



**Report on  
CSLF Task Force 6  
on  
Reviewing Best Practices and Standards  
for Geologic Storage and Monitoring of CO<sub>2</sub>**

# Best Practices and Standards for Geologic Storage and Monitoring of CO<sub>2</sub>



- This web-site is intended for those who want a quick look at available standards, guidelines and best practice manuals to safe and efficient storage of CO<sub>2</sub>. It is based on the CSL report **Reviewing Best Practices and Standards for Geologic Storage and Monitoring of CO<sub>2</sub>, an Initial Compilation of Standards, Best Practices and Guidelines for CO<sub>2</sub> Storage and Monitoring**  
[http://www.cslforum.org/publications/documents/ReviewingBestPracticesStandards\\_2013Report.pdf](http://www.cslforum.org/publications/documents/ReviewingBestPracticesStandards_2013Report.pdf)
- The web site is structured so that by clicking on the titles in the Content one is directed to one or more page with relevant documents. Each page contains title, link to the document and a brief description of the content.
- Please note that efforts are being made to keep the links updated. However, no responsibility or liability can be transferred to CSLF in case a web site is outdated.
- Guidelines to regulations, directives etc. can be found under a separate heading. These will often address all or close to all of the topics.
- Efforts have been made to sort the BPMs into different topics of the CO<sub>2</sub> storage complex. However, it must be noted that several of the documents address more than one topic. Those documents are listed under the topic to which they pay most attention.

# Best Practices and Standards for Geologic Storage and Monitoring of CO<sub>2</sub>



- Disclaimer
  - The opinions, findings, solutions and conclusions made on this web site are the result of voluntary task force work and do not under any circumstance represent any official opinion of any of the CSLF member states and organizations. Moreover; although efforts have been made to ensure the correctness of the information contained herein, no responsibility whatsoever will be assumed by CSLF for any errors or omissions made. All use of the information given is at the users' sole risk. No liability is accepted for the content or for the consequences of any actions taken on the basis of the information provided. You must not rely on the information as an alternative to legal, taxation or other advice from an appropriately qualified professional.

# Best Practices and Standards for Geologic Storage and Monitoring of CO<sub>2</sub>



- Content
  - Summary
    - For a high level summary with indications of which storage topics are included in the documents, [click her](#)
  - Standards general
    - [CSA: Z741-12 - Geological storage of carbon dioxide](#)
    - [ISO/TC 265 "Carbon dioxide capture, transportation, and geological storage" – work in progress](#)
  - Guidelines
    - [Australia](#)
    - [European Commission](#)
    - [Alberta, Canada  
Summary Report of the Regulatory Framework Assessment](#)
    - [London Convention and Protocol](#)
    - [OSPAR](#)
    - [Site screening, characterization and selection](#)
    - [US EPA](#)
    - [World Resources Institute \(WRI\): Guidelines for CCS](#)
  - Best Practice Manuals
    - [General](#)
    - [Simulation and modelling](#)
    - [Well construction and integrity](#)
    - [Monitoring and verification](#)
    - [Risk assessment and management](#)
    - [Operation](#)
    - [Closure](#)

# CSA: Z741-12 - Geological storage of carbon dioxide



- Can be purchased from:
- <http://shop.csa.ca/en/canada/design-for-the-environment/z741-12/inv/27034612012>
- This standard addresses:
  - Management systems
  - Site screening, selection and characterisation
  - Risk management Well infrastructure
  - Well infrastructure development
  - Monitoring and verification
  - Closure
  - The first edition CSA Z741, *Geological storage of carbon dioxide*. It was developed by the Technical Committee on Geological Storage of Carbon dioxide, which is a joint Canada – USA Technical Committee, with support from IPAC-CO2 Research Inc.

# Best Practices, general



- [GEOSEQ: Geologic carbon dioxide sequestration: Site evaluation to implementation. Published in 2004](#)
- [CO2STORE: Best practice for the storage of CO<sub>2</sub> in saline aquifers](#). Guidelines developed as deliverable from the EU funded projects SACS (Saline Aquifer CO<sub>2</sub> Storage), SACS2 and CO2STORE, based on research around Sleipner CO<sub>2</sub> injection. Published in 2008
- [CO2 Capture Project \(CCP\): A technical basis for carbon dioxide storage](#). Published in 2009
- [DNV RP-J203: Geological Storage of Carbon Dioxide. A Recommended Practice](#) published in 2012
- [DNV DSS-402: Qualification Management for Geological Storage of CO<sub>2</sub>](#)
- [IEA Weyburn: Best Practices for Validating CO<sub>2</sub> Geological Storage](#). Book summarizing experiences and learnings from the Weyburn Project. Published in 2012

