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Methodological issues under the Kyoto Protocol
Carbon dioxide capture and storage in geological formations as clean development mechanism project activities

Synthesis of views on issues relevant to the consideration of carbon dioxide capture and storage in geological formations as clean development mechanism project activities

Note by the secretariat

Summary

This document has been prepared to support the consideration of carbon dioxide capture and geological storage as project activities under the clean development mechanism, in response to the conclusion of the Subsidiary Body for Scientific and Technological Advice, as contained in the report on its twenty-seventh session (FCCC/SBSTA/2007/16). In highlighting the technical, methodological, legal and policy issues, the note synthesizes the views of Parties contained in document FCCC/SBSTA/2007/MISC.18 and Add.1 and 2 and of intergovernmental and non-governmental organizations posted on the UNFCCC website.

CONTENTS

I. Introduction

A. Mandate

1. The Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP), by its decision 1/CMP.2, invited intergovernmental and non-governmental organizations to provide to the secretariat, by 31 May 2007, information on the following issues relevant to the consideration of carbon dioxide capture and storage (CCS) in geological formations as project activities under the clean development mechanism (CDM):[1]

(a) Long-term physical leakage (seepage) levels of risks and uncertainty;

(b) Project boundary issues (such as reservoirs in international waters, several projects using one reservoir) and projects involving more than one country (projects that cross national boundaries);

(c) Long-term responsibility for monitoring the reservoir and any remediation measures that may be necessary after the end of the crediting period;

(d) Long-term liability for storage sites;

(e) Accounting options for any long-term seepage from reservoirs;

(f) Criteria and steps for the selection of suitable storage sites with respect to the potential for release of greenhouse gases;

(g) Potential leakage paths and site characteristics and monitoring methodologies for physical leakage (seepage) from the storage site and related infrastructure for example, transportation;

(h) Operation of reservoirs (for example, well-sealing and abandonment procedures), dynamics of carbon dioxide (CO_2) distribution within the reservoir and remediation issues;

(i) Any other relevant matters, including environmental impacts.

2. By the same decision, the CMP also invited Parties to make submissions to the secretariat on the same issues, taking into account the submissions referred to above.

3. The Subsidiary Body for Scientific and Technological Advice (SBSTA), at its twenty-seventh session, took note of and considered the submissions and requested the secretariat to prepare a synthesis report based on these, highlighting technical, methodological, legal and policy issues contained therein.[2]

B. Scope of the note

4. This note presents a synthesis of information and views relevant to the consideration of CCS in geological formations as CDM project activities contained in six submissions from Parties, and eight submissions from intergovernmental or non-governmental organizations.[3] This synthesis report, together

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[1] FCCC/KP/CMP/2006/L.8, paragraph 21.

[2] FCCC/SBSTA/2007/16, paragraph 96.

[3] The submissions from Parties are compiled in document FCCC/SBSTA/2007/MISC.18 and Add.1 and 2, and the submissions from organizations are available at <http://unfccc.int/parties_and_observers/ngo/items/3689.php>.

with a further synthesis report,[4] will be considered by the SBSTA at its twenty-eighth and twenty-ninth sessions.

II. Background and synthesis approach

5. The four main chapters of this document cover the four areas for consideration requested by the SBSTA (technical, methodological, legal and policy issues). Each chapter is further divided into sections covering the relevant issues raised in decision 1/CMP.2 (see para. 1 above). The issues covered in each chapter are summarized in the table below.

Coverage of issues in decision 1/CMP.2, paragraph 21, and FCCC/SBSTA/2007/16, paragraph 98

Decision 1/CMP.2 item	Technical	Method-ological	Legal	Policy
(a) **Long-term physical leakage** (seepage) **levels of risks and uncertainty**				X
(b) **Project boundary issues** (such as reservoirs in international waters, several projects using one reservoir) and **projects involving more than one country** (projects that cross national boundaries)		X	X	
(c) **Long-term responsibility for monitoring the reservoir** and any **remediation measures** that may be necessary after the end of the crediting period	X		X	
(d) **Long-term liability** for storage sites			X	
(e) **Accounting options for any long-term seepage** from reservoirs				X
(f) **Criteria** and **steps for the selection of suitable storage sites** with respect to the potential for release of greenhouse gases		X		
(g) **Potential leakage paths** and **site characteristics** and **monitoring methodologies** for physical leakage (seepage) from the storage site and related infrastructure for example, transportation	X	X		
(h) **Operation of reservoirs** (for example, well-sealing and abandonment procedures), dynamics of carbon dioxide distribution within the reservoir and **remediation** issues	X			
(i) Any other relevant matters, including **environmental impacts**	X			

6. Many of the issues raised in decision 1/CMP.2 cut across technical, methodological, legal and policy categories, in so much as the underlying technical issues and methodological approaches to address the issues raised in paragraph 1 above also underpin legal and policy approaches that may need to be resolved first. In addition, interaction between legal developments and policy decisions has ramifications for how CCS projects might be implemented. For these reasons, the first section of chapters III–VI first identifies the issues that are covered in the chapter, and then provides references to other relevant parts of the document. A section covering general points raised in the submissions is also added to each chapter.

