform, in compliance with permit conditions and performance targets. This evaluation will then form a key input to the decision to renew or withdraw the storage permit. Where appropriate the regulator should update the permit conditions. If a site re-qualification process has been executed, e.g., due to altered operating conditions, then the regulator's role will be similar to the role described above for the initial storage permit application process. If the regulator decides to withdraw the storage permit, the project developer should be informed of the reasons for this decision.

3.2.5 Site closure conditions

Deliverable: Site closure conditions.

Documentation/input: Report from documentation review (Section 4.3 in guideline), previously specified performance targets and updated risk database.

Role of regulator: Contribute to reach consensus on performance targets for site closure, layout of post-injection MVAR plan, and any additional conditions for site closure. This task may be performed as part of the first permit review process after cessation of injection operations. Reasons for imposing site closure conditions that deviate significantly from conditions defined as part of storage permit or agreed during operation should be adequately substantiated.

3.2.6 Site closure / Transfer of responsibility

Deliverable:

- Endorsement of site closure.
- Transfer of responsibility

Documentation/input: Report from documentation review and updated Storage Performance Forecast (SPF) and Environmental Impact Assessment (EIA).

Role of regulator: Evaluate or verify site closure assessment. If the conclusion from the evaluation is positive, the regulator may express endorsement of site closure, e.g., by issuing a "*Certificate of fitness for site closure*" (see Section 3.3.5 below). If the regulator concludes that the available evidence is insufficient to endorse site closure, the concerns that the project developer should address prior to closure should be communicated to the project developer.

Following a positive evaluation of the site closure assessment, the regulator should express his intention to allow transfer of responsibility contingent upon execution of an approved decommissioning plan and, if required, a stakeholder communication process.

3.3 Guidance for verification

The guideline differentiates between the following two forms of verification:

- Verification of performance in terms of safety and the environment
- Verification of performance in terms of emission reductions

Although the guideline aims to lay the groundwork for verification of performance in terms of emission reductions, this form of verification is not within the scope of the guideline. The primary reason for this is that the guideline focuses on supporting and structuring communication between the project developer and the relevant regulator and stakeholders. The relevant verification tasks supporting these communication processes are therefore often of a technical and informal nature, i.e., not mandated by regulations. Verification of emission reductions, on the other hand, will be mandated to achieve emission credits and be performed by an independent accredited verification body subject to specific criteria in an applicable accounting framework.

The verification tasks described below, which relate to verification of performance in terms of safety and the environment, may be performed by the regulator, an entity acting on behalf of regulator (designated body), or an independent party (third party). The verification tasks typically comprise independent validation of results that form part of documentation provided to an external party, e.g., regulators with responsibility for managing safety and environmental issues related to CGS, financial stakeholders contributing to the project's financial security, or third parties and public groups that may be affected by the CGS operations. Most of the verification tasks are linked to permit application/review processes, potentially resulting in the issue of a corresponding qualification statement. The guideline introduces the following three qualification statements;

1. statement of storage site feasibility;
2. certificate of fitness for storage;
3. certificate of fitness for closure.

Whereas Statement 1 and 3 will only be issued once for each project, Statement 2 may be re-issued after successful completion of permit review or re-qualification processes, indicating that the storage site continues to be fit-for-storage, possibly subject to altered operating conditions.

The guideline identifies decision points in the CGS project life cycle where it is envisioned that some form of verification may be requested by a project developer, finance institution or regulator. The purpose of the following subsections is to describe the objective, scope and value of the verification process associated with these decision points. The verification tasks described below are discussed in the chronological order that they appear in the life-cycle workflow outlined in the guideline.

3.3.1 Pre-feasibility

Objective: Verify that the screening process associated with the first three steps in the Screen stage workflow has been sufficiently comprehensive and balanced to identify all sites within the targeted region that based on available data is assessed to meet appropriate defined screening criteria. The screening criteria should be defined so that there is a high probability that at least one of the sites that meet all screening criteria will prove to be suitable for storing the intended volumes of CO_2 with the level of confidence necessary for obtaining a storage permit.

Scope: Typically independent review of report documenting screening criteria and how screening criteria have been applied narrow down the list of suitable sites.

Value: Verification that the sites short-listed by the project developer represent the result of a transparent screening process using appropriate screening criteria for the objective at hand. A verification report with a positive conclusion may form an input to the decision to apply for an exploration permit. A negative conclusion may suggest that the project developer should re-iterate the screening process, or potentially look for prospective CGS sites elsewhere.

3.3.2 Feasibility

Objective: Verify that the screening process as documented in the SR has been adequate. In addition to documenting the work and results obtained in the pre-feasibility phase in order to identify prospective storage sites, the SR should present capacity estimates accompanied by an uncertainty band for these estimates and include an initial risk register.

Scope: Independent review of the SR, including an independent assessment of the validity of the derived capacity estimates and associated uncertainty bands, and the completeness of the initial risk register. If verification of the pre-feasibility phase has not been performed, the verification of the SR should also consider the appropriateness of the screening criteria and judge if the way they have been applied is adequate for meeting the objectives of the pre-feasibility phase.

Value: A positive conclusion from this verification task, which could be expressed in the form of a "*Statement of site feasibility*" issued by the verifier, would indicate that; the screening criteria have been appropriate; that the way the screening criteria have been applied is adequately balanced and reflects the available data; that the derived capacity estimates and associated uncertainty bands are reasonable and derived using an appropriate method based on the level of information available; and that the initial risk register is properly documented and reflects the results of an appropriate early stage risk and uncertainty identification process. A "*Statement of site feasibility*" may form part of the documentation for an exploration permit application.

3.3.3 Basis for engineering concept selection

Objective: Verify that the CR provides a sufficient basis to allow:

- the project developer to select site and engineering concept,
- the regulator to form an independent opinion of the site and concept selection,
- the project developer to move forward with the permit application process.

Scope: Independent review of CR. This includes evaluating if the data acquisition and analysis process has been sufficient relative to the criteria put forward in the selection basis, and to support a comprehensive risk and uncertainty identification and assessment process. The task should also assess if the preliminary monitoring plan is appropriate and properly reflects the risk assessment, and if all necessary baseline monitoring activities have been executed. If more than one site is considered, the current verification task should assess if the information provided gives an adequately balanced picture of the characteristics of the alternative sites, and support the recommendation made by the project developer with regard to the preferred site and concept.

Value: A positive conclusion from this verification task would support that the CR adequately documents that the level of knowledge gained to date for the sites considered is sufficient to meet the objective of this task. This conclusion would signal that the CR is sufficiently complete to be submitted to the regulator, indicating the project developer's intention to initiate the permit application process. A negative conclusion would indicate that the state of knowledge is considered insufficient for the site or concept selection. The project developer may then need to re-iterate some of the preceding steps in the Assess and Select workflow and update the CR accordingly before selecting site and concept and going ahead with the permit application.

3.3.4 Fitness for (continued) storage

Objective: Support permit application/review process by providing verification that the planned project development, as described in the SDP, is in compliance with regulations and qualification goals, and meets conditions for obtaining a (renewal of the) storage permit.

Scope: Evaluate if the SDP covers the applicable requirements expressed in regulations and provides sufficient confidence that the project, subject to the defined IOP and associated Risk Management Plan (RMP) will provide safe long term storage of CO_2 in compliance with regulations, qualifications goals, and any additional criteria in selection basis. This includes assessing if there is an adequate level of consistency between the documents included in the SDP. In the guideline, the layout of the SDP is structured so that the document(s) associated with each "box" provide(s) input to the subsequent "box" as follows:

- the IOP reflects the understanding of the site characteristics documented in the CR.
- the SPF and EIA document an adequate level of knowledge and understanding of future site performance (in terms of containment, capacity, injectivity, and potential safety and environmental impact stemming from the CGS operations) based on the operating conditions outlined in the IOP.
- the RMP reflects the performance targets, which are justified by analysis contained in the SPF and EIA, and provides confidence that all identified risks will be adequately controlled.
- the MVAR plan is in accordance with regulations and fulfils the needs for monitoring and verification identified in the RMP.

