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TECHNICAL GROUP

2013 Annual Report by the CSLF Task Force on Reviewing Best Practices and Standards for Geologic Storage and Monitoring of CO_2

Background

At the September 2011 CSLF Ministerial Meeting in Beijing, a Task Force was formed to investigate CCS Technology Opportunities and Gaps. The Task Force mandate was to perform initial identification and review of best practices and standards for storage and monitoring of injected CO_2. This document is the 2013 Annual Report from the Task Force.

Reviewing Best Practices and Standards for Geologic Storage and Monitoring of CO_2

Initial Compilation of Standards, Best Practices and Guidelines for CO_2 Storage and Monitoring

Content

Executive Summary

This report is the delivery of from Phase 1 of Task Force 6 of the Carbon Sequestration Leadership Forum (CSLF) Technical Group. As such it is an update of a report from CO2CRC (2011), which presented a list of standards, guidelines and best practice manuals (BPMs) related to carbon capture and storage (CCS). It gives an initial compilation of BPMs and similar documents and contains brief reviews of documents issued after the CO2CRC report.

So far (June 2013) only one standard on CCS has been identified, the Canadian CSA Z741-12. It is also the only identified document that appears to cover all topics listed. This initial compilation shows that site selection, monitoring and verification and risk assessment are well covered by existing standards, BPMs or guidance documents.

Recommendations for follow-up

It is recommended that Task Force 6 carries its work into a Phase 2. The objective of this phase will be to:

- Identify the applicability and the shortcomings of the various BPMs
- Communicate the results to ISO TC265 (ISO committee for development of a CCS standard).

The scope of the work in Phase 2 will be:

1. Remove documents which are outdated (this may apply to most documents more than five years old) or have been issued in revised/updated versions
2. Sort the BPMs and guidelines according to topic (monitoring, risk assessment, etc.)
3. Link the BPMs and guidelines to topics in the Canadian Standard on geological storage of carbon dioxide (CSA Z741-12) and stakeholders (operators, regulators, technology providers)
4. Suggest layout of a web based solution for annual updates, e.g. using the web site proposed by the CSLF Projects Interaction and Review Team (PIRT).

Points 3 and 4 will be the most important contribution of the Task Force. They will help users of the standard to find more detailed assistance in a concise way, e.g. in form of a matrix, and will reveal shortcomings of the suite of PBMs and guidelines.

Deliverables

- A brief report describing the relevance of the various BPMs and guidelines to existing standards on CCS and various stakeholders
- A proposal for further updates using a web based solution

Schedule

- Approval of further work: November 2013
- Commitment by Task Force members by November 2013 (essential to complete the suggested programme)
- Annual report: December 2013
- Deliverables: End of march 2014.

1. Background

At the meeting of the CSLF technical Group in Bergen, Norway June 12, 2012, it was agreed that the new Task Force on "Monitoring of Geologic Storage for Commercial Projects" (TF6) should:

1. Identify and review existing standards for geological CO_2 storage and monitoring on an annual basis;
2. Identify and review existing guidelines for communication with and engagement of involved communities and regulators on an annual basis;
3. Identify shortcomings and/or weaknesses in standards/guidelines;
4. Communicate findings to the ISO TC 265 that has been established to produce a standards on CCS;
5. Produce annual summaries of new as well as updated standards, guidelines and best practice documents regarding geological storage of CO_2 and monitoring of CO_2 sites; and
6. Follow the work of other task forces related to CO_2 storage, e.g.:
    a. Task Force on Action Plan #7 – Technical Challenges for Conversion of CO_2-EOR to CCS (Chaired by Canada).
    b. Task Force on Action Plan #1 – Technology Gap Closure (Chaired by Australia)^

A list of Task Force members can be found in Appendix H.

The following schedule was agreed following the Bergen meeting in June 2012:

- Early Sept 2012. Draft of initial compilation of standards etc to TF
- Mid-Dec. 2012 Interim report
- 15. May 2013 Draft of compilation of standards, guidelines etc
- 01. July 2013 Comments from TF on draft
- Mid Sept. 2013 Report to Secretariat
- Oct. 2013 Report to Ministerial Meeting

It was also agreed that the fall 2013 report should be a decision gate for termination or continuation, depending on e.g. progress made by ISO. Further deliverables will be decided after the decision gate in fall 2013.

Thus it will be useful to divide the work of the Task Force into phases as follows:

- Phase 1: The initial compilation of BPMs, to be delivered in September 2013
- Phase 2: Identifying the applicability and the shortcomings of the various BPMs, with a report to be delivered in time for the fall CSLF meeting 2014
- Phase 3: Annual updates of the compilation.

Each phase will represent a decision gate, with recommendation on continuation or termination of the Task Force. The final report will in any circumstance be completed no later than by fall 2016. Communication with ISO TC265 will be a continuous process.

2. Scope of this note

This is the report from Phase 1 of the Task Force, the initial compilation of standards, Best Practices Manuals (BPMs) and guidelines for technical aspects of geologic storage of CO_2. Hereafter the term BPM is used for all three concepts. The report lists relevant BPMs on geologic storage of CO_2 and gives a very brief summary of the contents.

As stated at the Bergen meeting in June 2012, the report is an update of a summary by CO2CRC (2011), issued in March 2011, in which BPMs issued after March 2011 have been added.

The BPMs and other documents listed in the various tables and appendices of this report have been carefully compiled and are publicly available. Nevertheless, the lists may not be exhaustive.

Some guidelines and BPMs concerned with regulatory issues, community engagement and communication are listed in Appendices A and B, respectively but not discussed further.

Appendix C gives a list of monitoring methods used in some storage projects and Appendices D, E and F list some publications related to, respectively, risk assessment methods, CO_2 storage atlases and BPMs for CO_2 pipelines. These have been included as a result of input from inside and outside the Task Force but will not pursued further unless the proponents take on to do the work.

There is a substantial body of general literature (lessons learned, experiences, etc) with content that may contribute to improving or supplementing best practices, standards etc. Such literature is not included in this first overview but a selection of publications will be included in an update.