7. The secretariat received submissions from six Parties: Canada, Japan, Norway, Portugal on behalf of the European Community and its member States (as supported by Albania, Bosnia and Herzegovina, Croatia, Serbia, the former Yugoslav Republic of Macedonia, Turkey and Ukraine), the Republic of Korea and Saudi Arabia. Eight organizations submitted information: the Bellona

[4] As outlined in document FCCC/SBSTA/2007/16, paragraph 98.

Foundation, Greenpeace International, the International Risk Governance Council, the International Petroleum Industry Environmental Conservation Association (IPIECA), the International Emissions Trading Association, the Norwegian Forum for Environment and Development, the World Coal Institute and WWF. For ease of reading, the above organizations are referred to collectively in this note as organizations.

III. Technical issues

A. Scope of chapter and links with other chapters

8. The following issues raised in decision 1/CMP.2 are relevant to this chapter on technical issues: site characteristics; potential leakage paths from the storage site and related infrastructure (both part of para. 21 (g)); operation of reservoirs including the dynamics of CO_2 distribution in the reservoir and remediation issues (para. 21 (h)); any remediation measures that may be necessary after the end of the crediting period (part of para. 21 (c)); and environmental impacts (para. 21 (i)).

9. There are inherent links between technical and other issues identified by Parties in decision 1/CMP.2. To ensure coherent coverage in this document, the following approach has been taken: steps for the selection of suitable storage sites (para. 21 (f)) is considered as a methodological issue under criteria and steps for site selection (chapter IV C); and monitoring methodologies for physical leakage (para. 21 (g)) is considered under monitoring methodologies (chapter IV E).

B. General points

10. Several Parties and organizations indicated that the Intergovernmental Panel on Climate Change (IPCC) *Special Report on Carbon Dioxide Capture and Storage*[5] (SRCCS) and the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (2006 IPCC Guidelines) provide up-to-date information with respect to scientific and technical issues, taken from a broad range of stakeholders. In this context, the SRCCS concludes that: "Components of CCS are in various stages of development. Complete CCS systems can be assembled from existing technologies that are mature or economically feasible under specific conditions, although the state of development of the overall system may be less than some of its separate components." It also states that: "Information and experience gained from the injection and/or storage of CO_2 from a large number of existing enhanced oil recovery and acid gas projects, as well as from the Sleipner, Weyburn and In Salah projects, indicate that it is feasible to store CO_2 in geological formations as a CO_2 mitigation option."

11. Several submissions noted that decades of industry experience have been accumulated in developing and deploying technologies applicable to CCS, as well as in monitoring geologically stored CO_2, including from over 70 sites where CO_2 is used for enhanced oil recovery. This includes expertise in subsurface behaviour of CO_2, which has been gained, in part through computer model simulation, from existing CCS projects (e.g. Sleipner Vest in the Norwegian sector of the North Sea, where monitoring techniques have been applied to detect an injected CO_2 plume of around 10 million tonnes at depths of over 1,000 m below the seabed), natural gas storage, enhanced petroleum extraction activities and other CO_2 geological storage-related activities.

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[5] Metz B, Davidson O, de Coninck, HC, Loos M, and Meyer LA (eds.). 2005. *IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change.* Cambridge and New York: Cambridge University Press. Available at <http://www.ipcc.ch/pdf/special-reports/srccs/srccs_wholereport.pdf>.

C. Site characteristics

12. It was noted by several Parties that geological storage of CO_2 may take place in saline formations, in depleted or partially depleted oilfields or natural gas fields, or in coal seams. One Party highlighted that saline formations, which provide the greatest opportunities for storage, are porous rock formations and composed of rock grains, organic material and minerals, with pores occupied by fluid (generally saline water). Another Party described how CO_2 is injected into the pore space and fractures in permeable rock formations as opposed to large caverns. Once injected, the CO_2 may displace, dissolve in or mix with formation fluids, or react with mineral grains, or a combination of these processes may occur.

D. Potential leakage paths

13. Parties and organizations highlighted the following "leakage" emission types or sources from CCS projects:

(a) Fugitive emissions (above-ground physical leakage of CO_2 from the capture, transport and injection system);

(b) Indirect emissions (resulting from the use of electrical and/or other energy sources required for the project such as natural gas combustion to provide heat for amine scrubbing or electrical power for compression on pipelines);

(c) Seepage[6] emissions (gradual, long-term physical release of CO_2 from the storage site);

(d) Storage site breach (sudden release of CO_2 from the storage site).

14. One organization suggested that seepage may result from imperfect sealing mechanisms, whereas storage site breach may occur through an abandoned well. According to other submissions, a storage site breach is unlikely if site selection and project design have been carried out correctly.

15. Information from submissions regarding seepage occurrence and potential seepage pathways covered the following areas:

(a) Seal failure owing to, for example, openings, fractures and/or faults in the cap rock, or to the capillary entry pressure of the cap rock being exceeded;

(b) Seepage through the pore system of low-permeability rocks;

(c) Seepage from the storage site owing to natural hydrodynamic movement of dissolved CO_2 or excessive injection past the "spill point" of the formation;

(d) Seepage (or breach) from operational or abandoned wells as a result of a lack of well integrity.