For verification as part of permit review process, part of this task will be to re-evaluate if the site characterization, modeling and simulation activities performed to date during operation have been in accordance with plans and permit conditions, and have been adequate to demonstrate proper and responsible management of opportunities and risks. In particular, verify that the documents in the SDP and the performance targets have been updated in a transparent and traceable way.

Value: Verification of completeness and consistency of SDP, and that the activities performed to date have been in accordance with SDP and permit conditions. The deliverable from this process may be a "*Certificate of fitness for storage*", or "*Certificate fitness for storage renewal*." Such a certificate may be valuable when documenting responsible operatorship as part of a site closure qualification process.

3.3.5 Fitness for closure

Objective: Verify that the project, contingent upon approval of the decommissioning plan, meets the requirements for site closure stated in the storage permit, the performance targets for site closure, and any additional requirements imposed by applicable regulations or by the regulator.

Scope: The primary task associated with verification of "*Fitness for closure*" involves a review of all documents compiled to support the site closure qualification process as outlined in the guideline, and assess if the conclusions drawn by the project developer with regard to future performance of the storage site are credible and adequately substantiated.

Value: A positive site closure assessment, which may be expressed in the form of a "*Certificate of fitness for closure*" issued by the verifier, signifies that the project, contingent upon execution of the approved decommissioning plan and, if required, a stakeholder communication process, meets the applicable conditions for transfer of liability to the national or state authority.

4 RELEVANT EMERGING CODES, REGULATIONS AND CONVENTIONS

This section is to maps and compares the CO2QUALSTORE guideline against the following emerging regulatory frameworks for CCS:

- the EU CCS Directive (on geological storage of CO_2) [1], henceforth called "EU CCS Directive".
- the proposed federal requirements proposed by the U.S. Environmental Protection Agency (EPA) for regulation of wells for injection of CO_2 for the purpose of geological storage [3], henceforth referred to as "proposed rule by U.S. EPA".
- the Australian offshore greenhouse gas storage bill [4], called the "Australian offshore GGS bill".

The purpose of the mapping is to help guideline users assure compliance with conventions, regulations and directives; and to support development of regulatory frameworks aligned with current best practise guidelines and standards for CGS.

4.1 EU CCS Directive

The EU CCS Directive sets out a legal framework for environmentally safe CGS, defined as "*permanent containment of CO_2 in such a way as to prevent and, where this is not possible, eliminate as far as possible negative effects and any risk to the environment and human health.*" The directive applies to the EU "*member states, their exclusive economic zones and on their continental shelves within the meaning of the United nations Conventions on the Law of the Sea*".

The following subsections explain how articles of the EU CCS Directive are addressed in the guideline, and point out potential areas of discrepancy. These findings are summarized in Table 2. The definitions in the guideline are broadly aligned with the nomenclature in the EU CCS Directive, but with a few notable differences noted in Table 3 below.

4.1.1 Article 7: Storage permit applications

The EU CCS Directive states that applications for storage permits shall include at least the following information:

1. name and address of the potential operator;
2. proof of the technical competence of the potential operator;
3. the characterization of the storage complex and an assessment of the expected security of the storage pursuant to Article 4(3) and (4);
4. the total quantity of CO_2 to be injected and stored, as well as the prospective sources and transport methods, the composition of CO_2 streams, the injection rates and pressures, and the location of injection facilities;
5. description of measures to prevent significant irregularities;
6. a proposed monitoring plan pursuant to Article 13(2);
7. a proposed corrective measures plan pursuant to Article 16(2);
8. a proposed provisional post-closure plan pursuant to Article 17(3);
9. the information provided pursuant to Article 5 of Directive 85/337/EEC;
10. proof that the financial security or other equivalent provision as required under Article 19 will be valid and effective before commencement of injection.

Table 2: Overview of articles in EU CCS Directive covered by stages in the guideline.

Description	**Articles in EU CCS Directive**	**Sections in the guideline**
Application for storage permits	Article 7	Sections 3.9-3.11
Changes, review, update and withdrawal of storage permits	Article 11	Section 4
Monitoring, Reporting by the operator and Inspections	Articles 13-15	Appendix B.5
Measures in case of leakages or significant irregularities	Article 16	Section 3.9 and Section 4.5 and Appendix B.4.
Closure and post-closure obligations	Article 17	Section 4.5
Transfer of responsibility	Article 18	Section 5
Criteria for the characterization and assessment of the potential storage complex and surrounding area.	Annex I	Section 2 and Sections 3.1-3.7.
Criteria for establishing and updating the monitoring plan and for post-closure monitoring	Annex II	Section 3.10, Section 4.6 and Appendix B.5.

Table 3: Relationship between analogous terms in the guideline and the EU CCS Directive.

Guideline	**EU CCS Directive**	**Comment**
Storage volume	Storage complex	Essentially same definition
Project developer	Operator	Essentially same definition
Site closure	Closure	The EU CCS Directive defines *closure* as "definitive cessation of CO_2 injection into the storage site", whereas the guideline defines *site closure* as "Abandonment of a storage site, including abandonment of all unplugged wells within the permit area, and the decommissioning of all associated surface or subsurface facilities."
Post-closure	Post-closure	Different meaning due to different definition of closure. Period after *closure* in EU CCS Directive, and period after *site closure* in the guideline.

Table 4: Comparison of CO_2 storage permit requirements in the EU CCS Directive and the guideline.

Information requirement in EU CCS Directive	**Relevant document in guideline (within SDP)**
3: Characterization of storage site and complex and an assessment of the expected security of the storage; • The suitability of a geological formation for use as a storage site shall be determined through a characterization and assessment of the potential storage complex and surrounding area pursuant to the criteria specified in Annex I of the EU CCS Directive. • A geological formation shall only be selected as a storage site, if under the proposed conditions of use there is no significant risk of leakage, and if no significant environmental or health risks exist.	Characterization Report (CR) and Impact Hypothesis (IH)
4: The total quantity of CO_2 to be injected and stored, as well as the prospective sources and transport methods, the composition of CO_2 streams, the injection rates and pressures, and the location of injection facilities	Injection and Operating Plan (IOP)
5: A description of measures to prevent significant irregularities	Impact Hypothesis (IH)
6: A proposed monitoring plan pursuant to requirements laid down in Annex II of EU CCS Directive.	Monitoring, Verification, Accounting and Reporting (MVAR) plan
7: A proposed corrective measures plan.	Contingency Plan (CP)
8: A provisional post closure plan	• IOP: Provisional site abandonment and decommissioning plan • IH: Performance targets for site closure, including associated measures to prevent significant irregularities • MVAR plan: including monitoring after cessation of injection.

Apart from items 1, 2, 9 and 10 which relate to issues outside the scope of the guideline, all remaining items are included in the CO_2 Storage Development Plan (SDP). The guideline suggests that the SDP should form the technical basis for the regulatory decision to grant/renew a storage permit. Table 4 shows which document in the SDP covers the items listed above.

4.1.2 Article 11: Changes, review, update and withdrawal of storage permits

The contents of Article 11(1), 11(2) and 11(3) in the EU CCS Directive is addressed in Section 4 of the guideline covering permit review and site re-qualification. The guideline proposes a workflow that can be applied to both permit review and site re-qualification processes, but it is anticipated that the associated documentation requirements for site re-qualification will be more comprehensive than the associated requirements to permit review processes.

According to the recommendations in the guideline, the occurrence of any of the cases described in Article 11(3a-3d) in the EU CCS Directive may call for a site re-qualification process to be performed. Article 11(3e) states that a permit review process should be executed without prejudice to points 11(3a-3d) five years after the initial permit and every 10 years thereafter. This illustrates the relevance of defining a workflow for the permit review process. Indeed, it will be important for project developers to understand what the permit review process will encompass.

4.1.3 Articles 13-15: Monitoring, Reporting and Inspection

Articles 13-15 in the EU CCS Directive are covered by the MVAR plan, which will need to be tailored to the specific requirements in applicable regulations. However, whereas the scope of the monitoring, as defined in Article 13(1) is consistent with the guidance provided in the guideline, the guideline also describes some principles that could help ensure completeness of the monitoring plan, including needs for internal quality control and external verification. A key principle is that the monitoring plan should be informed by a risk analysis, and be designed to ensure that an adequate understanding of site performance to allow proper management of risks.