3. Identified standards, best practices manuals and guidelines for CO_2 storage

Table 1 lists the short names used for the BPMs that are included in Tables 2-5.. Tables 2 – 5 show the following:

- Table 2: This is a copy CO2CRC's summaries, with the exception of CO2NET Work Package 7 Best Practice Review from 2004, which is not included here due to its age and very limited scope
- Table 3: This table gives brief summaries of content of BPMs not included in the CO2CRC report or issued after March 2011
- Table 4: A selection of guidance documents or guidelines that have been published as annexes or similar to regulations on CO_2 storage
- Table 5: This table repeats CO2CRC's assessment of the BPMs in Table 2 and supplements it with *suggested* assessment of the BPMs and guidelines in Tables 3 and 4.

CO2CRC (2011) has assessed the scope and content of the BPMs listed in Table 2 with respect level of details for the following aspects: pre-feasibility, site selection,

capacity estimation, simulation and modelling, construction, operation, closure, monitoring and verification, risk assessment, community consultation and regulation.

Table 1. Short name of BPMs listed in Tables 2 – 5.

Short name used in Table 2	Full name
CO2STORE	Best practice for the storage of CO_2 in saline aquifers
CCP	A technical basis for carbon dioxide storage
DNV CO2QUAL	Guideline for selection and qualification of sites and projects for geologic storage of CO_2
DNV CO2WELLS	CO2WELLSGuideline for the risk management of existing wells at CO_2 geological storage site
DNV RP-J203	Geological Storage of Carbon Dioxide (DNV-RP-J203)
LBNL/GEOSEQ	Geologic carbon dioxide sequestration: Site evaluation to implementation
NETL MVA	Best practices for: Monitoring, verification, and accounting of CO_2 stored in deep geologic formation
NETL GS	Best practices for: 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_2 in deep geologic formations
NETL RA	Risk analysis and simulation for geologic storage of CO_2
NETL WM	Best practices for: Carbon Storage Systems and Well Management Activities
WRI CCS	Guidelines for CCS
IEA Weyburn	Best Practice Manual developed through learning from Weyburn project
CSA	Z741-12 Geological storage of carbon dioxide
AU1	Australian Guiding Principles for Carbon Dioxide Capture and Geological Storage(Guiding Principles)
AU2	Environmental Guidelines for Carbon Dioxide Capture and Geological Storage – 2009
EC1	Guidance Document 1. CO_2 Storage Life Cycle Risk Management Framework
EC2	Guidance Document 2. Characterization of the Storage Complex, CO_2 Stream Composition, Monitoring and Corrective Measures
OSPAR	OSPAR Guidelines for Risk Assessment and Management of Storage of CO_2 Streams in Geological Formations
London	London Convention and Protocol: Specific Guidelines to Risk Assessment and Management Framework (RAMF) 2006
EPA	Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Project Plan Development Guidance

Table 2. Most relevant best practice manuals listed in CO2CRC (2011), excluding those addressing regulatory and public engagement issues as well as those purely addressing capacity estimation, sorted alphabetically by issuing organization and then chronologically. Comments are based on CO2CRC (2011).

Date	Issued by	Title (Short name used in Table 5, followed by full name and link)	Contents	Comment
2008	BGS	CO2STORE: Best practice for the storage of CO_2 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.
Jan. 2009	CO_2 Capture Project (CCP)	CCP: A technical basis for carbon dioxide storage (http://www.co2capturepproject.org/co2_storage_technical_book.html)	Covers: • 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). The BPM covers, with enough detail to be considered beyond basic, a technical understanding of the aspects of CO_2storage.	Based on experiences from participating companies in CO_2injection. Use a large number of case studies, separated from the text as standalone examples, to illustrate how the advice given in each section was used in reality. It is a guide to developing a storage project.

Feb. 2010	DNV	DNV CO2QUAL: Guideline for selection and qualification of sites and projects for geological storage of CO_2 (http://www.dnv.com.au/binaries/CO2QUALSTORE_guideline_tcm162-412142.pdf)	A step by step guide to selecting a CO_2 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).	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.
Sept. 2004	LBNL (GEO-SEQ Project Team)	GEOSEQ: Geologic carbon dioxide sequestration: Site evaluation to implementation (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/GEO-SEQ_BestPract_Rev1-1.pdf)	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_2 streams • Modelling and simulation	An early manual that covers many aspects.
Jan. 2009	NETL	NETL MVA: Best practices for: Monitoring, verification, and accounting of CO_2 stored in deep geologic formations (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/MVA_Document.pdf)	Comprehensive BPM addressing the need for and requirements of a monitoring program at a CCS project. Covers: • Atmospheric, near-surface, and subsurface monitoring • Simulation techniques • Geophysical techniques, geochemical techniques and crustal and surface techniques • Pre-operational, operational, and post-operational phases of monitoring • Discussion on possible regulatory requirements.	Utilizes numerous case studies and international projects to address what has been achieved so far and what will be required in the future.

Sept. 2010	NETL	NETL GS: Best practices for: Geologic storage formation classification: Understanding its importance and impacts on CCS opportunities in the United States (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM_GeologicStorageClassification.pdf)	Written for the purpose of understanding and applying geology to a CCS project. Covers background on: • Geological terminology, • Rock types and how they fit into CCS and which are most suitable. As well as more technical issues including different depositional environments and what each one means for CCS.	This BPM covers only a very specific topic: understanding how geology affects a CCS project.
Nov. 2010	NETL	NETL SS: Best practices for: Site screening, site selection, and initial characterization for storage of CO_2indeep geologic formations (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-SiteScreening.pdf)	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.	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.

2008	WRI	WRI CCS: Guidelines for CCS (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.

Table 3. Relevant best practice manuals published after the CO2CRC (2011) report (March 2011). Sorted alphabetically by issuing organization and then chronologically..