16. One organization noted that work published by the IPIECA and the American Petroleum Institute (API)[7] has addressed technical issues related to potential leakage paths. This document (hereinafter referred to as the IPIECA/API report) includes reference to faults, fractures and existing wells (active, inactive or abandoned) as potential leakage pathways.

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[6] Seepage is the term used in this document to refer to physical leakage from storage sites.

[7] IPIECA and API. 2007. *Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reduction Projects, Part II: Carbon Capture and Geological Storage Emission Reduction Family*. London: IPIECA.

E. Operation of reservoirs and remediation

17. On dynamics of CO_2 distribution, it was outlined in one submission that when CO_2 is injected into a formation, it displaces saline formation water, oil or gas and migrates upwards, because it is less dense than formation fluids. When it reaches the top of a formation, it continues to migrate in a separate phase until it is trapped as residual CO_2 saturation or in local structural or stratigraphic traps within the sealing formation (known as physical trapping of CO_2). Over the long term, large quantities of CO_2 dissolve in the formation water and then migrate with the groundwater. CO_2 in the subsurface can undergo a sequence of geochemical interactions with the rock and the formation, resulting in geochemical trapping.

18. With regard to monitoring the dynamics of CO_2 distribution, one Party highlighted experience from the Sleipner Vest field, noting that repeat seismic surveys for the baseline (1994) and repeat surveys in 1999, 2001, 2004 and 2006, as well as pressure, temperature and well-head monitoring, have been undertaken to monitor and understand CO_2 behaviour. On the other hand, levels and precision of leakage detection and efficacy were raised as an issue by a Party, with the suggestion that more research on real leakage monitoring is needed.

19. In terms of site operation and remediation, several Parties and organizations stated that proper management of CO_2 storage sites is critical in minimizing migration of CO_2 to the surface. The following approaches to preventing fugitive emissions during pipeline transport and injection, and seepage emissions from geological storage[8] were mentioned:

(a) The establishment of pressure differences to stop the flow of fluids;

(b) Operational monitoring to maintain injection pressures at or below any limits imposed by regulatory agencies on the storage of CO_2, particularly in regard to reservoir and cap rock integrity, and identifying the need for changes to reservoir management to avoid physical leakage;

(c) Plume interception;

(d) In the unlikely event of a breakthrough of stored CO_2, plugging the locations with low-permeability materials.

20. Other operational and post-closure considerations for wells highlighted by Parties and organizations include:

(a) Proper design (including CO_2 resistant design), completion and operation of CO_2 injection wells (drawing on industry experience in technologies and practices for the drilling, injection and construction of CO_2 injection wells in relation to enhanced oil recovery);

(b) Identification of all abandoned wells in the vicinity of the storage site (this is covered under steps for storage site selection, see para. 40 below);

(c) Maintenance regulations for injection wells to avoid seepage during project operation and post-closure phases;

(d) Proper closure;

[8] Includes approaches referred to in the report cited in footnote 7 above and by the International Energy Agency Greenhouse Gas R&D Programme's Risk Assessment Network. More information on the latter can be found at <http://www.co2captureandstorage.info/networks/riskassess.htm>.

(e) Monitoring of the sealing performance of wells after storage operations have been completed;

(f) Good quality control and quality assurance regulations.

21. One Party mentioned that the SRCSS provides a suitable characterization of injection well technologies and guidance on safe injection pressure.[9] As noted by an organization, approaches to remediation are also discussed in the SRCCS.[10]

22. One Party suggested that detailed contingency plans for remediation should be established and provided as part of project documentation. A contingency plan should include remediation options for all the most likely seepage scenarios, based on knowledge of potential leakage paths (see paras. 13–16 above).

23. Modelling was frequently described as a key to understanding and predicting both CO_2 behaviour and the storage performance of the reservoir, as described further below (chapter IV C), as well as the need for comprehensive monitoring for early warning of impending seepage. Modelling may also provide information on CO_2 movement (see chapter IV E below).

F. Environmental impacts

24. One Party quoted from the SRCCS: "Seepage from offshore geological storage sites may pose a hazard to benthic environments and organisms as the CO_2 moves from deep geological structures through benthic sediments to the ocean. While leaking CO_2 might be hazardous to the benthic environment, the seabed and overlying seawater can also provide a barrier, reducing the escape of seeping CO_2 to the atmosphere." It concludes that presently "no studies specifically address the environmental effects of seepage from sub-seabed geological storage sites".

25. CO_2 purity issues were discussed in one submission, where it was suggested that no waste or other matter should be added to a stream for the purpose of discarding that waste or other matter. However, CO_2 streams for injection could contain incidental associated substances derived from the source material and the capture, transport and storage processes used. In all cases, the submission recommended that the acceptable concentration of any substance should depend on its potential impact on the integrity of the storage site and relevant transport infrastructure, the risk to the environment and requirements of the applicable regulations. In this context, it was suggested elsewhere that potential operators of CCS projects under the CDM be required to prove that their CO_2 streams are sufficiently pure and that they have adequately considered the relationship between stream purity and the surrounding cap rock, including environmental and other risks of CO_2 storage.