Annex II in the EU CCS Directive further describes parameters to be monitored or measured, and state that the choice of monitoring technology shall be based on best practice available at the time of design. The guideline does not prescribe which parameters should be monitored or which monitoring technologies should be employed. It is assumed that parameters to be monitored will partly be defined by regulation and partly derived from the results of the risk assessment, i.e., to reduce the risk profile of a storage site over its lifetime. The choice of monitoring technology best suited for the purpose at hand may be subject to discussion between the project developer and the regulator. A premise for this discussion is that the project developer can demonstrate adequate risk control, i.e., the ability to manage all risks down to an acceptable level. Risk performance targets may be used to guide this discussion, and open for considerations regarding cost versus risk reduction and/or information benefit.

Similarly, the reporting requirements laid down in Article 14 are quite general, implying the need to detail project specific reporting requirements on a case-by-case basis. This philosophy is consistent with the guideline, which suggests that project monitoring and reporting requirements should be tuned to site specific characteristics and the identified risks.

Finally, plans for inspection of surface and monitoring facilities should be included in the MVAR plan in the SDP. Again, the guideline describes some principles that may help ensure that the verification plan is adequate, but leaves flexibility to tune verification requirements to the site specific conditions and requirements in applicable regulations.

4.1.4 Article 16: Measures in case of leakages and significant irregularities

This article addresses primarily the responsibilities of the competent authority (regulator) in case of leakages or significant irregularities occur. The operator is required to implement appropriate measures in the corrective measures plan, which is analogous to the CP in the guideline.

4.1.5 Article 17: Closure and post-closure obligations

The guideline does not distinguish between the injection and post-injection phase (prior to transfer of responsibility). These two phases are both part of the "Operate" stage. The main reasoning for this is that, apart from cessation of the injection operations, the site management of the storage site will largely continue as before, including iterative cycles of monitoring, modeling and performance prediction, and risk assessments. However, to support demonstration of compliance with regulatory conditions for transfer of responsibility, the guideline introduces the concept of "performance targets for site closure (i.e., transfer of responsibility)". To provide more predictability to project developers and regulators on actual criteria for transfer of responsibility, the guideline suggests that the performance targets for site closure should be agreed or approved at the end of injection, i.e., at the time of closure as it is defined in the EU CCS Directive.

The performance targets for site closure defined at this stage, along with a possibly updated site abandonment and decommissioning plan in the IOP, and a possibly updated monitoring plan in the MVAR plan, correspond to the post-closure plan as referred to in Article 17(3).

4.1.6 Article 18: Transfer of responsibility

The "Close" stage in the guideline aims to support demonstration of compliance with Article 18 in the EU CCS Directive, or corresponding articles in other regulations (recall that the EU CCS directive defines *closure* as cessation of injection while the guideline defines *site closure* as site abandonment and transfer of responsibility). The primary means to facilitate demonstration of compliance with Article 18 comprise specification of performance targets for site closure.

The performance targets for site closure relate to the technical and environmental conditions for transfer of responsibility. The intention is that these targets should concretize the conditions for transfer of responsibility as laid down by regulations, tuning the conditions to the characteristics of the site. In particular, these performance targets should help provide predictability to both regulators and project developers on how the conditions for transfer of responsibility stated in regulations will be interpreted for a particular site and project. With regard to the conditions for transfer of responsibility in the EU CCS Directive, the performance targets for site closure should provide a site-specific interpretation of the conditions stated in Articles 18(1a) and 18(2a-2c).

Article 18(2) indicates that the European Commission may adopt guidelines on the assessment of the matters referred to in Article 18(1a-1c). Rather than developing guidelines for how to assess compliance with Article 18(1a), the guideline proposes that criteria for transfer of responsibility related to site performance should be assessed and evaluated based on a site-specific assessment following a structured qualification process. It is further suggested that this process should build on an iterative interactive dialogue between the project developer and the regulator which includes an up-to-date consideration of appropriate and project specific performance targets for site closure. It is anticipated that adopting such a structured qualification process may alleviate the need for further guidelines on this issue.

The guideline does not suggest a minimum period for post-injection operation prior to transfer of responsibility, as is suggested in Article 18(1b). In contrast, the guideline asserts that risk-based site closure conditions (as reflected in Articles 18(1a) and 18(2a-2c)) can often be demonstrated before the end of the default post-injection period of 20 years suggested in the EU CCS Directive.

The last step in the workflow for the "Close" stage, after regulatory approval that the site closure conditions have been met, is the update of the decommissioning plan. Transfer of responsibility is indicated to occur after approval of the site abandonment and decommissioning operations. This is consistent with Article 18(1d).

4.2 Proposed rule by U.S. EPA

The proposed rule by the U.S. EPA applies to owners or operators of CO_2 injection wells for the purpose of long-term CGS and the scope is thus more limited than that of the CO2QUALSTORE guideline or the EU CCS Directive. Also note that the owners and operators of the CO_2 injection wells may be different from the storage site developer. The proposed rule by the U.S. EPA does, however set out a regulatory framework for managing CO_2 injection for CGS in the USA and this provides the motivation for the following comparison with the guideline.

It should be noted that the proposed framework is based on a "tailored requirements approach" to CGS that also includes consideration of storage site suitability and is not only restricted to well design and operations. This approach builds on technical standards for deep-well injection of non-hazardous fluids where appropriate, and tailors them to address challenges of long-term CGS. An incentive for choosing this approach is that it gives permitting authorities discretion in how to permit certain elements and in requiring additional information.

The relevant section of the proposed rule by the U.S. EPA is structured into the following parts:

1. geologic siting requirements,
2. Area of Review (AoR) and corrective actions requirements,
3. injection well construction requirements,
4. injection well operating requirements,
5. mechanical integrity testing requirements,
6. plume and pressure front monitoring requirements,
7. record keeping and reporting requirements,
8. well plugging, post-injection site care, and site closure requirements,
9. financial responsibility and long-term care requirements.

Parts 3-5 and 9 give detailed prescriptive requirements that are outside the scope of the guideline itself, although such requirements could potentially arise on a site specific basis as a result of the risk management process described in the guideline. For example, whereas the proposed rule by

U.S. EPA states that "the pressure in the injection zone should not exceed 90% of the fracture pressure of the injection zone", the guideline attempts to leave flexibility to tailor operating parameters to each site.

The following section discusses how parts 1-2 and 6-8 are addressed in the guideline and how the proposed requirements support or deviate from a risk-based approach. The findings are summarized in Table 5.

Table 5: Overview of guideline coverage of relevant sections in the proposed rule by U.S. EPA.

Proposed requirements in proposed rule by U.S. EPA	Relevant section(s) in guideline
1: Geologic siting	Section 2 and Sections 3.1-3.7.
2: Area of Review (AoR) and corrective actions	Sections 3.4, 4 and Appendix B.4
6: Plume and pressure front monitoring	Section 3.10 and Appendix B.5
7: Recordkeeping and reporting	Section 3.10 and Sections 4-5
8: Well plugging, post-injection site care, and site closure	Section 5.

4.2.1 Geologic siting requirements

The content of this section is largely aligned with a risk-based philosophy, and supports the approach taken in the guideline. Section 2 and Sections 3.1-3.7 in the guideline outline a process for the geologic siting, and provide a basis for specification of geologic siting requirements. In addition, Appendix B.2 proposes a template for the CR which includes a summary of the main data types that may be considered collected for site assessment.

4.2.2 Area of Review (AoR) and corrective actions requirements

In the proposed rule by the U.S. EPA the AoR is defined as "the (surface) region surrounding the geological sequestration project that may be impacted by the injection activity". Thus, the AoR corresponds to the surface footprint of the storage volume (storage complex). The U.S. EPA proposes that the AoR (and the subsurface storage site) should be delineated using computational fluid flow models designed for the specific site conditions and injection regime. This recommendation supports the risk-based and site-specific approach proposed in the guideline.