# GEOSEQ: Geologic carbon dioxide sequestration: Site evaluation to implementation



- <http://escholarship.org/uc/item/27k6d70j#page-1>
- An early manual that covers many aspects
- This manual covers:
  - A non-detailed discussion on capacity estimation. Also covers
  - A section dedicated to EOR.
  - Characterization of brine-formation sequestration.
  - Monitoring
  - Verification
  - Disposal of impure CO<sub>2</sub> streams
  - Modelling and simulation

# CO2STORE: Best practice for the storage of CO<sub>2</sub> in saline aquifers



- <http://nora.nerc.ac.uk/2959/>
- First published in 2003. The latest version (2008) covers all aspects of storage in saline aquifers:
  - Identifying ideal reservoir
  - Seal properties
  - Capacity estimation
  - Predictive flow modelling,
  - Geochemical and geomechanical site characterization
  - Operating the site
  - Cost estimation
  - Transport needs
  - Monitoring plan design
  - History matching based on monitoring data
  - Safety and risk assessment procedures.
- The information is presented through case studies of what was done and learned at 5 separate projects, offshore and onshore, including Sleipner and Schwarze Pumpe.

# CCP: A technical basis for carbon dioxide storage



- [http://www.co2captureproject.org/co2\\_storage\\_technical\\_book.html](http://www.co2captureproject.org/co2_storage_technical_book.html)
- This BPM covers, with enough detail to be considered beyond basic, a technical understanding of the aspects of CO<sub>2</sub> storage.
- It is based on experiences from participating companies in CO<sub>2</sub> injection.
- It uses a large number of case studies, separated from the text as stand-alone examples, to illustrate how the advice given in each section was used in reality.
- It is a guide to developing a storage project.
- Content:
  - Background and site selection
  - Operation
  - Closure
  - Monitoring
  - Detailed guide for well construction and completion that contains discussions on materials and the factors that govern which you can use and when (a significant addition that this publication includes and others do not).

# DNV RP-J203: Geological Storage of Carbon Dioxide. A Recommended Practice



- [http://www.dnv.com/news\\_events/news/2012/newcertificationframeworkforco2storage.asp](http://www.dnv.com/news_events/news/2012/newcertificationframeworkforco2storage.asp)
- This Recommended Practice (RP) is part of DNV's series of RPs. The main objective is to provide a systematic approach to the selection, qualification and management of geological CO<sub>2</sub> storage sites. It covers:
  - Storage screening and appraisal
  - Permitting
    - Context and requirements
    - Risk performance targets
    - Storage and closure permits
  - Risk management, assessment and treatment
  - Well qualification
- The RP incorporates and combines the guidance given in:
- CO2QUALSTORE and CO2WELLS
  - These two guidelines were the final deliverables from joint industry projects whereas this RP has been developed, and will be maintained, by DNV GL.

# DNV DSS-402: Qualification Management for Geological Storage of CO<sub>2</sub>



- [http://www.dnv.com/news\\_events/news/2012/newcertificationframeworkforco2storage.asp](http://www.dnv.com/news_events/news/2012/newcertificationframeworkforco2storage.asp)
- Not really a BPM but a description of DNV's services within selection, qualification and management of geological storage sites. As such it provides some guidance for CO<sub>2</sub> storage project developers and other parties, but the most important document is DNV-Rp-J203
  - This DNV Service Specification (DSS) provides a framework for the certification of geological storage sites for CO<sub>2</sub>. It covers:
    - Principles for selection, qualification and management of geological storage sites for CO<sub>2</sub>
    - Service overview (basically what services DNV can provide)
    - Examples of CO<sub>2</sub> storage certification documents

# IEA Weyburn: Best Practices for Validating CO<sub>2</sub> Geological Storage



- Available from Geoscience Publishing, 2012  
<http://www.geosciencepublishing.ca/>, ISBN: 978-0-9680844-7-2  
or contact the Petroleum Technology Research Centre, Regina, Saskatchewan, Canada ([www.ptrc.ca](http://www.ptrc.ca))
- This “Best Practices manual” provides a summary of key knowledge gained from research during the IEAGHG Weyburn-Midale Monitoring and Storage project in Saskatchewan, Canada over 12 years. The project was managed by Petroleum Technology Research Centre (PTRC) and the research was carried out in two distinct phases. The first, 2000 – 2004, demonstrated that the Weyburn reservoir provided a suitable site for storage of CO<sub>2</sub>; the second, 2005 – 2012, incorporated the Midale oilfield. The book aims to provide technical guidance to future operators, regulators and other stakeholders.
- The book addresses:
  - Characterization
  - Storage performance predictions
  - Geochemical monitoring
  - Geophysical monitoring
  - History matching and performance validation
  - Well integrity
  - Risk assessment
  - Community outreach

# Best Practices, Site screening, characterization and selection



- [DNV CO2QUALSTORE: Guideline for selection and qualification of sites and projects for geological storage of CO<sub>2</sub>](#)
- [NETL GS: Geologic storage formation classification: Understanding its importance and impacts on CCS opportunities in the United States](#)
- [NETL SS: Best practices for: Site screening, site selection, and initial characterization for storage of CO<sub>2</sub> in deep geologic formations](#)
- [EC Project CGS: State of the art review of CO<sub>2</sub> Storage Site Selection and Characterisation Methods](#)