Date	Issued by	Title (Short name used in Table 5, followed by full name and link)	Contents	Comment
Oct. 2012	CSA Group	CSA: Z741-12 - Geological storage of carbon dioxide	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.
June 2011	DNV	DNV CO2WELLS: Guideline for the risk management of existing wells at CO_2 geological	Describes a transparent methodology to evaluate the integrity of wells, and risk-based procedure for re-qualification of wells for CO_2-injection. Content includes: • Well integrity risk	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

		storage site (http://www.dnv.com/industry/energy/segments/carbon_capture_storage/recommended_practice_guidelines/co2qualstore_co2wells/index.asp)	o Risk assessment and risk criteria o Identification, analyses and evaluation of well risks o Communication • Qualification of existing wells • Assess performance of and qualification of wells	management of storage sites.
April 2012	DNV	DNV RP-J203: Geological Storage of Carbon Dioxide (DNV-RP-J203) (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_2 storage sites. It covers: • Storage screening and appraisal • Permitting o Context and requirements o Risk performance targets o Storage and closure permits • Risk management, assessment and treatment • Well qualification	The RP incorporates and combines the guidance given in: • CO2QUALSTORE • CO2WELLS These two guidelines were the final deliverables from joint industry projects whereas this RP has been developed, and will be maintained, by DNV. Monitoring and verification is mentioned only indirectly as part of permitting.
June 2012	DNV	DNV DSS-402 (not in table 5): Qualification Management for Geological Storage of CO_2 (DNV-DSS-402) (http://www.dnv.com/news_events/news/2012/newcertificationframeworkforco2storage.asp)	This DNV Service Specification (DSS) provides a framework for the certification of geological storage sites for CO_2. It covers: • Principles for selection, qualification and management of geological storage sites for CO_2 • Service overview (basically what services DNV can provide) • Examples of CO_2 storage certification documents	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_2storage project developers and other parties, but the most important document is DNV-Rp-J203.
March 2011	NETL	NETL RA: Risk analysis and simulation for geologic storage ofCO_2 (http://www.netl.doe.g	The BPM includes elements that are required for accurate simulation for risk: • Fundamentals • Identification • Assessment (including quantifying) and characterization	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

		ov/technologies/carbon_seq/refshelf/BPM_RiskAnalysisSimulation.pdf)	• 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.	Regional Carbon Sequestration Partnership (RCSP).
April 2012	NETL	NETL WM: Best practices for: Carbon Storage Systems and Well Management Activities (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-Carbon-Storage-Systems-and-Well-Mgt.pdf)	This BPM covers: • Assessment 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	Purpose: 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. The BPM is part of NETL's series of BPMs for CCUS.

Oct. 2012	NETL	Best Practices for Monitoring, Verification, and Accounting of CO2 Stored in Deep Geologic Formations – 2012 Update http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-MVA-2012.pdf	Addressing the Objectives and Goals of Monitoring Overview of Existing MVA Technologies Field Readiness of CO2 Monitoring Tools Applicability to Regulatory and Reservoir Management Needs Monitoring Plan Monitoring of CO2 in the Atmosphere Near-Surface Monitoring Techniques Subsurface Monitoring MVA Data Integration and Analysis Technologies Review of EPA Permitting Requirements	Update of 2009 version
Oct. 2012	IEAGHG/PTRC	Hitchon, B. (ed), 2012, Best Practices for Validating CO_2 Geological Storage. Geoscience Publishing	This book addresses • Characterization • Storage performance predictions • Geochemical monitoring • Geophysical monitoring • History matching and performance validation • Well integrity • Risk assessment • Community outreach -	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 he Weyburn reservoir provided a suitable site for storage of CO_2; the second, 2005 – 2012, incorporated the Midale oilfield. The book aims to provide technical guidance to future operators, regulators and other stakeholders.
Jan. 2013	DNV	CO2RISKMAN Levels 1 – 4. http://www.dnv.com/industry/energy/segments/carbon_capture_storage/recommended_practice_guidelines/co2riskman/co2riskman_guidance.asp	This 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.	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.

Table 3 may later be supplemented by project specific BPM like documents, as the EU funded projects CASTOR [1], CO2REMOVE [2], CO2CARE [3], SITECHAR [4], MUSTANG [5] and PANACEA [6] have issued or plan to issue such publications.

It is outside the scope of TF6 to venture into CCS legislation. However, it is deemed relevant to include a list of guidance documents or guidelines that have been published as annexes or similar to regulations on CO_2 storage. Such guidelines often have contents and structure that resemble standards. A selection of such guidelines is shown in Table 4. The relevant regulations and legislation is given in Appendix A. More information on legal aspects of CCS can be found at the general website of the Carbon Capture Legal Programme (CCLP) of the University College of London (UCL) [7] and more directly related to dedicated CCUS legislation [8]. The websites provide summarizations, analyses, and responses to global CCUS legislation and regulations. The CCLP offers both their own interpretation of the legal works as well as links to the legislation and links to position and discussion papers from other organizations. Along with the section dedicated to existing legislation, the CCLP provides several short-report style papers and presentations that address particular issues surrounding the workings of regulatory issues. Additionally, CCLP mentions also the status in selected Member States of the transposition of the EU CCS Directive[9].

Table 5 repeats CO2CRC's assessment of the BPMs in Table 2 and supplements it with *suggested* assessment of the BPMs and guidelines in Tables 3 and 4. We have also excluded the DNV DSS-402 Qualification management for geological storage of CO_2.

Table 5 indicates that only one of the identified documents (CSA Z741-12) covers all topics listed. This is the only standard issued on CCS by June 2013. Table 5 also shows that site selection, monitoring and verification and risk assessment are covered by existing standards, BPMs or guidance documents. Strengths, weaknesses and needs for additions or improvements of the documents listed in Tables 2– 4 will be examined in Phase 2.

Monitoring is an important part of CO_2 storage. A useful tool for selection of monitoring methods and technologies has been developed by the IEA Greenhouse Ga R&D Programme[10].

Appendix B gives a preliminary list of monitoring tools used in operative storage projects (Table B.1) and links to the websites of some large scale integrated CCS projects under execution, where it may be possible to find information on planned monitoring (Table B.2).

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[1] http://www.castor-project.eu/
[2] http://www.co2remove.eu/
[3] http://www.co2care.org/
[4] http://www.sitechar-co2.eu/
[5] http://www.co2mustang.eu/
[6] http://panacea-co2.org/
[7] http://www.ucl.ac.uk/cclp/,
[8] http://www.ucl.ac.uk/cclp/ccsdedleg.php
[9] http://www.ucl.ac.uk/cclp/ccseutransposition.php
[10] http://www.ieaghg.org/index.php?/Monitoring-Selection-Tool.html; users have to register

Appendix C gives an overview of some risk assessment (RA) methodologies. These are generally classified in two main groups: qualitative and quantitative. Most common qualitative methods, which do not provide concrete or numerical results, are the features, events, and processes (FEP), and the Vulnerability Evaluation Framework (VEF). The quantitative methods are used in well-known systems where the level of uncertainty is relatively low. Two main kinds of methods belong to this group: Deterministic Risk Assessment (DRA) and Probabilistic Risk Assessment (PRA).