This section of the proposed rule also discusses the basis on which flow models should be based, and the purpose of modeling "CO_2 movement and reservoir pressure". The proposed rule suggests that operators should be allowed flexibility in choosing modeling methods and tools, e.g., also proprietary models may be used provided the code assumptions, relevant equations, and scientific basis are disclosed.

In addition to delineation of the AoR and subsurface storage volume, the proposed rule by the U.S. EPA states that "models can be used to develop monitoring plans, help evaluate long-term containment, select and characterize suitable storage formations, assess the risk associated with CO_2 leakage and other impacts to USDWs (underground sources of drinking water), and to design remediation strategies". This is consistent with the defined purposes of numerical simulations defined in Section 3.4.5 in the guideline. In addition, the guideline highlights the need to perform multiple simulations based on different (geostatistical) realizations of the geology in order to allow estimation of the variability of the key output parameters.

The proposed rule by the U.S. EPA does not dictate specific corrective action methods, but instead requires that the corrective action methods be appropriate to the CO_2 injection. This would be aligned with the approach taken in the guideline where it is suggested that project specific corrective actions should be identified and documented in the impact hypothesis or the contingency plan, depending on whether the corrective actions are planned as part of the base case site management plan, or will be triggered by unexpected features events or processes.

Finally, this section of the proposed rule by the U.S. EPA proposes that the AoR should be re-evaluated on a periodic basis, or when monitoring data differ significantly from modeled predictions or there are appreciable operational changes. It also suggests that corrective actions could be implemented on an iterative phased basis, e.g., performing potentially necessary corrective actions (on wells) in a proactive fashion during site operation. This is consistent with the permit review and site requalification process described in Section 4 of the guideline.

4.2.3 Plume and pressure front monitoring requirements

The U.S. EPA considers CO_2 plume and pressure monitoring to be necessary for verification of model predictions and states that an integrated monitoring and modeling strategy should be used to track the evolution of the CO_2 plume and associated pressure front. This statement may suggest that such monitoring is necessary for proper site and risk management. However, for some projects it may be possible to demonstrate adequate management of risks without accurate tracking of the CO_2 plume and pressure front. Thus, instead of suggesting that monitoring of the CO_2 plume and pressure front should be mandatory, the guideline provides general guidance, e.g., that the monitoring plan should be designed to pro-actively reduce the risk profile of a project over its life time and build assurance that the specified risk performance targets will be met.

The proposed rule by USA EPA also introduces a testing and monitoring plan to be submitted along with the (injection) permit application. The purpose of this plan is to verify that the CGS project is operating as intended and is not endangering USDWs. This plan corresponds to part of the MVAR plan that is specified within the SDP in the guideline. Whereas the EPA document is focussed solely on USDWs, the MVAR plan is more general.

Although the rule states that the monitoring and testing program should be site-specific based on the assessment of potential CO_2 leakage routes, it also proposes a list of minimum requirements (in addition to tracking the subsurface extent of the CO_2 plume and pressure front). Rather than specifying similar minimum requirements, the guideline states that the monitoring program should be designed as a proactive system to address known or perceived risks. This implies that the design of the monitoring program will in general proceed in several feedback loops where the risk assessments inform the design of the monitoring program and vice versa.

4.2.4 Record keeping and reporting requirements

The U.S. EPA suggests that the following information should be submitted to the permitting authority for consideration of permit applications (relevant document in SDP in parenthesis):

1. Maps of injection wells, the AoR, all artificial penetrations of the AoR, maps of the general vertical and lateral limits of the USDWs, maps of the geologic cross sections of the local area, the proposed operating data and injection procedures, proposed formation testing program, and stimulation program, well schematics and construction procedures, and contingency plans for shut-ins or well failures (IOP).
2. Monitoring and testing plan (MVAR plan).
3. Corrective action plan (CP)
4. Post-injection site care plan (IOP, Risk Management Plan (IH & CP), and MVAR plan)
5. Site closure plan (IOP (decommissioning plan) and IH (performance targets for closure)

The current section also lays down reporting requirements for permit review and site closure. These requirements form a key input to the *define documentation basis for permit review/re-qualification* and *define closure basis* of Section 4 and Section 5 of the guideline, respectively.

4.2.5 Well plugging, post-injection site care, and site closure requirements

This section of the EPA ruling proposes requirements for the plugging of injection wells. The content of the provisional site closure plan (included in the IOP), and the decommissioning plan (to be updated prior to closure) would need to be tailored to the applicable requirements. This section also requires that owners or operators of CO_2 injection wells develop a post-injection site-care and closure plan, to be submitted as part of the permit application. This requirement is consistent with the proposed requirements for the SDP described in the guideline. However, in the SDP the proposed plan for post-injection monitoring is included as part of the general MVAR plan.

The U.S. EPA proposes a default post-injection site care period of 50 years. The default timeframe could be lengthened if potential for endangerment to USDWs still exists after 50 years or if modeling and monitoring results demonstrate that the plume and pressure front have not stabilized in this period. Conversely, the timeframe could be reduced if data on pressure, fluid movement, mineralization, and/or dissolution reactions support a determination that movement of the plume and pressure front have ceased and the injectate does not pose a risk to USDWs.

Thus, the U.S. EPA is proposing a combination of a default post-injection site care period, and a performance standard. The performance based criterion for closure that the plume and pressure front has stabilized (ceased to move) is not supportive of a risk-based approach and may potentially imply that closure may only be permitted centuries after the end of injection. The proposed rule by U.S. EPA is therefore not consistent with the guideline on this issue.

The second criterion, that the injectate does not pose a risk to USDWs is consistent with the guideline, but more limited in scope. The guideline also considers other potential future negative impacts from the CO_2 injection operations.

It should also be noted that it can be difficult to assess with a high level of accuracy that the CO_2 plume has ceased to move. It is therefore important to ensure that any imposed performance based criteria are supported by verifiable (measurable) criteria for site closure that take into account site-specific conditions. This is indeed the intent behind the specification of site-specific performance targets for closure suggested in the guideline.

4.3

Australian Offshore GGS Bill

The Australian Offshore GGS Bill provides a regulatory licensing regime for CGS projects with CO_2 storage in the Australian offshore area, and a framework for reviewing and approving CGS operations. This legislative framework is based on amendments to the existing offshore petroleum legislation and entails a framework for deciding upon competing claims of petroleum and CGS operations. The purpose of this section is to review the key elements in the Australian Offshore GGS Bill, and how the guideline may help project developers in implementing projects in compliance with the legislation. This section follows the discussion of the Australian Offshore GGS Bill (from a Canadian perspective) in [14], which provides an excellent introduction to the particulars of the Australian Offshore CGS Bill, also from a general perspective.

Table **6** shows the sections in the guideline discussing related parts of the Australian Offshore GGS Bill.

Table 6: Comparison of elements in Australian Offshore GGS Bill with related elements in guideline.

Australian Offshore GGS Bill	**CO2QUALSTORE guideline (Section)**
Licensing regime • GHG Assessment permit • Holding Lease • Injection Licence	Permits considered • Exploration permit: Section 3.1. • Storage permit: Section 3.9-3.11.
Regulatory elements particular for CO_2 storage • Site plan • Site closing certificate	Corresponding elements in guideline • SDP: Section 3.10. • Site closure: Section 5.

4.3.1 Licensing regime

The licensing regime in the Australian Offshore GGS Bill entails three principal forms of tenure.

1. A greenhouse gas (GHG) assessment permit
2. A GHG holding lease
3. A GHG injection licence

Here the GHG assessment permit corresponds to the exploration permit in the guideline, and the GHG injection licence corresponds to the storage permit. Note that the Australian legislation refers to the storage of Green House Gases (GHGs) in general whereas the guideline is limited to CO_2 storage only.

4.3.1.1 Assessment permit

The GHG assessment permit may be granted on the basis of either a work-bid or cash-bid, and grants the permittee the following rights within the permit area:

- to explore for a potential GHG storage formation;
- to explore for a potential GHG injection site;
- to inject GHGs into a part of a geological formation for appraisal purposes; and
- to store GHGs on an appraisal basis;
- to inject, air, water or petroleum on an appraisal basis;
- to store the same substances on an appraisal basis;
- […] recover petroleum in the permit area for appraisal purposes […].