# DNV CO2QUALSTORE: Guideline for selection and qualification of sites and projects for geological storage of CO<sub>2</sub>



- [http://www.dnv.com/binaries/co2qualstore\\_guideline\\_tcm4-412142.pdf](http://www.dnv.com/binaries/co2qualstore_guideline_tcm4-412142.pdf)
- Covers the many different aspects that need to be considered and provides best practice for accomplishing each step often providing deliverables that could be expected. However, although it must be assumed that the best practices are based on lessons-learned; there are few direct case studies or examples that are mentioned as proof of the success of the best practices provided.
- A step by step guide to selecting a CO<sub>2</sub> storage site that covers
  - Pre-feasibility stages of developing a screening plan
  - Data acquisition
  - Capacity estimation
  - Modelling and simulation
  - Risk assessment
  - Regulation
  - Operation and closure (but majority of the BPM is on site selection and characterization).

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# NETL GS: Geologic storage formation classification: Understanding its importance and impacts on CCS opportunities in the United States



- <http://www.netl.doe.gov/research/coal/carbon-storage/carbon-storage-infrastructure/best-practices>
- <http://www.netl.doe.gov/research/coal/carbon-storage/publications>
- This is a Best Practices from the US National Energy Technology Laboratory (NETL) that covers only a very specific topic: understanding how geology affects a CCS project.
- Written for the purpose of understanding and applying geology to a CCS project, it covers background on:
  - Geological terminology,
  - Rock types and how they fit into CCS and which are most suitable.
  - More technical issues including different depositional environments and what each one means for CCS.

# NETL SS: Best practices for: Site screening, site selection, and initial characterization for storage of CO<sub>2</sub> in deep geologic formations



- <http://www.netl.doe.gov/research/coal/carbon-storage/publications>
- <http://www.netl.doe.gov/research/coal/carbon-storage/carbon-storage-infrastructure/best-practices>
- A 110 page comprehensive discussion of 'what you need to know with regard to storage. It addresses this from a fundamental standpoint covering basic scientific understanding and only occasionally inserting application examples. It does not cover simulation, risk and monitoring to a technical level as there are separate BPMs published to cover these.
- Relates specifically to the needs of a generic CCS project covering all possible opportunities and what is necessary to select and characterize a site. Covers:
  - Identifying and developing all potential injection sites and requirements for each type (saline/depleted reservoir/coal)
  - Data analysis
  - Injection strategies
  - Model development and refinement
  - Capacity estimation and overall suitability analysis
  - Social and environmental considerations in developing and operating a site.

# EC Project CGS: State of the art review of CO2 Storage Site Selection and Characterisation Methods



- <http://www.cgseurope.net/Sections.aspx?section=491.493>
- This document is a deliverable of the Pan-European coordination action on CO2 Geological Storage (CGS).
- The main objective of this report is to identify and review site selection and characterisation methods. This report presents and discusses all the steps required to assess the capacity, performance and integrity of a site
- The content includes
  - Geological characterisation of the site
  - Flow modelling
  - Reactive flow modelling
  - Coupled geomechanical and flow modelling
  - Environmental impact and risk assessment
  - Economoc analysis
  - Public perception and acceptance
  - Conclusions and recommendations

## Best Practices, Simulation and modelling



- This topic is best covered in two general Best Practices:
- [CO2STORE: Best practice for the storage of CO<sub>2</sub> in saline aquifers](#). Guidelines developed as deliverable from the EU funded projects SACS (Saline Aquifer CO<sub>2</sub> Storage), SACS2 and CO2STORE, based on research around Sleipner CO<sub>2</sub> injection. Published in 2008
- [IEA Weyburn: Best Practices for Validating CO<sub>2</sub> Geological Storage](#). Book summarizing experiences and learnings from the Weyburn Project. Published in 2012

## Best Practices, Well construction and integrity



- [DNV CO2WELLS: Guideline for the risk management of existing wells at CO<sub>2</sub> geological storage site](#)
- [NETL WM: Best practices for: Carbon Storage Systems and Well Management Activities](#)

# DNV CO2WELLS: Guideline for the risk management of existing wells at CO<sub>2</sub> geological storage site



- [http://www.dnv.com/binaries/co2wells\\_guideline\\_tcm4-465269.pdf](http://www.dnv.com/binaries/co2wells_guideline_tcm4-465269.pdf)
- Describes a transparent methodology to evaluate the integrity of *existing* wells, and risk-based procedure for re-qualification of wells for CO<sub>2</sub>-injection. Content includes:
  - Well integrity risk
    - Risk assessment and risk criteria
    - Identification, analyses and evaluation of well risks
    - Communication
  - Qualification of existing wells
  - Assess performance of and qualification of wells
- The guideline provides a tool for independent validation and verification. Contributes to build confidence among regulators and stakeholders in risk informed approaches to selection and management of storage sites.