26. One Party proposed that environmental impact concerns should be addressed in line with the CDM modalities and procedures, as set down in decision 3/CMP.1. This requires project participants to submit an analysis of the environmental (including transboundary) impacts of projects; it further requires an environmental impact assessment to be carried out, should the impacts be considered significant by the project participants or host country (see also para. 73 below). Another submission suggested that a risk assessment study could be required in addition as part of the due diligence of the project and submitted with the other project documentation. On the other hand, one Party argued that an expert panel is needed to convene in-depth discussion regarding the risks of CCS and the impact of CO_2 leakage on the environment and atmosphere (see also paras. 36 and 73 below).

[9] See section 5.5, pages 230–233 of the SRCCS.
[10] See section 5.7.7, pages 252–253 of the SRCCS.

27. According to one organization, application of CCS in coal-fired power plants in developing countries could have the added benefit of reducing air pollution and negative health impacts as well as acid rain. It was noted by a Party, however, that CCS projects should not lead to clean air technologies being neglected or no longer applied.

IV. Methodological issues

A. Scope of chapter and links with other chapters

28. The following issues raised in decision 1/CMP.2 are relevant to this chapter on methodological issues: criteria and steps for selection of suitable storage sites (para. 21 (f)); project boundary issues (in the context of emissions sources and control, and for several projects using one reservoir) (para. 21 (b)); and monitoring methodologies for physical leakage (seepage) (para. 21 (g)).

29. It is important to note that monitoring methodologies for geological CO_2 storage sites are intimately linked to site selection criteria and steps (chapter IV C), project boundaries (chapter IV D), operation of reservoirs (chapter III E) and potential leakage paths (chapter III D). This is because the monitoring applied to a geological storage site should be based on the specific characteristics of the particular site, its boundaries and the potential leakage paths identified therein, as well as on good operational practice in managing the storage site.

B. General points

30. A range of general methodological issues were raised in the submissions, including the general methodological approach, handling temporal issues around CO_2 retention, several specific accounting issues, approaches to developing methodological procedures, project documentation, and modalities and institutional arrangements. To some extent, these issues also relate to legal issues (chapter V) and policy issues (chapter VI), in particular suggestions relating to institutional arrangements and accounting options for any long-term seepage.

31. For the most part, Parties and organizations believe that flexibility is required to allow for improvements in knowledge of and experience in CCS, and to accommodate different geological conditions and the distinct storage characteristics thereof, the latter potentially presenting different capacities of different geological formations to isolate CO_2 from the atmosphere. One organization noted that such differences can also be present within a single geological formation. Most submissions agreed that these differences mean that sound characterization of reservoirs and good site selection procedures are needed to ensure long-term integrity of storage. One Party noted that only emissions from seepage and storage site breaches (see chapter III D above) present new issues to consider for the CDM.

32. As regards the issue of CO_2 retention time, it was noted by several Parties that the SRCCS suggests that a retention time of thousands of years is possible for well selected, designed and managed geological storage sites. Furthermore, gradual immobilization through different trapping mechanisms means that CO_2 could be contained for millions of years. In this context, several Parties also noted that unlike other CDM project activities, potential CCS projects will require long-term monitoring beyond the end of any crediting period to watch for any seepage emissions (or storage site breach) and for safety reasons. One organization raised the issue of operation of a CCS project after a crediting period has expired,[11] posing the question of whether storage sites might be closed at the end of the crediting period, continue to operate and store CO_2, or simply be switched off and start to emit CO_2. It was suggested in some submissions that the time span for monitoring obligations also needs to be kept to a practical length so as not to discourage project proponents.

[11] For instance, if the project goes on beyond the maximum 21-year CDM crediting period.

33. One organization discussed methodological accounting issues relating to the use of CO_2 for enhanced oil recovery and to the leakage risks that it presents. It suggested that CO_2 flooding (in the context of flooding oil reservoirs) is quite rare, and that other baseline options would need to be taken in account (e.g. water flooding, natural gas and steam) in determining the baseline and assessing additionality in such projects. Another organization recommended that a life cycle analysis approach be taken towards CCS accounting methodologies. One Party suggested that if a seven-year renewable crediting period were chosen for a CCS project, then renewal could be contingent on a thorough analysis of the storage site, and if that analysis suggested signs of direct or indirect leakage, then renewal could be denied, as this could indicate unsafe storage.

34. In terms of developing methodological procedures, one Party recommended that the CMP request the Executive Board of the CDM (CDM-EB) to draw up guidance on selecting storage sites, including criteria and a step-wise procedure for selection, and guidance on how this might be incorporated into the CDM. The CDM-EB should liaise with knowledgeable experts and governmental and non-governmental bodies, and the guidance should draw on existing work (e.g. of the IPCC, national and regional governments, the London Convention[12] and OSPAR Convention,[13] the Carbon Sequestration Leadership Forum (CSLF)) and growing industry experience.

35. Several Party submissions suggested that project boundaries, site characterization, including potential leakage paths, and the monitoring plan should all be documented in any CDM application; that is, within a CDM project design document (PDD).