The Australian Offshore CGS Bill suggests that when there are competing applications for an assessment permit, the permit may be granted to the “most deserving” applicant based on published criteria, possibly including both financial and technical (storage security) criteria. In case of a single applicant, a permit could be granted based on specified terms and conditions.

The guideline does not consider a cash-bid process for exploration permits, but aims instead at supporting work-bid application processes. While the guideline does not detail specific requirements for exploration permits, as this will be specified by regulations, the guideline suggests that whenever technical qualification criteria apply, the SR could be tailored to demonstrate that these criteria have been met.

The objective of the work to be performed under an assessment permit is to classify potential storage formations into one of the following three categories; potential, eligible, and identified. Each category is associated with increased knowledge and confidence in the suitability of a geological formation for CGS. Approval for injection of CO_2 into a particular geological formation for the purpose of permanent storage, i.e., the granting of an injection licence, requires that the target formation is declared “an identified GHG storage formation”. This corresponds to the site and engineering concept selection in the guideline, i.e., completion of the work up to and including Section 3.8 in the guideline.

A declaration of an identified GHG storage formation is a document that specifies the activities that can be carried out under a GHG injection licence and the areal extent of such operations. The declaration retains its significance over the life of the CCS project, and may only be revoked if the Minister is satisfied the formation is no longer an eligible GHG storage formation.

4.3.1.2 Holding lease

The holding lease is not discussed in the guideline. This lease is designed to protect the rights of an investor that has invested in site assessment activities under an assessment permit. The holding lease gives the holder the ability to continue to explore for additional GHG storage formations which can be declared as a new *identified GHG storage formation*. A holding lease may also be granted to a project developer that has declared a site *identified*, but for which an injection licence cannot be granted, for example due to potential conflicts with petroleum activities. This lease prevents other operators from utilizing *identified* site(s) for CGS or other purposes.

4.3.1.3 Injection licence

The Australian "injection licence" corresponds to the storage permit in the EU CCS Directive and the approval of Class VI injection wells in the proposed rule by the U.S. EPA. An application for an injection licence can only be made by a holder of a GHG assessment permit or holding lease or by a holder of a petroleum production licence (an injection licence granted to the holder of a petroleum production licence is only for the injection of CO_2 obtained through the production of natural gas). The Australian injection licence gives the licensee the following rights;

- the same exploration rights as those conferred with the assessment permit and the holding lease;
- the right to inject a GHG substance in an "identified GHG storage formation" located in the licence area;
- the right to permanently store a GHG substance in an "identified GHG storage formation" located in the licence area.

The GHG injection licences are subject to several conditions including conditions with respect to the kind and origin of GHG substance injected, the injection period, the total amount of GHG injected and the rate of injection. The conditions that the licensee wants specified must be consistent with the "fundamental suitability determinants" of the indentified GHG storage formation. Fundamental suitability determinants are used in the determination of the spatial extent of an eligible GHG storage formation, and include the particular GHG substance, the amount of GHG substance injected, point or points of injection, period of injection, and the effective sealing feature, attribute or mechanism that enable permanent storage.

In addition, the application must be accompanied by a draft site plan for each identified GHG storage formation, containing the details of the proposed work and expenditure by storage formation and the technical qualifications and advice available to the applicant and its financial resources.

In the SDP defined in the guideline, the "fundamental suitability determinants" could be assessed in the CR, in which case the corresponding IOP would define a project development plan consistent with the defined "fundamental suitability determinants". The SDP should therefore cover the specification of proposed work in the draft site plan, see Section 4.3.2.1.

A GHG injection licence has an indefinite duration but is subject to termination if there are no operations to inject a GHG substance for a continuous period of five years excluding any non-production period beyond the licensee's control or when the licence is suspended under the Minister's power to protect petroleum discovered in an area.

4.3.2 Regulatory elements particular for GHG storage

The Australian Offshore GGS Bill was accompanied by a Regulation Impact Statement and a Readers' Guide. The Regulation Impact Statement identified a need for new legislation to regulate selection and approval of storage sites, and site closure. All other regulatory aspects of the CCS industry, such as general environmental approvals and occupational health and safety issues, were considered adequately covered in existing legislation.

This section discusses two of the new regulatory elements particular for storage of GHGs in geological formations, i.e., the site plan and regulatory conditions for site closure.

4.3.2.1 Site plan

The Australian Offshore GGS Bill requires that the site plan must set out predictions for the behaviour of the GHG substance stored in the identified GHG storage formation and demonstrates to the satisfaction of the regulator that the project will result in "safe and secure" storage. While not explicitly expressed in the Australian Offshore GGS Bill, the Readers' Guide suggests that the matters to be addressed by the site plan are prescribed by regulations modeled on existing petroleum regulations and will require the applicant to address such matters as:

1. the geological attributes or features of the storage formation;
2. current and proposed injection and storage operations;
3. the operations and techniques to be used by the licensee to monitor and verify the behaviour of the GHG over the life of the project;
4. operations management systems, including processes for identification, assessment and management of risks; and
5. predictions as to the short, medium and long-term behaviour and fate of the GHG in the identified storage formation and associated geological formation(s).

All of these matters are covered in respective documents in the SDP in the guideline; (1) is described in the CR; (2) is contained in the IOP; (3) is described in the MVAR plan; (4) is covered by the IOP and the Risk Management Plan; and (5) is covered by the SPF and EIA.

4.3.2.2 Site closure

The Australian Offshore GGS Bill defines closure similar to the guideline, i.e., is associated with transfer of responsibility from the licensee to the government. The legislation suggests that site closure proceeds in the following six steps:

1. licensee submits application for site closing certificate, including a proposal for a monitoring and verification program to be conducted by the government.
2. Minister issues directions to the licensee for a site closing certificate, e.g., requirements to decommissioning or remedial work.
3. Minister communicates tentative position with regard to issue of site closing certificate.
4. licensee posts security to cover monitoring and verification after closure.
5. Minister issues site closing certificate.
6. surrender of injection licence provided the licensee has fulfilled all of its obligations, including removal of injection facilities and plugging of wells.

The application for the site closing certificate must be accompanied by a written report that sets out the applicant's modeling of the GHG plume and an assessment of the behaviour of the plume including the expected migration pathway, the short- and long-term consequences of the migration, and the applicant's suggested approach for long-term monitoring of the plume to be undertaken by the government once the closing certificate has been issued.

The site closing certificate is analogous to the "*Certificate of fitness for closure*" described in the guideline. The site closure qualification process defined in the guideline should also meet the requirements for the site closing certificate application, with the exception of the monitoring and verification program to be conducted by the government. To tune the qualification process to cover this requirement, an extra step (to develop a post-closure monitoring and verification program) would need to be added following the development of the final IH.

There is also a difference between the "transfer of responsibility" described in the guideline (and the EU CCS Directive) and the closing certificate. The closing certificate transfers responsibility for further monitoring and verification to the government, but there is nothing in the legislation which suggests that a closing certificate eliminates future liability of the licensee.

4.4 Other relevant codes and guidelines

The purpose of this section is to provide a brief description of three conventions/guidelines that form part of a regulatory regime for CGS. These are;

- the 2006 IPCC Guidelines for national greenhouse gas inventories [5], henceforth called "IPCC guidelines."
- the OSPAR Convention [8];
- the London Convention and its 1996 Protocol [9].

The scope of some of these frameworks is either complementary or only partly overlapping the scope of the guideline. The focus in the following discussion is put on aspects that are particularly relevant for issues within the scope of the guideline.

4.4.1 IPCC guidelines

The IPCC guidelines [5] outline an accounting framework for CGS. Because such a framework is outside the scope of the CO2QUALSTORE guideline, the two documents are largely complementary.

The IPCC guidelines define *leakage* as a transfer of CO_2 from beneath the ground surface or sea bed to the atmosphere or ocean. Thus, the only CO_2 emissions pathways that need to be considered in the accounting are CO_2 leakage to the ground surface or seabed from the geological storage reservoir.

The IPCC guidelines suggest that it would be *good practice* to undertake appropriate assessment of the potential for associated methane emissions and, if necessary, include any such emissions attributable to the CO_2 storage process in the inventory.