# NETL WM: Best practices for: Carbon Storage Systems and Well Management Activities



- <http://www.netl.doe.gov/File%20Library/Research/Carbon-Storage/Project-Portfolio/BPM-Carbon-Storage-Systems-and-Well-Mgt.pdf>
- <http://www.netl.doe.gov/research/coal/carbon-storage/publications>
- The purpose of this BPM is to share lessons learned regarding site-specific management activities for carbon storage well systems. Builds on the experiences of the RCSPs and the petroleum and other private industry.
- It is part of NETL's series of BPMs for CCUS.
- This BPM covers:
  - Assessing initial site characterization
  - Injection design
  - Project cost revisions
  - Permitting
  - Establishing site security and access
  - Well and facility layout
  - Well pad preparations
  - Well drilling
  - Formation evaluation
  - Well construction
  - Well testing
  - Suitability of well
  - Pre-injection baseline
  - Injection system completion
  - Injection
  - Post-injection operations, including well and site closure and MVA

# Monitoring, Verification and Accounting (MVA)



- [NETL: Best Practices for Monitoring, Verification, and Accounting of CO<sub>2</sub> Stored in Deep Geologic Formations](#)
- [CO<sub>2</sub>STORE: Best practice for the storage of CO<sub>2</sub> in saline aquifers](#). Guidelines developed as deliverable from the EU funded projects SACS (Saline Aquifer CO<sub>2</sub> Storage), SACS2 and CO<sub>2</sub>STORE, based on research around Sleipner CO<sub>2</sub> injection. Published in 2008
- [CO<sub>2</sub> Capture Project \(CCP\): A technical basis for carbon dioxide storage](#). Published in 2009
- [DNV RP-J203: Geological Storage of Carbon Dioxide. A Recommended Practice](#) published in 2012 (Not very detailed on MVA)
- [IEA Weyburn: Best Practices for Validating CO<sub>2</sub> Geological Storage](#). Book summarizing experiences and learnings from the Weyburn Project. Published in 2012
- [EC Project CGS: Monitoring methods](#)

# NETL: Best Practices for Monitoring, Verification, and Accounting of CO<sub>2</sub> Stored in Deep Geologic Formations



- <http://www.netl.doe.gov/research/coal/carbon-storage/carbon-storage-infrastructure/best-practices>
- <http://www.netl.doe.gov/research/coal/carbon-storage/publications>
- This BPM covers:
  - Objectives and Goals of Monitoring
  - Overview of Existing MVA Technologies
  - Field Readiness of CO<sub>2</sub> Monitoring Tools
  - Applicability to Regulatory and Reservoir Management Needs Monitoring Plan
  - Monitoring of CO<sub>2</sub> in the Atmosphere
  - Near-Surface Monitoring Techniques
  - Subsurface Monitoring
  - MVA Data Integration and Analysis Technologies
  - Review of EPA Permitting Requirements

# EC Project CGS: Monitoring methods



- <http://www.cgseurope.net/Sections.aspx?section=491.493>
- This document is a deliverable of the Pan-European coordination action on CO<sub>2</sub> Geological Storage (CGS)
- The main objective of this report is to identify and review monitoring methods for a performance assessment of geological CO<sub>2</sub> storage sites. This report includes
  - state-of-the-art monitoring techniques
  - Monitoring concepts – status quo
  - Setting up a site-specific monitoring plan
  - Conclusions and recommendations
- This is complemented by an overview of monitoring applications employed at demo or pilot CO<sub>2</sub> storage sites or in field tests. The section on establishing site-specific monitoring plans includes two examples selected to represent the two major storage options in Europe and worldwide, namely saline aquifers (Romanian example) and depleted gas fields (Slovakian example).

# Best Practices, Risk assessment and management



- [NETL RA: Risk analysis and simulation for geologic storage of CO<sub>2</sub>](#)
- [DNV CO2RISKMAN Levels 1 – 4.](#)
- Information/discussions on risk assessment and management can also be found in:
  - [CO2STORE: Best practice for the storage of CO<sub>2</sub> in saline aquifers.](#) Guidelines developed as deliverable from the EU funded projects SACS (Saline Aquifer CO<sub>2</sub> Storage), SACS2 and CO2STORE, based on research around Sleipner CO<sub>2</sub> injection. Published in 2008
  - [DNV RP-J203: Geological Storage of Carbon Dioxide. A Recommended Practice](#)
  - [IEA Weyburn: Best Practices for Validating CO<sub>2</sub> Geological Storage](#)
  - [DNV CO2QUALSTORE: Guideline for selection and qualification of sites and projects for geological storage of CO<sub>2</sub>](#)
  - [NETL SS: Best practices for: Site screening, site selection, and initial characterization for storage of CO<sub>2</sub> in deep geologic formations](#)
  - [DNV CO2WELLS: Guideline for the risk management of existing wells at CO<sub>2</sub> geological storage site \(existing wells only\)](#)
  - [CSA: Z741-12 - Geological storage of carbon dioxide](#)