36. Modalities, application approvals and institutional arrangements were also discussed. One Party proposed that an independent monitoring agency or expert group under the CDM-EB be established in order to guarantee a transparent, stable and sustainable system to clarify where to attribute the liability for long-term monitoring; it also proposed the establishment of a monitoring system to manage and supervise every CCS CDM project (see also chapter V D below). This view was shared by most of the organizations. These organizations suggested that an independent international authority, a roster of experts or other body be set up and given responsibility for, inter alia: developing modalities and procedures including minimum performance standards for CCS; approving or rejecting all applications; ensuring transparency of approvals; storage integrity assessment; and advising on liability allocation (e.g. deciding on the type of and time frame for monitoring and remediation and approving reports). One organization recommended that a new sectoral scope be introduced in the CDM for CCS, so that designated operational entities with CCS knowledge may gain accreditation to validate and verify CCS projects. Another suggested that the methodology approval and project verification process would need to be much more interactive, iterative and expert than it is now, in order to deal with CCS in the CDM.

C. Criteria and steps for storage site selection

37. Parties and organizations all broadly agree that site characterization and selection is the most critical element in ensuring long-term or permanent CO_2 storage from CCS. Thus, the main objective of site characterization, according to submissions, is to identify the capacity of the geological formation to structurally, physically and chemically trap CO_2. Several Parties and most organizations referred to the 2006 IPCC Guidelines, which state that site characterization should also identify and characterize potential seepage pathways such as faults and pre-existing wells, and quantify properties of the storage system, particularly with respect to CO_2 migration. It was mentioned that the SRCCS provides a general framework for site selection and good characterization of sites.[14]

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[12] The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, and 1996 Protocol thereto.

[13] The 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic.

[14] See section 5.3, pages 213–215 and section 5.4, pages 225–230 of the SRCCS.

38. The following factors to be taken into account in site selection were mentioned in the submissions:

(a) Depth of the storage formation;

(b) Vertical and lateral extent of the formation(s) and thus the subsurface project boundary;

(c) Physical and chemical nature of the geological trapping mechanisms, including the reservoir and seal (cap rock thickness and integrity, and lateral sealing);

(d) Geological homogeneity or heterogeneity in the storage formation;

(e) The formation's permeability and fluid migration rate;

(f) Geological storage volume in the formation;

(g) Regional and/or local geological stability;

(h) Environmental conditions in the vicinity of the planned storage site and their sensitivity to potential CO_2 leakage.

39. One organization highlighted the work undertaken by the International Energy Agency (IEA) Greenhouse Gas R&D Programme (hereinafter referred to as the IEA GHG report)[15] in addressing issues related to criteria for storage site selection. These criteria are largely aligned with the factors listed in paragraph 38 (a)–(h) above in respect of the subsurface components.

40. A number of requirements were mentioned in the submissions in relation to steps in selecting a site, including:

(a) Conducting a detailed site characterization of the reservoir which encompasses an assessment of the geological (hydrogeological, geochemical, geomechanical and environmental) characteristics of the storage reservoir and cap rock, including the site history (e.g. whether the rock has been intentionally fractured in the past for hydrocarbon extraction purposes; presence of abandoned wells). This will also need to be informed by planned CO_2 delivery rates, the injection rate and the total anticipated mass or volume of stored CO_2;

(b) Understanding the effects on surrounding strata of the stress field created by injecting CO_2 into the geological formation, including the effects of CO_2 purity on the reservoir and other infrastructure (e.g. wells and pipework);

(c) Assessing and analysing possible leakage pathways;

(d) Assessing the sensitivity of environments in the vicinity of the planned storage site to potential CO_2 leakage, and the potential to reduce damage and restore the environment in the event of leakage;

(e) Considering if neighbouring countries could be affected by leaking CO_2.

41. There is broad agreement among Parties and organizations that short- and long-term computer modelling, can provide the basis for collecting relevant site information as outlined in paragraphs 38 and 40 above. Such modelling should provide the basis for determining the likely timing, location and flux

[15] IEA Greenhouse Gas R&D Programme. 2007. *ERM – Carbon Dioxide Capture and Storage in the Clean Development Mechanism*. Available at: <http://www.co2captureandstorage.info/networks/CCS-CDM.htm>.

rate of any seepage emissions from the storage reservoir, or for demonstrating that seepage is not expected to occur in the short and long term.

42. Most Parties and organizations also agree that procedures of the type outlined in paragraph 40 above could support decisions regarding site selection and approval, and that the CDM-EB could develop such procedures. It is important that these and other steps are rigorous and applied consistently, irrespective of the projects' location.

D. Project boundaries

43. All submissions indicated that the project boundary for a CCS project should accommodate the full life cycle (covering capture, transportation, intermediate storage and injection/storage) and be broad enough to encompass greenhouse gas (GHG) emissions from transport and injection (see chapter III D above). Indeed, several Parties inferred that a project boundary can be defined by the emissions sources that must be accounted for, following the sources identified above.