Appendix E lists some relevant BPMs or related documents for storage capacity estimation. Community consultation and engagement is important to achieve understanding of CCUS has a greenhouse gas mitigating option. Appendix F lists some BPMs related to the topic. These will not be pursued further until a decision has been made on whether or not this is the responsibility of the CSLF TG. Comments are by CO2CRC (2011).

Table 4. Guidelines included as annexes etc to regulations

Date	Issued by	Title (Short name used in Table 5, followed by full name and link)	Contents	Comment
2005	Australian Government	AU1: Australian Guiding Principles for Carbon Dioxide Capture and Geological Storage(Guiding Principles) (http://www.ret.gov.au/resources/Documents/ccs/CCS_Aust_Regulatory_Guiding_Principles.pdf)	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: 1. Assessment and approval processes 2. Access and property rights 3. Transportation issues 4. Monitoring and verification 5. Liability and post-closure responsibilities 6. Financial issues The Guiding principles are non-binding.	The Australian Government has developed a regulatory framework for offshore CO_2 storage based on amendments to existing petroleum legislation. (See e.g. http://www.ucl.ac.uk/cclp/ccsoffnational-AUS.php#envregs). 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.
2009	Australian Government	AU2: Environmental Guidelines for Carbon Dioxide Capture and Geological Storage - 2009 (http://www.ephc.gov.au/sites/default/files/Climate_GL__Environmental_Guidelines_for_CCS_200905_0.pdf)	Environmental Guidelines are non-binding but do provide some high level supplementary information on 1. Environmental assessment of CCS activities 2. Monitoring of injected GHG substances 3. Site closure 4. The need for co-ordination across jurisdictions.	

2011	European Commission	EC1: Guidance Document 1 CO_2Storage Life Cycle Risk Management Framework (http://ec.europa.eu/clima/policies/lowcarbon/ccs/implementation/docs/gd1_en.pdf)	Of 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). Document 1 (GD1) addresses the overall framework for geological storage in the CCS Directive for the entire life cycle of geological CO_2storageactivities including 1. The phases 2. Main activities 3. Major regulatory milestones. 4. High-level approach to risk assessment and management	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 1. Risk management 2. Characterization and monitoring 3. Transfer of responsibility 4. Financial security and mechanism
2011	European Commission	EC2: Guidance Document 2 Characterisation of the Storage Complex, CO_2Stream Composition, Monitoring and Corrective Measures (http://ec.europa.eu/clima/policies/lowcarbon/ccs/implementation/docs/gd2_en.pdf)	Guidance Document 2 (GD2) builds on GD1 provides guidance on: 1. Site selection; 2. Composition of the CO_2stream; 3. Monitoring; 4. Corrective measures. The Guidance documents are non- legally binding.	
June 2007	OSPAR Convention	OSPAR: Guidelines for Risk Assessment and Management of Storage of CO_2 Streams in Geological Formations (http://www.ucl.ac.uk/cclp/pdf/OSPAR2007-Annex-7.pdf)	The Guidelines provide generic guidance for Contracting Parties when considering applications for permits to store CO_2in geological formations under the seabed. The Guidelines have four Annexes, whereof Annex 1 – Framework for Risk Assessment and management of Storage of CO_2 Streams in Geological Formations (FRAM) – is relevant for this overview. It addresses: 1. Problem formulation 2. Site selection and characterisation 3. Exposure assessment 4. Effects assessment 5. Risk characterization 6. Risk management	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 with Guidelines (http://www.ucl.ac.uk/cclp/pdf/OSPAR2007-Annex-6.pdf)

2006, 2007, and 2012	London Convention and Protocol	Risk Assessment and Management Framework (RAMF) 2006 CO2 Specific Guidelines 2007 CO2 Specific Guidelines revised 2012	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 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 The Guidelines were updated in 2012 to include transboundary movement subsurface.	The RAMF forms the basis for the OSPAR Guidelines. The CO2 Specific Guidelines are to be followed by London Protocol Parties when issuing a permit for CO2 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). Work is ongoing on including transboundary movement above-surface.
August 2012	EPA (US Government)	EPA: Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Project Plan Development Guidance (http://water.epa.gov/type/groundwater/uic/class6/upload/epa816r11017.pdf)	This document describes the required elements of each of the five plans prospective Class VI injection well owners and operators must submit with a permit application under the Class VI Rule requirements: o Area of Review and Corrective Action Plan, o Testing and Monitoring Plan, o Injection Well Plugging Plan, o Post-Injection Site Care (PISC) and o Site Closure Plan, and Emergency and Remedial Response Plan	This is a basic and non-technical guidance document with some emphasis on corrective action plans and emergency and remedial response plans. It is adapted to the US regulation for Class VI Wells and therefore also has guidance on how to prepare plans that relate specifically to US regulations.

Table 5. Assessment of scope and content of BPMs listed in Tables 1 –4. For BPMs listed in Table 3 the assessment is by CO2CRC (2011). For the other BPMs the assessment is by TF6 and is to be regarded as suggestions.