# NETL RA: Risk analysis and simulation for geologic storage of CO<sub>2</sub>



- <http://www.netl.doe.gov/research/coal/carbon-storage/publications>
- <http://www.netl.doe.gov/research/coal/carbon-storage/carbon-storage-infrastructure/best-practices>
- A generic publication that provides an understanding of what risk and numerical simulation is and why it is an essential aspect to CCS. This BPM was developed from the lessons learned at numerous projects run by the Regional Carbon Sequestration Partnership (RCSP).
- The BPM includes elements that are required for accurate simulation for risk:
  - Fundamentals
  - Identification
  - Assessment (including quantifying) and characterization
  - Mitigation;
  - And for simulation the many different processes (thermal, chemical, biological, etc...).
  - The BPM also covers how risk plans and numerical simulations can be applied separately and together to a CCS project in order to handle the potential risks of a CCS site.

## DNV CO2RISKMAN Levels 1 – 4.



- [http://www.dnv.com/industry/energy/segments/carbon\\_capture\\_storage/recommended\\_practice\\_guidelines/co2riskman/co2riskman\\_guidance.asp](http://www.dnv.com/industry/energy/segments/carbon_capture_storage/recommended_practice_guidelines/co2riskman/co2riskman_guidance.asp)
- The CO2RISKMAN Guidance document is intended to provide a robust knowledge source to assist CCS projects with the development and implementation of their hazard management processes.
- It is basically a risk management guidance document for most of the CCS chain, in four parts. Storage related items are found in Level 4 and covers management of well risk, injection facility risk and intermediate storage risk.

## Best Practices, Operations



- Some guidance on operations of CO<sub>2</sub> storage sites can be found in the following Best Practice manuals:
  - [CO2 Capture Project \(CCP\): A technical basis for carbon dioxide storage](#)
  - [DNV CO2QUALSTORE: Guideline for selection and qualification of sites and projects for geological storage of CO<sub>2</sub>](#)
  - [NETL: Best Practices for Monitoring, Verification, and Accounting of CO2 Stored in Deep Geologic Formations](#)
  - [NETL WM: Best practices for: Carbon Storage Systems and Well Management Activities](#)
  - [EC project CGS: Operational and safety risk regulations](#)

# EC project CGS: Operational and safety risk regulations



- <http://www.cgseurope.net/Sections.aspx?section=491.493>
- The report is not a monograph, but rather an edited compendium of contributions from individual network partners. Only individual chapters are available at the above web-site. Chapters and sections may vary in style and level of detail.
- This report is the result of a joint effort carried out by various members of the CGS Europe project ([www.cgseurope.net](http://www.cgseurope.net)) - the "Pan-European Coordination Action on CO<sub>2</sub> Geological Storage", funded within the 7<sup>th</sup> framework programme of the EU. The report is based on current literature Directives and Regulatory Regimes Related to Operational and Safety Risks. It focuses on Europe and the EU CCS and Emission Trading Directives, as well as international regulations and closely follows their definitions and terminology.
- Content includes:
  - CO<sub>2</sub> storage site operation risks and regulations
  - Potential leakage events – related regulations and guidelines
  - Directives and regulations related to storage site monitoring, remediation and closure
- The report is public so that any interested party can readily make use of it. CGS Europe does not claim completeness, nor comprehensive consideration of all legal or regulatory requirements on operational and safety risks in Europe.

## Best Practices, Closure



- The following Best Practice manuals address site closure, albeit at differing levels of detail or different aspects:
  - [CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research: Best Practice Guidelines.](#)
  - [CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research. Plan for risk management supporting site abandonment](#)
  - [CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research Criteria for decision making in site abandonment](#)
  - [CO2STORE: Best practice for the storage of CO<sub>2</sub> in saline aquifers](#)
  - [DNV CO2QUALSTORE: Guideline for selection and qualification of sites and projects for geological storage of CO<sub>2</sub>](#)
  - [NETL: Best Practices for Monitoring, Verification, and Accounting of CO<sub>2</sub> Stored in Deep Geologic Formations](#)
  - [IEA Weyburn: Best Practices for Validating CO<sub>2</sub> Geological Storage](#)
  - [NETL WM: Best practices for: Carbon Storage Systems and Well Management Activities](#)

# CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research Best Practice Guidelines



- <http://www.co2care.org/SciPublicationsData.aspx?IdPublication=45&IdType=327>
- This document is a deliverable from the EU funded project CO2CARE (<http://www.co2care.org>). It is one of a series of Best Practice Guidelines produced by the project. It gives recommendations on the following topics:
  - Post-closure wellbore management
  - Post-closure reservoir management
  - Risk management
  - Transfer of responsibility from the Operator to the State
  - Communication with the public
- It also gives recommendations for the possible modification of Directive 2009/31/EC of the European Union, on the geological storage of carbon dioxide and its associated guidance documents
- Must be seen in context with
  - [CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research. Plan for risk management supporting site abandonment](#)
  - [CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research Criteria for decision making in site abandonment](#)

CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research  
Plan for risk management  
supporting site abandonment



- <http://www.co2care.org/SciPublicationsData.aspx?IdPublication=43&IdType=327>
- This document is a deliverable from the EU funded project CO2CARE (<http://www.co2care.org>). It is one of a series of Best Practice Guidelines produced by the project. It addresses the following topics:
  - Requirements of EC Directive 2009/31/EC
  - Timeline and site-closure milestones
  - Evaluation of the milestone chart
- Must be seen in context with
- [CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research: Best Practice Guidelines](#)
- [CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research  
Criteria for decision making in site abandonment](#)

# CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research Criteria for decision making in site abandonment



- <http://www.co2care.org/SciPublicationsData.aspx?IdPublication=44&IdType=327>
- This document is a deliverable from the EU funded project CO2CARE (<http://www.co2care.org>). It is one of a series of Best Practice Guidelines produced by the project. It addresses the following topics:
  - Risk management plan
  - Traffic light system to assess model-monitoring offset
  - Traffic light system evaluation on K-12-B
- Must be seen in context with
- [CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research: Best Practice Guidelines](#)
- [CO<sub>2</sub>CARE: CO<sub>2</sub> Site Closure Assessment Research. Plan for risk management supporting site abandonment](#)

## Australia



- The Australian Government has developed a regulatory framework for offshore CO<sub>2</sub> storage based on amendments to existing petroleum legislation
- Two sets of non-binding guidelines have been developed to promote a consistent approach to the application of CCS activities in Australia, including offshore storage activities. These guidelines are summarised briefly in the column to the left.
  - [Carbon dioxide capture and geological storage : Australian regulatory guiding principles / Ministerial Council on Mineral and Petroleum Resources.](#)
  - [Environmental Guidelines for Carbon Dioxide. Capture and Geological Storage - 2009](#)

Carbon dioxide capture and geological storage :  
Australian regulatory guiding principles / Ministerial Council  
on Mineral and Petroleum Resources.



- <http://trove.nla.gov.au/work/30967080?selectedversion=NBD40004701>
- The purpose of the Guiding Principles is to promote consistency in the development of a CCS regulatory framework across the Australian states and territories. The Guiding Principles address six areas of CCS activities:
  - Assessment and approval processes
  - Access and property rights
  - Transportation issues
  - Monitoring and verification
  - Liability and post-closure responsibilities
  - Financial issues
- The Guiding principles are non-binding.

# Environmental Guidelines for Carbon Dioxide Capture and Geological Storage - 2009



- <http://www.scew.gov.au/system/files/resources/afb015f4-8b55-6904-716c-d26bcf317c86/files/environmental-guidelines-ccs.pdf>
- Environmental Guidelines are non-binding but do provide some high level supplementary information on
  - Environmental assessment of CCS activities
  - Monitoring of injected GHG substances
  - Site closure
  - The need for co-ordination across jurisdictions.

# European Commission



- European Commission:
- The European Commission has issued a directive, DIRECTIVE 2009/31/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the geological storage of carbon dioxide and amending. The directive has four guidance documents, on
  - Risk management
  - Characterization and monitoring
  - Transfer of responsibility
  - Financial security and mechanism
- Two the four guidance documents Directive 2009/31/EC nos. 1 and 2 are relevant for this overview. The purpose of the Guidance Documents is to assist stakeholders to implement the Directive (so-called CCS Directive Guidance)
  - [Guidance Document 1. CO<sub>2</sub> Storage Life Cycle Risk Management Framework](#)
  - [Guidance Document 2. Characterisation of the Storage Complex, CO<sub>2</sub> Stream Composition, Monitoring and Corrective Measures](#)

# EC Guidance Document 1



- Guidance Document 1. CO<sub>2</sub> Storage Life Cycle Risk Management Framework
- <http://www.zeroemissionsplatform.eu/news/news/673-ec-guidance-documents-for-implementation-of-ccs-directive.html>
- [http://ec.europa.eu/clima/policies/lowcarbon/ccs/implementation/docs/gd1\\_en.pdf](http://ec.europa.eu/clima/policies/lowcarbon/ccs/implementation/docs/gd1_en.pdf)
- This document 1 (GD1) addresses the overall framework for geological storage in the CCS Directive for the entire life cycle of geological CO<sub>2</sub> storage activities including
  - The phases
  - Main activities
  - Major regulatory milestones.
  - High-level approach to risk assessment and management