44. There is also broad agreement in the submissions that project boundaries should be flexible enough to accommodate a range of storage types and different geological conditions. Some submissions also mentioned that they should include enhanced resource recovery techniques such as enhanced oil recovery (EOR) or enhanced coal bed methane (CH_4) extraction.

45. Building on the potential leakage paths identified in chapter III D above, one Party stated that the following components will need to be considered to be within the project boundary:[16]

(a) **The above-ground components** such as the industrial installation where the CO_2 is generated, the capture plant, any additional CO_2 treatment facilities, the compression facility, the transportation equipment and booster stations along a pipeline, any reception facilities or holding tanks at the injection site, and the injection facility;

(b) **Wells and other potential direct seepage pathways** such as injection, observation and abandoned wells, mineshafts and boreholes. These potential seepage pathways will need to be monitored as part of the overall project monitoring plan;

(c) **The reservoir where the CO_2 is stored.** Site characterization and storage performance assessments carried out as part of the feasibility study in advance of CO_2 injection operations will define the project boundary for the reservoir;

(d) **The locations around the reservoir** such as the cap rock or spill points at the lateral edges of a geological structural trap;

(e) **Emissions associated with enhanced hydrocarbon recovery** using CO_2, which may include breakthrough of injected anthropogenic CO_2 at extraction wells and additional energy used in the hydrocarbon recovery operation.

46. Where more than one project uses the same storage site, it was suggested by one Party that a cooperative approach to monitoring, reporting and remediation would be needed, and that all operators involved would need to agree on a monitoring and responsibility concept for the storage site in advance of operations. Another Party suggested that this should all be included in a business plan collectively prepared by the operators in advance.

[16] Several submissions referred to the IEA GHG report (see footnote 15), in the context of components within a project boundary, which is consistent with the points highlighted. See pages 9–10 of section 3.2.

E. Monitoring methodologies for leakage

47. Most Parties and organizations noted a link between site characterization and monitoring. There was broad support for the view that site characterization and proper management should provide the basis for ensuring that fugitive emissions, seepage or storage site breach are unlikely. In addition, there is also wide agreement that site characterization should include a monitoring programme to verify whether the site is performing as forecast in computer modelling. The results of monitoring should be used to recalibrate any models applied (see para. 41 above) and to further assist in the identification of seepage. One Party indicated that seismic exploration methods can be used to detect leakage.

48. The 2006 IPCC Guidelines – which are supported by most Parties and organizations – outline the following approach to estimating seepage or storage site breach:[17]

(a) Site characterization: confirmation that the geology of the storage site has been evaluated and that local and regional hydrogeology and leakage pathways have been identified;

(b) Assessment of seepage: confirmation that the potential for seepage has been evaluated through a combination of site characterization and realistic models that predict both the movement of CO_2 over time and the locations where emissions might occur;

(c) Monitoring: ensuring that an adequate monitoring plan is in place. The monitoring plan should identify potential leakage pathways, measure leakage and/or validate or update models as appropriate;

(d) Reporting: reporting the CO_2 injected and emissions from the storage site.

49. Several Parties provided information on elements that should be included in a monitoring programme. All of these are consistent with the 2006 IPCC Guidelines, which suggest that a monitoring programme should include provisions for the following:

(a) Measurement of background fluxes of CO_2 and, if appropriate, CH_4 at the storage site and any likely emission points beyond the site;

(b) Continuous measurement of the mass of CO_2 injected at each well throughout the injection period;

(c) Monitoring to determine any fugitive or indirect CO_2 emissions from the injection system;

(d) Monitoring to determine any CO_2 seepage or breach and, if appropriate, CH_4 fluxes through the seabed or ground surface; periodic investigations of the entire site and any additional area below which monitoring and modelling suggest CO_2 is distributed (to detect any unpredicted leaks);

(e) Post-injection monitoring of the site, taking account of the results of the modelling of CO_2 distribution to ensure that the monitoring equipment is deployed at the appropriate places and times;

(f) Incorporation of improvements in monitoring techniques and technologies over time;

(g) Periodic verification of emissions estimates;

[17] Summarized from the 2006 IPCC Guidelines, volume 2, chapter 5, figure 5.3.

(h) Continuous monitoring of the injection pressure and periodic monitoring of the distribution of CO_2 in the subsurface (directly or remotely), as this can provide valuable information on the reservoir characteristics, evidence of any migration of CO_2 and early warning of potential seepage.

50. One Party suggested that for EOR projects, injection and recycle/re-injection rates of breakthrough CO_2 should also be monitored.

51. According to one organization, monitoring should continue after injection has been completed, but the frequency of the monitoring is likely to decrease over time as confidence increases that the CO_2 is behaving as predicted. This time frame, the organization noted, is project-specific and cannot be defined ahead of the project.

52. It was highlighted in a submission from an organization that the IPIECA/API report and work carried out by the Risk Assessment Network[18] also provide proposals for monitoring methodologies for leakage. The former covers a range of monitoring issues in detail, including: monitoring definition and purpose; a range of direct and indirect monitoring techniques; monitoring methods (operational monitoring and closure monitoring); monitoring for storage site risk management (re-operational evaluation and operational monitoring); and closure monitoring. The Risk Assessment Network is a research network, organized by the IEA GHG R&D Programme and others, focusing on regulatory needs and the role of risk assessment for CCS projects, covering data management, risk analysis, regulatory engagement and environmental impacts.