BPM	Planning/pre-feasibility	Site screening, selection and characterisation	Simulation and modelling	Well construction/ integrity	Operation	Closure	Monitoring and verification	Risk management, incl. assessment
CO2STORE	Basic	Technical	Technical	-	Basic	Detailed	Technical	Detailed
CCP	-	Basic	-	Detailed	Detailed	Basic	Technical	Basic
DNV CO2QUAL	Detailed	Detailed	Basic	-	Detailed	Detailed	Basic	Detailed
DNV CO2WELLS	-	Technical (existing wells)	-	-	-	-	-	Technical (existing wells)
DNV RP-J203	Basic	Detailed	Basic	Detailed	-	-	Detailed	Detailed
DVN CO2RISKMAN	-	-	-	-	-	-	-	Detailed
GEOSEQ	-	Basic	Basic	-	-	-	Detailed	-
NETL MVA	-	-	-	-	Technical	Technical	Technical	Basic
NETL GS	Technical	Technical	-	-	-	-	-	-
NETL SS	Basic	Detailed	Basic	-	-	-	-	Technical
NETL RA+update	-	-	Technical	-	-	-	-	Technical
NETL WM	-	-	-	Technical	Technical	Technical	-	-
WRI CCS	Basic	Detailed	Basic	Basic	Basic	Detailed	Detailed	Detailed
IEA Weyburn	-	Technical	Technical	Technical	-	-	Technical	Technical
CSA	Basic	Detailed	Detailed	Detailed	Basic	Detailed	Detailed	Detailed
AU1	-	-	-	-	-	-	-	-
AU2	-	-	-	-	-	-	(Very) Basic	(Env. risk very basic)
EC1	-	-	-	-	-	-	-	Detailed
EC2	-	Detailed	Basic	-	-	-	Detailed	(only corrective part)
OSPAR	Basic	Basic	-	-	-	-	-	Basic
London	-	Very basic	-	-	-	-	Very basic	Very basic
EPA	-	-	-	-	-	Basic	Basic	Basic

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

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

4. Other related documents

Appendix D lists relevant documents and related references for storage capacity of CO_2 in different regions of the world. The list is a combination of atlases and GIS (geo databases and tools). Each of them bears specificity due to regional coverage (e.g. South Africa, Brazil) but also methodology (e.g. BGR, ETI, Caprock Italy). The references may not lead to the document or database itself but to a website where more information may be found.

Pipelines are outside the scope for TF6 but some standards, BPMs and guidance documents are shown in Appendix G as it was suggested to include this.

5. ISO TC 265 Carbon capture and storage (CCS)

At the Bergen meeting, the Task Force on Monitoring Geologic Storage for Commercial Projects had recommended that the CSLF request a formal liaison with the ISO Technical Committee on CO_2 Capture, Transportation and Geological Storage (ISO/TC 265). To that end, the CSLF Policy Group Chair, in August, sent a letter to the ISO/TC 265 Secretariat that requested liaison status, which has been accepted. The CSLF Secretariat will coordinate communication between ISO/TC265 and the CSLT Technical Group Executive Committee in that regard.

As of June 2013 the status of ISO/TC65 is:

There are currently 16 participating member countries, 10 observing members, and 6 liaison organisations involved in ISO/TC 265. 13 of the participating and three of the observing members countries are also members of the CSLF.

A business plan and a preliminary scoping document have been developed and work is continuing to further develop and refine the scope of work. The scope of work is anticipated to include not only elements that require standardisation now, but also be forward looking and include elements that will require standardisation in the future. Initially the following working groups (WGs) have been defined:

1. Capture, secretariat Japan
2. Transport, secretariat Germany
3. Storage, secretariat Canada
4. Quantification and verification, secretariat China
5. Cross cutting issues, secretariat France

A call for experts to the working groups has been issued. Detailed strategies and priorities will be established for each of the working groups and the business plan will be updated as work progresses.

On this background it is suggested to continue the work of CSLF Task Force 6, as its work will complement ISO TC265.

6. References

CO2CRC (2011) A review of best practice manuals for carbon dioxide storage and regulation. http://www.globalccsinstitute.com/publications/review-existing-best-practice-manuals-carbon-dioxide-storage-and-regulation

Appendix A. Regulations

Table A.1. Legislation and regulations to which the guidelines of Chapter 3, table 4, are associated. Comments are not provided, as legislation is outside the scope for Task Force 6 "Monitoring of Geologic Storage for Commercial Projects".

Date	Issued by	Title
2008 - 2011	Australian Government	Offshore Petroleum Amendment (Greenhouse Gas Storage) Act 2008 (OPGGS Act); Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009; Offshore Petroleum and Greenhouse Gas Storage (Management of Greenhouse Gas Well Operations) Regulations 2010; Offshore Petroleum and Greenhouse Gas Storage (Management of Greenhouse Gas Well Operations) Regulations 2010; Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011 (RMA Regs); Offshore Petroleum and Greenhouse Gas Storage (Injection and Storage) Regulations 2010 Draft), see also http://www.ucl.ac.uk/cclp/ccsdedlegnat-AUS.php.
Dec. 2010	Alberta, Canada	Carbon Capture and Storage Statutes Amendments Act 2010, see also http://www.ucl.ac.uk/cclp/ccsdedlegnat-CAN.php
April 2009	European Commission	DIRECTIVE 2009/31/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0114:0135:EN:PDF)
2006, 2007 and 2012	International Maritime Organization (IMO)	London Convention and Protocal. Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 and 1996 Protocol Thereto http://www.imo.org/OurWork/Environment/SpecialProgrammesAndInitiatives/Pages/London-Convention-and-Protocol.aspx
June 2007	OSPAR Convention	OSPAR Decision 2007/2 on the Storage of Carbon Dioxide Streams in Geological Formations (http://www.ucl.ac.uk/cclp/pdf/OSPAR2007-Annex-6.pdf);(http://www.ucl.ac.uk/cclp/ccsoffeuropeospar.php) (http://www.ucl.ac.uk/cclp/pdf/OSPAR_Convention_e_updated_text_2007.pdf); 8 http://www.ucl.ac.uk/cclp/pdf/OSPAR2007-Annex-5.pdf)
2008	UK	Energy Act 2008 (http://www.legislation.gov.uk/ukpga/2008/32/pdfs/ukpga_20080032_en.pdf). See also .ucl.ac.uk/cclp/ccsdedlegnat-UK.php
July 2008	EPA (US Government)	Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells; see also http://www.ucl.ac.uk/cclp/ccsdedlegnat-US-Federal.php
Dec. 2010	EPA (US Government)	Final rule for Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells (http://water.epa.gov/type/groundwater/uic/class6/gsregulations.cfm)

Appendix B. Monitoring tools and techniques used in some projects

Table B.1.Monitoring technologies used at some present storage sites. The list is based on the references supplemented by Myer (2011) and should not be regarded as complete. Supplemented by information from Jones and Chadwick (2012; http://www.cgseurope.net/UserFiles/file/Ankara%20workshop_june%202012/presentations/DavidJones.pdf). There may also be differences in how the monitoring approaches are described by the project; thus, there may be some inconsistencies and not completely corrects marks in the table.