## EC – Guidance Document 2



- Guidance Document 2. Characterisation of the Storage Complex, CO<sub>2</sub> Stream Composition, Monitoring and Corrective Measures
- <http://www.zeroemissionsplatform.eu/news/news/673-ec-guidance-documents-for-implementation-of-ccs-directive.html>
- [http://ec.europa.eu/clima/policies/lowcarbon/ccs/implementation/docs/gd2\\_en.pdf](http://ec.europa.eu/clima/policies/lowcarbon/ccs/implementation/docs/gd2_en.pdf)
- This document 2 (GD2) builds on GD1 and provides guidance on:
  - Site selection;
  - Composition of the CO<sub>2</sub> stream;
  - Monitoring;
  - Corrective measures.
  - The Guidance documents are non- legally binding

# London Convention and Protocol



- The London Convention and Protocol has two documents that relate to storage of CO<sub>2</sub>:
  - Risk Assessment and Management Framework (RAMF) 2006
  - CO<sub>2</sub> Specific Guidelines
- They can be found at
- <http://www.imo.org/OurWork/Environment/LCLP/EmergingIssues/CCS/Pages/default.aspx>
- The RAMF 2006 provides generic guidance in order to characterize the risks to the marine environment on a site-specific basis, and collect the necessary information to develop a management strategy to address uncertainties and any residual risks.
- The RAMF forms the basis for the OSPAR Guidelines.
- The CO<sub>2</sub> Specific Guidelines are to be followed by London Protocol Parties when issuing a permit for CO<sub>2</sub> geological storage in the marine environment and ensure compliance with Annex 2 of the Protocol (Assessment of wastes or other matter that may be considered for dumping). The Guidelines were updated in 2012 to include transboundary movement subsurface
- 
- The Guidelines cover:
  - Carbon Dioxide Stream Characterization
  - Site Selection and Characterization;
  - Assessment of Potential Impacts
  - Permit and Permit Conditions;
  - Monitoring and Risk Management;
  - Mitigation or Remediation Plan

# OSPAR



- The OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic has issued Decision 2007/2 on the Storage of Carbon Dioxide Streams in Geological Formations
- [http://www.ospar.org/html\\_documents/ospar/html/ospar\\_convention\\_e\\_updated\\_text\\_2007.pdf](http://www.ospar.org/html_documents/ospar/html/ospar_convention_e_updated_text_2007.pdf)
- [http://www.google.no/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCQQFjAA&url=http%3A%2F%2Fwww.ospar.org%2Fdocuments%2Fdbase%2Fdecrecs%2Fagreements%2F07-12e\\_co2%2520gl%2520and%2520fram.doc&ei=yvBAVOq0CYWxaeSpgPgL&usg=AFQjCNF2Gwg\\_5zwO-SWZyOZ3zVgaTOdHVA&bvm=bv.77648437,d.d2s](http://www.google.no/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCQQFjAA&url=http%3A%2F%2Fwww.ospar.org%2Fdocuments%2Fdbase%2Fdecrecs%2Fagreements%2F07-12e_co2%2520gl%2520and%2520fram.doc&ei=yvBAVOq0CYWxaeSpgPgL&usg=AFQjCNF2Gwg_5zwO-SWZyOZ3zVgaTOdHVA&bvm=bv.77648437,d.d2s)
- The Convention is accompanied by Guidelines for Risk Assessment and Management of Storage of CO<sub>2</sub> Streams in Geological Formations
- The Guidelines provide generic guidance for Contracting Parties when considering applications for permits to store CO<sub>2</sub> in geological formations under the seabed. The Guidelines have four Annexes, whereof Annex 1 – Framework for Risk Assessment and management of Storage of CO<sub>2</sub> Streams in Geological Formations (FRAM) – is relevant for this overview. It addresses:
  - Problem formulation
  - Site selection and characterization
  - Exposure assessment
  - Effects assessment
  - Risk characterization
  - Risk management

# US EPA



- EPA is currently developing guidance documents to support the Class VI Rule regulations. These documents are geared towards Directors and Owners and Operators of Class VI wells. Periodically, the page will be updated with drafts of new guidance documents open for comment.
- Information and documents related to Class VI Injection Wells Geologic Sequestration Guidance Documents can be found at
- <http://water.epa.gov/type/groundwater/uic/class6/gsguidedoc.cfm>
- The website includes completed as well as draft documents
- Completed guidance documents include
  - Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Primacy Manual for State Directors
  - Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Site Characterization Guidance (
  - Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Area of Review and Corrective Action Guidance)
  - Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance
  - Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Project Plan Development Guidance
  - Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Construction Guidance

# World Resources Institute (WRI): Guidelines for CCS



- <http://www.wri.org/our-work/project/carbon-dioxide-capture-and-storage-ccs>
- [http://pdf.wri.org/ccs\\_guidelines.pdf](http://pdf.wri.org/ccs_guidelines.pdf)
- Covers the entire CCS process (Capture, transport, storage). Storage topics addressed are recommended guidelines for:
  - MMV
  - Risk assessment
  - Financial responsibility
  - Property rights and ownership
  - Site selection and characterization
  - Injection operations
  - Site closure
  - Post-closure
- Unable to achieve the same level of detail as other BPMs, more an overview of a theoretical project development and what proponents 'should' consider and do to be successful. It is best described as a dictionary of CCS project aspects as opposed to a BPM. That being said, it does not call itself directly a best practice manual.