V. Legal issues

A. Scope of chapter and links with other chapters

53. The following issues raised in decision 1/CMP.2 are relevant to this chapter on legal issues: project boundary issues, such as reservoirs in international waters and projects involving more than one country (projects that cross national boundaries) (part of para. 21 (b)); long-term responsibility for monitoring the reservoir and any remediation measures that may be necessary after the end of the crediting period (para. 21 (c)) and long-term liability for storage sites (para. 21 (d)).

54. Legal issues relating to long-term responsibility for monitoring and liability are intimately linked to accounting options for long-term seepage from reservoirs as reviewed in chapter VI C below. This is because policy decisions regarding options for accounting will determine how liability is coupled or unbundled from any certified emissions reductions (CERs) created by a CCS project activity.

B. General points

55. It is widely agreed among Parties and organizations that the critical step of selecting a site needs rigorous and consistent application of procedures, irrespective of project location. One Party suggested that if a host country does not yet have a suitable national regulatory regime to ensure that this happens, such a regime would have to be developed and implemented before a CCS project under the CDM could be deployed. Another Party, however, felt that implementing CCS under the CDM would contribute to experience in consideration and practical implementation, building on existing arrangements in development of legal systems, which could be replicated, and that the absence of such should not be a reason to exclude the CCS from the CDM. It also argued that these issues are institutional in nature, and could be solved by the countries concerned with a particular project in mind.

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[18] Report available at <http://www.co2captureandstorage.info/networks/riskassess.htm>.

56. One organization maintained that as CCS is novel and site-specific, it will require open-ended regulations – “a menu of techniques and options guided by dialogue with regulators and relying on iterative consultation with experts to come to an agreement about appropriate approach at any one site”. This view is broadly consistent with the approaches advocated by other Parties and organizations, which call for flexibility in approaches to CCS project design and approval (see para. 31 above) and favour a development of processes and procedures to arrive at storage site approval, rather than the adoption of rigid, prescriptive approaches. One Party noted that regulation plays a key role in ensuring that wells are properly designed, operated and closed and that appropriate construction materials which can resist CO_2 degradation are used (see para. 20 above).

57. Several submissions highlighted that useful work has been undertaken to develop enabling legal frameworks for CCS across the world, and suggested that these frameworks could provide useful models for enabling CCS in other countries. For example:

(a) **The European Union** (EU) has designed a draft legal framework with the aim of creating conditions for environmentally safe deployment of CCS. It contains means for including CCS within the EU emissions trading scheme;

(b) **The OSPAR and London Conventions** could be applicable to offshore CCS in the CDM, in particular the legally binding risk assessment frameworks recently adopted by the OSPAR Commission[19] and under the London Convention;

(c) In **Western Australia** liability transfer for the Gorgon Project[20] is being discussed between the project developer and the Western Australia Department of Industry and Natural Resources. In particular, the organization of issues into different project phases is suggested as a useful lesson to draw upon.

58. Several Parties and organizations suggested that the EU legal proposals and the OSPAR and London Convention proposals for CCS regulation all adopted the framework outlined in the 2006 IPCC Guidelines (see chapter IV E).

59. One organization was of the view that short-term liability may be the most complex area of CCS liability as it may involve joint and several liabilities being applied to multiple entities involved in a storage project, and therefore complicate the assignment of liability for any emissions. Such liability would need to be passed back to the Party receiving credit for the reduction in emissions. However, most submissions focused on long-term liability and argued that short-term liability is more straightforward.

60. It was suggested by one organization that all the approval mechanisms for CCS projects (i.e. assurances over site selection, permanence, monitoring, remediation and allocation of liability for third party damages and remediation in event of leakage) can be accommodated within the existing CDM approval framework (e.g. host country approval, validation, CDM-EB approval). On the other hand, two other submissions (by one Party and one organization) proposed that an international agency be established to oversee certain parts of the CCS approvals process (see para. 36 above).

61. CO_2 purity standards for injection and legal aspects thereof are covered in chapter III F above.

[19] The Commission of the Convention for the Protection of the Marine Environment of the North-East Atlantic.
[20] A planned CCS project where approximately 3.5 million tonnes of CO_2 will be injected below the seabed.

C. Projects in international waters and/or crossing national boundaries

62. This section should be considered in conjunction with chapter IV D above, as methodological approaches to project boundary issues are useful in shaping the way cross-border accounting for CO_2 may work in the context of CCS.

63. It was suggested by one Party that projects which cross national boundaries do not pose any additional challenges from a project boundary perspective, as the full life cycle emissions would need to be accounted for.