	Site											
	Sleipner [1]	Weyburn [2]	In Salah [3]	Snøhvit [4]	K12-B	Otway [5]	Ketzin [6]	Decatuar[7]	Quest	Lacq[8]	Gorgon	Aquistore
Seismic surface (2D/3D)	x	x	x	x		x	x	x	x			x
Seismic surface (3C/9C)		x										
Seismic downhole (VSP, Crosshole)		x				x	x	x	x			x
Electrical (EM, ERT) surface	x						x					
Electrical (EM, ERT) downhole		x					x		x			
Gravity surface / seabed	x	x										x
Tiltmeters			x									x
Satellite interferometry (InSAR)		x	x				x	x	x			x
Downhole P, T		x		x	x	x	x	x	x	x		x
Continuous downhole temperature							x		x	x		
Acoustic seabed imaging (echosounder, sonar)	x			x								
Acoustic water column imaging	x											
Geophones								x				
Water column chemistry	x											
Seabed video (ROV/AUV)	x											
Soil gas		x	x			x	x	x		x		x
Surface gas flux		x	x			x		x		x		
Passive CO_2 detectors			x			x						
Ecosystem & biomarkers	x		x	x						x		
Microseismic (passive seismic)		x	x			x	x			x		
Observation wells		x	x		x	x	x	x	x			x
Tracers		x	x		x		x		x			
Microbiology			x				x					

Wireline logs			x		x		x					
Fluid samples (reservoir, aquifers, groundwater)		x	x		x	x	x	x	x	x		x
Atmospheric CO_2 mobile/spatial		x	x			x		x	x	x		
Atmospheric CO_2 flux tower		x	x			x				x		
Well head pressure	x	x	x	x	x	x	x	x	x	x		x
Temperature	x	x	x	x	x	x	x	x	x	x		x
Well integrity monitoring (EMIT, PMIT)					x				x			
Well integrity downhole camera log					x		x					

[1] CO2STORE (2006) Best Practice for the storage CO2 in saline Aquifers. Observations and guidelines from the SACS and CO2STORE projects. http://www.co2store.org/TEK/FOT/SVG03178.nsf/web/092d69538cd9be22c1256db8003e59d1?opendocument

[2] Wilson and Monea, (2005) IEA GHG Weyburn CO2 Monitoring & Storage Project. Summary Report 2000 – 2004. Petroleum Research Centre, Regina, Canada. OSBN 0-9736290-0-2

Hitchon, B. (ed), 2012, Best Practices for Validating CO_2 Geological Storage.
Geoscience Publishing

[3] Mathieson, A., J. Midgely, I. Wright, N. Saoula, and P. Ringrose (2010), *In Salah CO2 Storage JIP: CO2 sequestration monitoring and verification technologies applied at Krechba,Algeri.* Energy Procedia, © Elsevier, Proceedings of 10th International Conference on Greenhouse Gas Control Technologies, IEA Greenhouse Gas Programme, Amsterdam, The Netherlands.

[3] Wright, I., A. Mathieson, F. Riddiford, and C. Bishop (2010), In Salah CO2 JIP: Site Selection, Management, Field Development Plan and Monitoring Overview. Energy Procedia, © Elsevier, Proceedings of 10th International Conference on Greenhouse Gas Control Technologies, IEA Greenhouse Gas Programme, Amsterdam, The Netherlands.

[4] Myer (2011) Global Status of Geologic CO2 Storage Technology Development. Report from the United States Carbon sequestration Council July 25 2011. http://www.uscsc.org/Files/Admin/Educational_Papers/Global_Status_of_Geologic_CO2_Storage_Technology_Development_Updated_Final_Edition%5B1%5D.pdf

[5] CO2CRC (2012) (Cooperative Research Centre for Greenhouse Gas Technologies) Stage 1 results from the CO2CRC Otway Project. (http://www.co2crc.com.au/dls/otway/Otway_Project_stage_1_results.pdf)

[6] Würdemann, H., Moeller, F., Kuehn, M., Heidug, W., Christensen, N.P., Borm, G., Schilling, F.R., and the CO2Sink Group, 2010. CO2SINK—From site characterisation and risk assessment to monitoring and verification: One year of operational experience with the field laboratory for CO2storage at Ketzin, Germany. International Journal of Greenhouse Gas Control Volume 4.

[7] http://www.cslforum.org/projects/illinoisbasin.html

[8] Jacques Monne, Total (personal communication)

Table B.2.Links to some large scale integrated CCS project where information on monitoring technologies used at the storage may be found

Site	Link to web-site
Quest	http://www.shell.ca/en/aboutshell/our-business-tpkg/business-in-canada/upstream/oil-sands/quest.html
Gorgon	
Boundary Dam (EOR)	
Kemper County (EOR)	
Longannet - Golden-Eye	http://www.decc.gov.uk/en/content/cms/emissions/ccs/ukccscomm_prog/feed/scottish_power/scottish_power.aspx
Kingsnorth – storage in natural gas reservoirs	http://www.decc.gov.uk/en/content/cms/emissions/ccs/ukccscomm_prog/feed/e_on_feed_/e_on_feed_.aspx

Appendix C. Risk Assessment (RA) Methods

Table C.1. Some methodologies for risk assessment of geological storage of CO2 (Condor et a.,, Energy Procedia 4(2011) 4036-4043)