In order to understand the fate of CO_2 injected into geological reservoirs over long timescales, assess its potential to be emitted back to the atmosphere or seabed via the leakage pathways, and measure any fugitive emissions, the IPCC guidelines assert that it is necessary to

- properly and thoroughly characterise the geology of the storage site and surrounding strata;
- model the injection of CO_2 into the storage reservoir and the future behaviour of the storage system;
- monitor the storage system;
- use the results of the monitoring to validate and/or update the models of the storage system.

With regard to choice of monitoring technologies, the IPCC guidelines state that "the suitability and efficacy of [monitoring] technologies can be strongly influenced by the geology and potential emissions pathways at individual storage sites, so the choice of monitoring technologies will need to be made on a site-by-site basis. Monitoring should be conducted according to a suitable plan that takes into account the expectations from the modeling on where leakage might occur, as well as measurements made over the entire zone in which CO_2 is likely to be present".

The IPCC guidelines also suggest that it would be part of *good practice* to include an uncertainty assessment when estimating emissions. Uncertainty in the emissions estimates will depend on the precision of the monitoring techniques used to verify and measure any emissions and the modeling used to predict leakage from the storage site. Whereas the concept of percentage uncertainties may not be applicable for CGS, confidence intervals and/or probability curves could be given. Moreover, the guidelines point out that if the detection capabilities of monitoring equipment improve over time, or if previously unrecorded emissions are identified, or if updating of models suggests that unidentified emissions have occurred, and an updated monitoring program corroborates this, appropriate recalculation of emissions will be necessary.

4.4.2 OSPAR Convention

Two reports from the OSPAR Commission which are particularly relevant for the CO2QUALSTORE are discussed here.

The OSPAR report, *Placement of* CO_2 *in Subsea Geological Structures (2006)* [6] looks at the technical aspects of CO_2 capture and storage (CCS) in geological structures under the seabed. The report concludes that CCS in sub-seabed geological structures is technically feasible using existing tried and tested technology. The North-East Atlantic offers significant potential for CCS: it could take most of the European Union's CO_2 emissions from major point sources for several centuries. With well selected, designed and managed sites, retention of CO_2 for several thousand years (or even longer) could be achieved. Evaluation of any proposed sites needs to take account of the risks to the marine environment as well as the benefits in mitigating climate change and acidification of the oceans. Monitoring will be important and the report describes how seismic and gravimetric techniques can be used. The report concludes that guidelines or a framework for risk management for the storage of CO_2 are needed.

The amendment to the OSPAR Convention [8] was done under Annex II and III and will permit the storage of CO_2 provided that:

1. disposal is into a sub-soil geological formation;
2. the streams consist overwhelmingly of carbon dioxide. They may contain incidental associated substances derived from the source material and the capture, transport and storage processes used;
3. no wastes or other matter are added for the purpose of disposing of those wastes or other matter;
4. they are intended to be retained in these formations permanently and will not lead to significant adverse consequences for the marine environment, human health and other legitimate uses of the maritime area.

The wording of the amendment is very similar to what is found under the amended London Protocol. However, the OSPAR amendment has an additional requirement of permanently retaining CO_2 in the geological formations.

Whilst adopting the amendment, OSPAR also put in place a requirement to use the OSPAR Guidelines for Risk Assessment and Management of Storage of CO_2 streams in Geological Formations [7], henceforth called the OSPAR guidelines. The Framework for Risk Assessment and Management of storage of CO_2 streams in geological formations (FRAM) is an integral part of these guidelines. This Framework has made use of relevant developments within the framework of the London Convention and its 1996 Protocol, including developments relating to the draft Risk Assessment and Management Framework for CO_2 Sequestration in Sub-Seabed Geological Formations (see Section 4.4.3).

The primary aim of the OSPAR guidelines is to assist in the management of storage of CO_2 streams in geological formations in the sub-soil of the OSPAR maritime area, including sub-seabed geological formations. The OSPAR guidelines propose that at least the following aspects should be considered:

- assessment of the suitability of potential sites for permanent containment of CO_2 streams and identification of the necessary measures for hazard reduction, remediation and mitigation;
- characterization of the risks to the marine environment from storage of CO_2 streams in geological formations on a site-specific basis;
- collection of necessary information (monitoring) and development of a strategy to manage uncertainties and minimise risks.

According to the OSPAR guidelines, the ultimate objective of storage of CO_2 streams is to ensure permanent containment of CO_2 streams in geological formations, in a manner that avoids significant adverse consequences for the marine environment, human health and other legitimate uses of the maritime area, thereby contributing to reduced atmospheric levels of CO_2.

While the main purpose of the OSPAR guidelines is to provide a framework for CGS in the marine environment of the North Atlantic, the general framework in the OSPAR guidelines should be equally applicable onshore. In particular, the concept of an IH, which is part of the SDP in the CO2QUALSTORE guideline, is introduced in the OSPAR guidelines. The IH is a statement of the expected consequences of CO_2 storage, providing the basis for deciding whether to approve or reject a proposed site and for defining monitoring and verification requirements.

4.4.3 London Protocol

Contracting Parties to the London Protocol adopted in November 2006 amendments to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention). The amendments regulate the sequestration of CO_2 streams from CO_2 capture processes in sub-seabed geological formations.

With the new amendment to the Protocol, CO_2 streams from CO_2 capture processes for sequestration can be stored if they meet three criteria:

1. *disposal is into a sub-seabed geological formation;*
2. *the CO_2 stream is of high purity containing only incidental amounts of associated substances; and*
3. *no wastes or other matter are added for the purpose of disposing of those wastes or other matter.*

The parties also agreed to develop guidelines for sub-seabed geological sequestration of CO_2. A risk assessment and management framework was adopted under the London Convention and its London Protocol. In this draft guideline, six stages of a risk assessment and management framework are delineated and can be summarized as follows:

1. ***Problem Formulation*** is a critical scoping step of risk assessment as it defines the bounds of the assessment, including the scenarios and pathways to be considered.
2. ***Site Selection and Characterization*** concerns the collection of data necessary for describing the physical, geological, chemical, and biological conditions at the site.
3. ***Exposure Assessment*** is concerned with describing the movement of the CO_2 stream within geological structures and the marine environment. The processes and pathways for migration of CO_2 from geological storage reservoirs and leakage to the marine environment, during and after CO_2 injection, can be assessed.
4. ***Effects Assessment*** assembles the information necessary to describe the response of receptors within the marine environment resulting from exposure to the CO_2 stream if leakage were to occur. The main effects of concern to such an assessment include effects on human health, marine resources, relevant biological communities, habitats, and ecological processes, and other legitimate uses of the sea.
5. ***Risk Characterization*** integrates the exposure and effects information to provide an estimate of the likelihood for adverse impacts. Risk characterization should be considered using site-specific information.
6. ***Risk Management*** includes both monitoring during and after CO_2 injection, planning and mitigation actions.

5 SOME RELEVANT STANDARDS

5.1 ISO 31000 – Risk management

The guideline builds upon the general principles for risk management described in the ISO standard ISO 31000 First edition 2009-11-15 [15], and is specifically tailored to provide risk management principles for proper selection and management of CO_2 storage sites. The purpose of this section is to review relevant parts of this ISO standard, and link these parts to corresponding parts of the guideline.

The primary focus of the guideline with regard to risk management is to outline a risk management process tailored to the specific need of CGS. The guideline does not address organizational or policy issues of an organization's risk management framework, and does not consider requirements to internal communication.

The guideline puts emphasis on external communication and reporting processes, in particular with respect to regulators. To this end, certain aspects related to accountability and allocation of resources for risk management is briefly discussed in Appendix D of the guideline. Recommendations in the ISO 31000 standard on these latter issues are presented below. However, the primary focus of this section is to attempt to relate the risk management process described in the ISO 31000 to the risk management process described in the guideline. Terminology used in this ISO standard is given in Table 7.

Table 7: Terminology in ISO 31000. Note: this list is not comprehensive, additional terms are defined in [15].