# ISO/TC 265 "Carbon dioxide capture, transportation, and geological storage" – work in progress



- [http://www.iso.org/iso/iso\\_technical\\_committee?commid=648607](http://www.iso.org/iso/iso_technical_committee?commid=648607)
- Committee formed: 2011.
- Expected duration: 5 years
- Participating countries: 18
- Observing countries: 9
- Current work groups:
  - • WG 01 "Capture"
  - • WG 02 "Transportation"
  - • WG 03 "Storage"
  - • WG 04 "Quantification and Verification"
  - • WG 05 "Cross Cutting Issues"
  - • WG 06 "EOR Issues"

# Alberta, Canada

## Summary Report of the Regulatory Framework Assessment



- [www.solutionsstarthere.ca/](http://www.solutionsstarthere.ca/)

This document is neither a standard, guideline nor best practice manual but a useful document that describes in a summary way many aspects of CCS. As such, it covers capture and transport in addition to storage.

The document recommends regulatory changes to the Alberta Government regarding safe CCS.

The Regulatory Framework Assessment process was initiated in March 2011 in response to Alberta's \$1.3 billion investment in two commercial-scale CCS projects in the province. The process looked at the regulations that applied to CCS in Alberta at the time as well as regulations and best practices in other parts of the world. It examined in detail the

- technical,
- environmental,
- safety,
- monitoring and
- closure requirements that apply to a CCS project.

## High level comparative summary



In the following table a high level assessment has been made to highlight to what extents A range of storage topics have been addressed in the various documents.

The following assessment grades have been used. Some BPM have limited scope and the assigned “grade” applies to the topic of the BPM.

“Grade”	Meaning	“Grade”	Meaning
-	Not covered specifically	Technical	Provides technical details of projects, generally comprehensive
Basic	Briefly covered in a generic way	Detailed	Comprehensive discussion, generally generic



# High level summary Best Practices



Type	Document	Planning/pre-feasibility	Site screening, selection and characterisation	Simulation and modelling	Well construction/integrity	Operation	Closure	Monitoring and verification	Risk management, incl. assessment
Best Practices and reports	<a href="#">CO2STORE</a>	Basic	Technical	Technical	-	Basic	Detailed	Technical	Detailed
	<a href="#">CCP</a>	-	Basic	-	Detailed	Detailed	Basic	Technical	Basic
	<a href="#">DNV CO2QUAL</a>	Detailed	Detailed	Basic	-	Detailed	Detailed	Basic	Detailed
	<a href="#">DNV CO2WELLS</a>	-	Technical (existing wells)	-	-	-	-	-	Technical (existing wells)
	<a href="#">DNV RP-J203</a>	Basic	Detailed	Basic	Detailed	-	-	Detailed	Detailed
	<a href="#">DVN CO2RISKMAN</a>	-	-	-	-	-	-	-	Detailed
	<a href="#">GEOSEQ</a>	-	Basic	Basic	-	-	-	Detailed	-
	<a href="#">NETL MVA</a>	-	-	-	-	-	Technical	Technical	Technical
	<a href="#">NETL GS</a>	Technical	Technical	-	-	-	-	-	-

# High level summary Best Practices



Best Practices and reports	<a href="#">NETL SS</a>	Basic	Detailed	Basic	-	-	-	-	Technical
	<a href="#">NETL RA update</a>	-	-	Technical	-	-	-	-	Technical
	<a href="#">NETL WM</a>	-	-	-	Technical	Technical	Technical	-	-
	<a href="#">WRI CCS</a>	Basic	Detailed	Basic	Basic	Basic	Detailed	Detailed	Detailed
	<a href="#">IEA Weyburn</a>	-	Technical	Technical	Technical	-	-	Technical	Technical
	<a href="#">CO<sub>2</sub> Care Site Closure; best Practice Guidelines</a>	-	-	-	-	-	Detailed	-	-
	<a href="#">CO<sub>2</sub> Care Site Closure; Risk management</a>	-	-	-	-	-	Detailed	-	Detailed
	<a href="#">CO<sub>2</sub> Care Site Closure; Research</a>	-	-	-	-	-	-	-	-
	<a href="#">EC project CGS; Storage Site Selection</a>	-	Detailed	-	-	-	-	-	-
	<a href="#">EC project CGS; Monitoring</a>	-	-	-	-	-	-	Detailed	-
	<a href="#">EC project CGS; Operational and safety Risk regulations</a>	-	-	-	-	Detailed	-	-	-