Method	Goal	Data needed	Industrial application	Application for GSC
DRA	Analytical point estimate calculations	Numerical and qualitative expert estimation for scenario development and model development	Safety engineering (sensitivity analysis)	Initial risk assessment. No uncertainty estimations
PRA	Predict the probability of safety failures of complex system	Numerical qualitative expert estimation for scenario development, model development quantifying PDFs	Safety engineering	Detailed risk assessment. Uncertainty estimation
FEP	Scenario development	Qualitative expert estimation for scenario development	Scenario analysis	Screening and Site selection
VEF	Conceptual framework for regulators and technical experts	Qualitative expert estimation to identify which areas should be in-depth studied	Hazard identification and potential consequences	Framework for site selection and regulator guidance
SWIFT	Elaborate hypothesis	Qualitative expert estimation to identify hazards	Hazard identification in engineering	Hazard and consequence mapping
MCA/MAUT	Evaluation of alternatives in multiple objective	Qualitative and numerical expert estimation for data input utility	Decision making	Framework for screening and site selection
RISQUE	Systemic process with participation of expert panels estimation in event-tree approach	Qualitative and numerical expert	Hazard identification and potential consequences	Hazard and consequence mapping
CFA/SRF	Estimation of risk based on probabilities of occurrence in individual features	Qualitative and quantitative estimation of risk and uncertainty	Development of simple probabilistic models	Managing risks in GSC sites
MOSAR	Identifying and preventing risks	Qualitative and quantitative data for a well-known system	Risk reduction in complex systems	Systematic risk analysis for well-known sites
ESL	Identification of uncertainties in decisions	Qualitative and quantitative understanding of uncertainties	Reduction of uncertainties in well-known systems	Detailed PRA and dealing with uncertainties
P&R	Risk mapping in wellbores under the criteria of degradation scenarios	Qualitative and quantitative data for wellbores	Risk evaluation under the concept of ALARP	Long-term well integrity
SMA	Estimation of risk based on probabilities.	Quantitative estimation of risk and PDFs	Development of complex models in well-known systems	PRA for the whole CCS chain

Appendix D. Selection of CO_2 Storage Atlases

This list is a combination of Atlases and GIS (geo databases and tools). Each of them beares specificity due to regional coverage (e.g. South Africa, Brazil) but also methodology (e.g. BGR, ETI, Caprock Italy).

Carbon Sequestration Atlas of the United States and Canada I, II and III (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasIII/index.html)

The North American Carbon Storage Atlas 2012 (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/NACSA2012.pdf)

The CO2 Storage Atlas Norwegian North Sea 2011 (http://www.npd.no/Global/Norsk/3-Publikasjoner/Rapporter/PDF/CO2-ATLAS-lav.pdf)

Queensland carbon dioxide geological storage atlas. Compiled by Greenhouse Gas Storage Solutions on behalf of Queensland Department of Employment, Economic Development and Innovation. (http://www.cgss.com.au/Assessement%20of%20Qlds%20CO2%20geological%20storage%20prospectivity_web%20version.pdf)

South Africa CO2 Storage Atlas (http://www.sacccs.org.za/wp-content/uploads/2010/11/Atlas.pdf)

BGR Germany CO2 Storage "Atlas" (GIS) (http://www.bgr.bund.de/DE/Themen/CO2Speicherung/Downloads/Speicherkataster_Kartenanwendung.html. Description in: http://www.bgr.bund.de/DE/Themen/CO2Speicherung/Downloads/Speicherkataster_synthese.pdf?__blob=publicationFile&v=4;http://www.bgr.bund.de/DE/Themen/CO2Speicherung/Downloads/Speicherkataster_Nachweissystem.pdf?__blob=publicationFile&v=1)

ETI/The Crown Estate/BGS (in prep) CO2STORED – the UK Storage Appraisal Project. Online database/GIS.

The Brazilian Carbon Geological Sequestration Map (CARBMAP Project, some info at http://www.pucrs.br/cepac/index_e.php?p=programas)

The geo-database of caprock quality and deep saline aquifers distribution for geological storage of CO2 in Italy (GIS) (http://www.sciencedirect.com/science/article/pii/S036054421100137X)

Appendix E. BPMs on CO_2 storage capacity

Table E.1. Best practices and similar that relates to capacity estimation

Date	Issued by	Title	Contents	Comment
March 2003	Stefan Bachu	Screening and Ranking of sedimentary basins for sequestration of CO2 (http://www.geology.wmich.edu/bachu_Barnes_2003.pdf) Screening and Ranking of hydrocarbon reservoirs for CO2storage (http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/p21.pdf)		One of the first articles on the subject of site selection for CO2 storage. The subject matter is very broad and applied to regional scale assessment. It represents a thorough attempt to provide a guide and understanding to CCS site screening.
March 2008	CO2CRC	Storage Capacity Estimation, Site Selection and Characterisation for CO_2Storage Projects (http://www.ukerc.ac.uk/support/tiki-download_file.php?fileId=2395)		A comprehensive, although generic, report on what is necessary to select and characterize a site and assess the storage capacity. We have not considered it a best practice manual because, although it provides a thorough and valuable resource on site selection, it is presented as more of a 'what to consider' as opposed to what practices should be undertaken.
2005, 2007 and 2008	CSLF Task Force for Review and Identification of Standards for CO_2 Storage Capacity	Measurement, Phase I, II and III (http://www.cslforum.org/publications/index.html?cid=nav_publications)		
2008	NETL	Methodology for Development of Geologic Storage Estimates for Carbon Dioxide (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/methodology2008.pdf)in		Included as an additional reference but it is limited in scope and has been superseded by NETL's site screening BPM, which contains a technical section on storage capacity.

2008	Netherlands Oil and Gas Exploration And Production Association	Potential for CO2 storage in depleted gas fields on the Netherlands Continental Shelf http://www.nogepa.nl/en/Home/OliegasinNederland/Energieklimaatverandering/CO2opslag.aspx	This report has two parts: Phase 1: Technical assessment Phase 2: Costs of transport and storage	
2010	CHINA(country based not BPM)	Chinese methodologies of storage capacity estimation. Near-term mega-scale CO2 capture and storage demonstration opportunities in China Zheng et. al., 2010. doi:10.1016/j.fuel.2011.07.004		
2011	JAPAN (country based not BPM)	Japanese methodology of storage capacity estimation. Saline-aquifer CO2 sequestration in Japan-methodology of storage capacity assessment. Ogawa et al., 2011. http://dx.doi.org/10.1016/j.ijggc.2010.09.009	National onshore and offshore assessment for Japan	A nationwide saline-aquifer CO2 storage capacity assessment carried out in Japan. The multiplication of S_f and S_g is analogous to efficiency factor in US DOE methodology and Capacity coefficient of CSLF methodology ranges from 1% to 20%
Others[1]	UK (country based not BPM)	UK CO2 Storage Appraisal Project (ETI 2011)	National offshore resource estimate for UK	Estimate of the storage resource that is theoretically accessible without recurse to pressure management and chase water injection. Chances of success and economics of each storage unit assessed.
	DE (country based not BPM) (http://www.bgr.bund.de/DE/Themen/CO2Speicherung/Downloads/Speicherkataster_Kartenanwendung.html)	GIS-basierte Kartenanwendung „Informationssystem Speicher-Kataster Deutschland“ (ArcReader 10 erforderlich, issued by BGR	Regional capacity assessment onshore and offshore for Germany	Capacity in structural and stratigraphic traps estimated. GIS/Spreadsheet

[1] *Source S. Holloway (IEA Seminar 2011). Please note also ongoing efforts towards a common methodology worldwide for CO2 Storage Capacity Assessment* – S. Brennan et al, 2011. GHG 11 Abstract. Towards international guidelines for CO2 storage capacity estimation.