Term	Definition
Risk	Effect of uncertainty on objectives
Risk management (RM)	Coordinated activities to direct and control an organization with regard to risk
RM framework	Set of components that provide the foundations and organizational arrangements for designing, implementing, monitoring, reviewing and continually improving RM throughout the organization
RM plan	Scheme within the RM framework specifying the approach, the management components and resources to be applied to the management of risk
Risk owner	Person or entity with the accountability and authority to manage risk
RM process	Systematic application of management policies, procedures and practices to the activities of communication, consulting, establishing the context, and identifying analyzing, evaluating, treating, monitoring and reviewing risk.
Establishing the context	Defining the external and internal parameters to be taken into account when managing risk, and setting the scope and risk criteria for the RM policy
Communication and consultation	Continual and iterative processes that an organization conducts to provide, share or obtain information and to engage in dialogue with stakeholders regarding the management of risk
Stakeholder	Person or organization that can affect, be affected by, or perceive themselves to be affected by a decision or activity
Risk assessment	Overall process of risk identification, risk analysis and risk evaluation
Risk identification	Process of finding, recognizing and describing risks
Risk source	Element which alone or in combination has intrinsic potential to give rise to risk
Risk analysis	Process to comprehend the nature of risk and to determine the level of risk
Risk criteria	Terms of reference against which the significance of risk is evaluated
Level of risk	Magnitude of a risk or combination of risks, expressed in terms of the combination of consequences and their likelihood
Risk evaluation	Process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable
Risk treatment	Process to modify risk
Monitoring	Continual checking, supervising, critically observing or determining the status in order to identify change from the performance level required or expected
Review	Activity undertaken to determine the suitability, adequacy and effectiveness of the subject matter to achieve established objectives

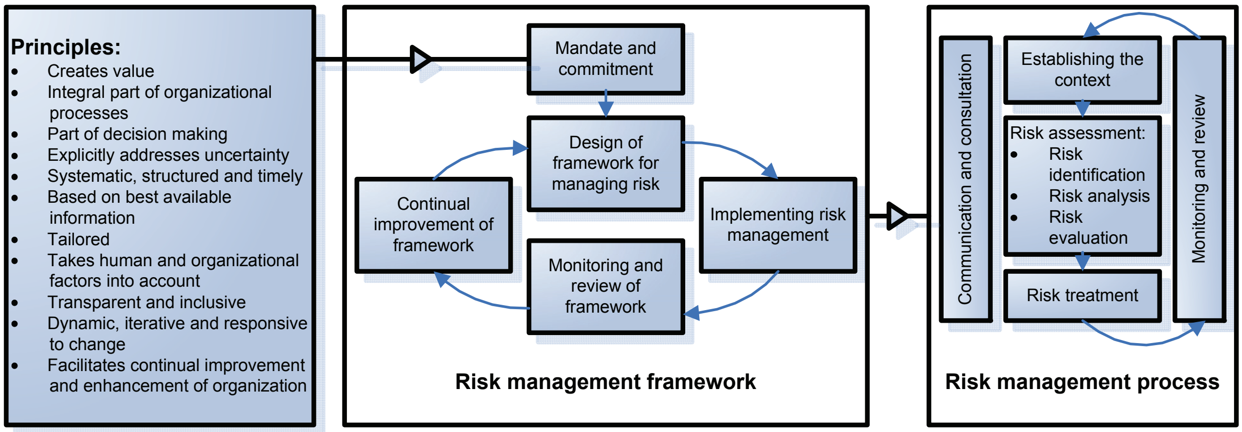

Figure 4: Relationship between the risk management principles, framework and process (after Figure 1 in ISO 31000 [15]).

The ISO 31000 standard describes the relationship between the principles for managing risk, the framework in which it occurs and the risk management process. The approach described in the guideline may be viewed as a risk management process for selection and qualification of storage projects, which corresponds to one component of the risk management framework described in [15]. Figure 4 shows a schematic of the relationship between the risk management principles, framework and process.

Implementing these risk management principles should, for example, enable an organization to

- increase the likelihood of achieving objectives,
- encourage proactive management,
- be aware of the need to identify and treat risk throughout the organization,
- improve the identification of opportunities and threats,
- comply with relevant legal and regulatory requirements and international norms,
- improve mandatory and voluntary reporting,
- improve governance,
- improve stakeholder confidence and trust,
- establish a reliable basis for decision making and planning,
- improve controls,
- effectively allocate and use resources for risk treatment,
- improve operational effectiveness and efficiency,
- enhance health and safety performance, as well as environmental protection,
- improve loss prevention and incident management,
- minimize losses,
- improve organizational learning,
- improve organizational resilience.

CGS project developers aiming to optimize cost, safety and environmental performance will need to implement a risk management framework that seeks to reach most of these objectives. The guideline, by outlining a risk management process tailored to CGS, provides guidance to CGS project developers on how to meet many, but not all, of the objectives.

Section 5.1.1 below describes which of the relevant parts of the risk management framework in [15] are fully or partly covered in the guideline.

5.1.1 Risk management framework

Mandate and commitment

This part of ISO 31000 addresses requirements to appropriate organizational risk management policies, which is generally not covered in the guideline. However, elements where the guideline enables the project developer to make the relevant proper commitments include

- ensuring legal and regulatory compliance,
- assigning accountabilities and responsibilities at appropriate levels within the organization,
- ensuring that the necessary resources are allocated to risk management.

Design framework for managing risk

This part of the risk management framework consists of the following seven categories:

1. understanding of the organization and its context,
2. establishing risk management policy,
3. accountability,
4. integration into organizational processes,
5. resources,
6. establishing internal communication and reporting mechanisms,

7. establishing external communication and reporting mechanisms.

The first category entails evaluating the organization's external and internal context, e.g., cultural, political, regulatory, financial, technological, organizational, policies, etc. This is not covered in the guideline. Note, however, that standards and guidelines adopted by an organization, such as the CO2QUALSTORE guideline, form part of the internal context.

The guideline forms a key input to the second category, establishing risk management policy, in particular in relation to accountabilities and responsibilities for managing risk, and how risk management performance is measured and reported.

With regard to the third category, accountability, the guideline recommends assigning a risk owner to each risk in the risk database. The risk owner has accountability and authority to manage the assigned risk. Furthermore, the guideline suggests defining performance targets for the key identified risks, and lays out an overall workflow where risks are iteratively assessed and evaluated. Risk management performance is evaluated partly based on the comprehensiveness of the risk assessments and partly based on the degree that performance targets are met.

The fourth category, integration into organizational processes, is essentially not covered.

The guideline does provide guidance a CGS project developer's processes, methods and tools to be used for managing risk, and associated documentation of processes and procedures. In particular, the qualification workflows describe high-level risk management processes, whereas Appendix D provides more specific guidance on risk management as part of the overall project qualification workflows. This also gives input to determine resources needed for each step of the risk management process, including people, skills, experience and competence. These elements are part of category five – resources.

The guideline does not address "establishing internal communication and reporting mechanisms", but focuses instead on "external communication and reporting mechanisms. The guideline does not discuss in detail how to communicate with external stakeholders, but suggests principles that underpin the external communication objectives described in [15].

Design framework for managing risk

This issue corresponds to the main purpose of the guideline, i.e., to outline a risk management process for CGS projects that aligns with the recommendations in [15]. This includes the issues that an organisation should consider (according to [15]) when implementing an organizational framework for managing risk. The risk management process will be discussed in more detail in Section 5.1.2 below.

Monitoring and review of the framework

The guideline puts emphasis on ensuring consistency, traceability and transparency of the risk management. In particular, it contains recommendations for permit review processes that measure the risk management performance against indicators (performance targets), which are also reviewed for appropriateness. Similarly, the risk management plan, i.e., the IH and CP, are updated as appropriate to ensure consistency, traceability and transparency in the risk management. These are core elements in the recommendations made in [15] with regard to monitoring and review of the risk management framework.

Continual improvement of the framework

ISO 31000 states that "based on the results of monitoring and reviews, decisions should be made on how the risk management framework, policy and plan can be improved. The guideline focuses on keeping the risk management plan updated and encourages the use of Best Available Technology (BAT), but does not describe further how project developers may improve the risk management framework itself.

5.1.2 Risk management process

According to ISO 31000 the risk management process comprises the following five activities:

1. communication and consultation,
2. establishing the context,
3. risk assessment,
4. risk treatment,
5. monitoring and review.

In addition, recording of the risk management process is defined as a separate activity.

The way risk management is defined in the guideline, it comprises Steps 2-4 above. The guideline, however, also addresses steps 1 and 5 above, as well as proper recording of the risk management process. We now briefly describe how these six issues are addressed.

Communication and consultation

The recommendations made in the guideline for communication and consultation are closely aligned with the ISO 31000 recommendations. In particular, the guideline emphasises the need to build a common understanding among regulators and key stakeholders of the opportunities and risks involved in a CGS project. The guideline further recommends that the project developer keeps regulators and stakeholders updated on project performance, demonstrates how individual risks and uncertainties evolve, and communicates the rationale for modifying models, forward predictions and the monitoring, verification, accounting and reporting program. Finally the guideline suggests that a "concise statement of the expected consequences – both positive and negative – of the CGS project" should be communicated to stakeholders in the form of the IH document.

Establishing the context

In the qualification workflows described in the guideline, the process of defining the context (and scope) of the risk management process is typically the first step of each of the qualification stages. This step is referred to as the basis of the four associated qualification processes, i.e., screening basis, selection basis, documentation basis and closure basis. The qualification basis should describe both the external and internal context, as well as the context for the risk management process. This entails defining the criteria and expectations to the qualification process, including, when relevant, criteria or performance targets used to evaluate risk significance.

Risk assessment

In accordance with ISO 31000, the framework for risk assessment described in the guideline entails risk identification, risk analysis and risk evaluation. However, the risk identification process is regarded as part of the risk analysis.

The objectives of the risk identification and analysis defined in [15] are fully in line with the guideline. In the risk analysis, the assessment, management and communication of uncertainty has been given special attention. The reason for this is that the assessment of probability and consequence of identified hazards for CGS projects will frequently be associated with significant uncertainty. Proper management of uncertainty will therefore be an integrated part of risk management. This point is emphasized (in a general way) in [15]:

> "*The confidence in determining the level of risk and its sensitivity to preconditions and assumptions should be considered in the analysis, and communicated effectively to decision makers and, as appropriate, other stakeholders. Factors such as divergence of opinion among experts, uncertainty, availability, quality, quantity and ongoing relevance of information, or limitations on modeling should be stated and highlighted.*"

All of the specific issues mentioned in this paragraph that contribute to uncertainty in the risk analysis are particularly relevant for CGS projects.

ISO 31000 also highlights that the risk of not pursuing an opportunity should also be identified. This underpins the statement that risks associated with CGS should be weighed against the risks of climate change, e.g., the consequences implied by not allowing projects to go ahead in an economically viable way. This fundamental principle is used as a guiding principle for specification of risk criteria (performance targets) in the guideline.

Other principles that may be applied to guide the dialogue between project developers and regulators aiming to evaluate and determine acceptable levels of risk are described in Appendix D.2.2 in the guideline.

Risk treatment

The guideline follows the general principles for risk treatment described in [15], with particular emphasis on identifying and evaluating alternative options for risk treatment. One of the premises for selection of risk treatment options is that the costs and efforts of implementation are not disproportionate to the benefits derived. This concept of using a cost-benefit analysis to provide decision support for deciding upon risk treatment options is also emphasized in [15]. However, the ISO 31000 also recommends that

> *"Decisions should take into account risks which can warrant risk treatment that is not justifiable on economic grounds, e.g., severe (high negative consequence) but rare (low likelihood) risks."*

This statement essentially states that decisions with regard to selection of risk treatment options should not solely be based on costs. The guideline follows this principle, although it is not explicitly stated. Instead it is recommended that the selection of risk treatment options for all significant risks should be defined and agreed between the project developer and the relevant regulator, allowing the regulator to raise additional issues (apart from cost) that may influence the selection. These selected risk treatment options form part of the associated performance targets.

The guideline also distinguishes between a base case risk management plan, essentially derived from the performance targets, and a contingency risk management plan triggered by unexpected features, events or processes with potential negative impact. The guideline recommends that the alternative risk treatment options that form the CP should be prioritized. This is in accordance with ISO 31000, which states that "the risk treatment plan should clearly identify the priority order in which individual risk treatments should be implemented."

Monitoring and review

For CGS projects, monitoring of storage performance against risk indicators or performance targets will be an integrated part of the project risk management. This is clearly reflected in the guideline. In particular it is emphasized that the monitor-model feedback loop used to assess and validate storage performance provides a key input to the design of the risk management plan and vice versa. This repetitive process serves to obtain information to improve the risk assessment and analyzing and learning from events or unexpected behaviour of the injected CO_2. This latter point is underpinned by stressing the need to adopt a responsible learning-by-doing approach in the early era of CCS deployment, in particular in the early stages of the first set of demonstration projects.

Recording of the risk management process

The final task described in ISO 31000 is the recording of risk management activities to ensure that the process is traceable. Traceable documentation of risk assessment activities and results from supporting monitoring and modeling activities has been given high priority in guideline. In particular, Appendix D.3 in the guideline provides specific guidance on traceable documentation of risk assessment activities. This includes tracking of individual risks throughout project life-cycle, and mapping of the evolving project risk picture. For CGS, traceable mapping of risks is particularly important as it forms the basis for regulatory decisions regarding renewal of storage permits and ultimately for accepting responsibility for a storage site beyond the operational life-time.

5.2 Other standards relevant for CGS

The ISO standard [15] for risk management discussed in the previous section was selected because the scope and objective is closely aligned with the scope and objective of the guideline. The task of comparing the guideline with a fully comprehensive list of applicable standards is beyond the scope of this guidance document. Instead we provide a list of some of the main classes of standards that may be considered by CGS project developers in Table 8. Note that the ISO 14000 series also covers management of greenhouse gas emissions.

Table 8: Some main classes of standards that may be relevant for CGS projects.

Standard	Description
ISO 9000	Family of international standards for quality management
ISO 14000	Family of international standards for environmental management. Includes several standards for measuring, verifying/validating and managing greenhouse gas emissions including CO_2.
OHSAS 18000	Occupational health and safety management standards. Comprises two parts, 18001 and 18002 and embraces BS8800 and a number of other publications.
ISO 13623	Pipeline transportation systems
ISO/IEC 31010	Risk Management – Risk assessment techniques
DNV-OS-F01	Submarine pipeline systems
ASME B31.4	Pipeline transportation systems for liquid hydrocarbons and other liquids.
API FH1	Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines

For more comprehensive lists of applicable standards we refer to, e.g.,

- [16]: Catalogue of international standards used in the petroleum and natural gas industries compiled by OGP – The International Association of Oil and Gas Producers.
- [17] Brief overview of some of the main standards that are applied within the oil and gas industries.
- [18]: Overview of ISO 14000 environmental management standards.
- [19]: Overview of ISO 9000 quality management standards
- [20]: Occupational health and safety management standards

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DNV Energy Regional Offices:

North America
Det Norske Veritas (USA) Inc
16340 Park Ten Place
Suite 100
Houston, TX 77084
United States
Phone: +1 281 721 6600

South America and West Africa
Det Norske Veritas Ltda
Rua Sete de Setembro
111/12 Floor
20050006 Rio de Janeiro
Brazil
Phone: +55 21 2517 7232

Asia and Middle East
Det Norske Veritas Sdn Bhd
24th Floor, Menara Weld
Jalan Raja Chulan
50200 Kuala Lumpur
Phone: +603 2050 2888

Europe and North Africa
Det Norske Veritas Ltd
Palace House
3 Cathedral Street
London SE1 9DE
United Kingdom
Phone: +44 20 7357 6080

Nordic and Eurasia
Det Norske Veritas AS
Veritasveien 1
N-1322 Hovik
Norway
Phone: +47 67 57 99 00

Offshore Class and Inspection
Det Norske Veritas AS
Veritasveien 1
N-1322 Hovik
Norway
Phone: +47 67 57 99 00

Cleaner Energy & Utilities
Det Norske Veritas AS
Veritasveien 1
N-1322 Hovik
Norway
Phone: +47 67 57 99 00

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