Appendix F. BPMs on regulatory issues, community engagement and communication

Table F.1. Best practices etc. that considers regulatory issues, community engagement and similar (based on CO2CRC, 2011)

Date	Issued by	Title	Contents	Comment
Nov. 2010	CCP	Update on Selected Regulation Issues for CO_2Capture and Geological Storage (http://www.co2capturepreject.org/reports/regulatory_report.pdf)	Covers the following sections • Carbon capture readiness • permitting and licensing, • impurities in injected CO_2 streams • pore space ownership, • liability issues • Monitoring, reporting and verification requirements Each section has a general overview followed by a country by country description of how some nations handle the particular issue.	Dedicated to understanding regulation, this manual is structured by regulatory subject. Although it does not cover as many issues as the IEA framework, the inclusion of thorough reviews of existing legislation on key issues merits regarding this BPM as a valuable resource.
Nov. 2010	IEA	CCS Model Regulatory Framework (http://www.iea.org/ccs/legal/model_framework.pdf)	Covers • the entire CCS chain from capture through to storage site closure and provides a comprehensive discussion of the issues regulators face • reporting and classification issues, liability, hazards and risk, inspections and monitoring, financial aspects • areas that need to be standardized such as fluid composition.	This framework provides a guideline for understanding what must go into developing regulations for CCS. It uses existing regulations as examples of how the guidelines proposed have been used. Although, focused on only one aspect of storage (regulation) it does so thoroughly.
Dec. 2009.	NETL	Best Practices for: Public outreach and education for carbon storage projects (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM_PublicOutreach.pdf)	This BPM covers • The importance of public outreach • How public outreach should be integrated into the development of the project • Identifying stakeholders, an information gathering practice termed ‘social characterization • Developing plans and strategies, • Clarification on what key messages should be and how to tailor them to a public audience.	This BPM takes the short social outreach discussion from the site screening BPM and expands it using a generic approach combining lessons learned from numerous projects in a non-specific way.

Oct. 2010	WRI	Guidelines for community engagement in CCS (http://pdf.wri.org/ccs_and_community_engagement.pdf)	Includes understanding • The importance of community engagement • The needs of different stakeholders • of applying community engagement to the specifics of CCS throughout the entire life of a project • Of how to cover impacts and risks effectively and what reactions to expect • The best practice for presenting and exchanging information.	Comprehensive review of the CCS community engagement process. Provides numerous examples from around the world of the case studies where these lessons were learned.
2010	USGS	A probabilistic assessment methodology for the evaluation of geologic carbon dioxide storage: U.S. Geological Survey Open-File Report 2010–1127, 31 p., (http://pubs.usgs.gov/of/2010/1127)		

Appendix G. BPMs and current guidance and standards related to CO_2 pipelines in connection with CCS projects

Table G.1. Some standards, BMPs and guidelines related to CO_2 transport in pipelines

Date	Issued by	Title	Contents
ALARP	HSE (UK)	Reducing risk As Low As Reasonably Practicable http://www.hse.gov.uk/pipelines/co2conveying.htm#a9	Application of good practice at the design stage is essential to demonstrating reduction of (ALARP). HSE expects duty holders to apply relevant good practice. Depending on the level of risk and complexity involved, it is possible the adoption of good practice alone may not be sufficient to comply with the law.
1996	PSR	Pipelines Safety Regulations	Regulation 5 requires that the design of a pipeline, or any modification to it, takes account of the operating regime of the pipeline and the conditions under which the fluid is to be conveyed as well as the environment to which the pipeline will be subjected. In particular with regard to the re-use of existing pipelines, any proposal to change the fluid conveyed will require a re-assessment of the original pipeline design to ensure that the pipeline is capable of conveying the fluid safely. European Standards implemented in the UK as British Normative Standards (BS EN series) and supported by published documents (such as the British Standards PD series) provide a sound basis for the design of pipelines. Other national or international codes e.g. a relevant standard or code of practice of a national standards body or equivalent body of any member state of the European Union are likely to be acceptable provided the proposed standard, code of practice, technical specification or procedure provides equivalent levels of safety.
	European Standards	PD 8010: 2004; BS EN 14161: 2003; Institute of Petroleum Pipeline Code IP6; DNV OS-F101 - Submarine Pipeline Systems (2007)	Codes IP6, BS EN 14161, BS PD 8010 and DNV OS-F101 are all applicable to pipelines transporting CO2; the last three categorising it as a non- flammable, non-toxic fluid which is gaseous at ambient temperature and pressure. IP6 also treats CO2 as a gas.

	US Pipeline Codes	US Federal Code of Regulations, Title 49, Volume 3, Part 195 – Transportation of Hazardous Liquids by Pipeline and the associated ASME standards B31.4 and B31.8	Main American codes which address the transportation of liquids and gases by pipeline respectively. The US Federal Code only applies to pipelines transporting CO2 in the supercritical phase and is therefore only relevant to proposals to use pipelines to convey supercritical CO2. There does not appear to be any equivalent code, which addresses the transport of gaseous or liquid CO2.
April 2010	DNV	Recommended Practice DNV-RP-J202. Design and operation of CO2 pipelines	The Recommended Practice (RP) was developed to address the need for guidance for how to manage risks and uncertainties specifically related to transportation of CO2 in pipelines. The document provides guidance and sets out criteria for the concept development, design, construction and operation of steel pipelines for the transportation of CO2. It is written to be a supplement to existing pipeline standards and is applicable to both onshore and offshore pipelines. The RP is intended to assist in delivering pipelines in compliance with international laws and regulations. The pipeline operator will also have to ensure that the project is in compliance with local laws and regulations.

Appendix H. Task Force Members

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