64. One Party mentioned that the 2006 IPCC Guidelines provide guidance on accounting responsibilities between countries involved with CCS projects, and that this could apply equally in the context of CDM project activities. The 2006 IPCC Guidelines offer the following guidance in this context:[21]

> "CO_2 captured in one country, Country A, and exported for storage in a different country, Country B. Under this scenario, Country A should report the amount of CO_2 captured, any emissions from transport and/or temporary storage that takes place, and the amount of CO_2 exported to Country B. Country B should report the amount of CO_2 imported, any emissions from transport and/or temporary storage, and any emissions from injection and geological storage sites.
>
> "If CO_2 is injected in one country, Country A, and travels from the storage site and leaks in a different country, Country B, Country A is responsible for reporting the emissions from the geological storage site. If such leakage is anticipated based on site characterization and modelling, Country A should make an arrangement with Country B to ensure that appropriate standards for long term storage and monitoring and/or estimation of emissions are applied (relevant regulatory bodies may have existing arrangements to address cross-border issues with regard to groundwater protection and/or oil and gas recovery).
>
> "If more than one country utilizes a common storage site, the country where the geological storage takes place is responsible for reporting emissions from that site. If the emissions occur outside of that country, they are still responsible for reporting those emissions as described above. In the case where a storage site occurs in more than one country, the countries concerned should make an arrangement whereby each reports an agreed fraction of the total emissions."

65. For reservoirs in international waters, one Party suggested that these should be considered in the context of applicable international laws relating to activities in international waters. The CDM need only focus on host country approval.

66. One organization suggested that in order to reduce complexity, initially projects should be allowed to take place only within national boundaries.

D. Long-term responsibility and liability for storage site monitoring and remediation

67. According to information provided by an organization, sources of liability include public health impacts, environmental and ecosystem impacts, and the contribution of leakage of CO_2 to climate change.

[21] "Reporting of cross-border CCS operations" in 2006 IPCC Guidelines, volume 2, chapter 5.

68. Options for handling long-term responsibility and liability – which also covers aspects of accounting options for long-term seepage as covered in chapter VI C below – as given in the submissions,[22] can be synthesized as follows:

(a) **Buyer/user country liability:** holders of the CERs from the CCS project activity (i.e. Parties included in Annex I to the Convention (Annex I Parties) using the CERs for compliance, or companies to which the liability may be transferred) would need to ensure full compensation for any seepage;

(b) **Seller/host country liability:** the country where the storage takes place would have the ultimate liability for the storage site and would need to ensure full compensation for any seepage;

(c) **Private entity liability:** this could include project owner liability or designated operational entity liability;

(d) **Application of a discount rate:** any future leakage would be taken into account for in the present day by reducing the number of credits given to developers;

(e) **Credit cancellation:** if there were significant leakage during the crediting period the project could be disqualified;[23]

(f) **Extending CDM crediting periods:** the period would be extended by up to 50 years, and the release of CERs would depend on monitoring results, with full release upon provision of evidence of long-term storage stability;[24]

(g) **Introducing long-term storage CER liability under common agreement:** this would involve preparation of a memorandum of understanding between interested parties whereby any leakage from storage sites in CDM projects would be compensated by purchases by Annex I Parties of CERs, assigned amount units or similar via a fund set up for that purpose.

69. Several organizations suggested that a “discount rate” model would not be possible as it requires a standard assumed rate of leakage by which to discount, and such rates are not presently available owing to a lack of empirical data from real storage sites. One organization stated that a “discount rate” model could not account for unexpected events or wilful releases, and if it did, would be so conservative that it would deter investors.

70. The majority of submissions supported the view that the ultimate liability for any long-term seepage emissions needs to be with the host country (i.e. the “seller/host country” liability model). Several reasons cited in support of this view. For example:

(a) The liability would lie with the party that is most able to ensure the operating conditions of the project, with the host country and project operator having control over the reservoir and any seepage emissions. The reservoir being under their control enables them to manage and mitigate risk;

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[22] One submission from an organization referred to the approach proposed in the IEA GHG report, which broadly follows these options.
[23] It should be noted that while this approach may provide an incentive for project developers to select only suitable storage sites, it may not address long-term liability issues, per se.
[24] Footnote 23 above also applies here.

(b) Because of the long-term nature of CCS (i.e. for millennia), practical perspectives dictate that post-project closure monitoring and remediation liability should be assumed by the host country.

71. Nevertheless, one Party and one organization indicated support for the “buyer/user country” liability model by suggesting:

(a) That the project developer or operator should take responsibility for leakage post completion;

(b) That over the long term, all Parties involved should take responsibility for leakage and remediation via consultation among involved Parties; the country which has gained credits from a CCS project should take financial responsibility (for monitoring, remediation and reporting);

(c) That risk must be removed from developing countries. The organization also suggested a potential role for novel forms of long-term financial bonds or insurance from the project developer in this context.

72. One Party proposed that, under the “seller/host country” liability model, insurance or establishment of funds to provide assurance over liability, monitoring and remediation could be a requirement. More generally, the same Party suggested that these funds could provide money to support remediation in the event that leakage is detected. Elsewhere, it was stressed that financial and organizational provisions must be in place to ensure the continuing viability of the storage operation beyond the crediting period. Several other Parties made various references to the use of insurance and/or bonds in managing liability. It was argued by one organization, however, that the full scope of the financial costs will be difficult to determine in advance, as remediation costs are not well known, and monitoring costs may increase as a CO_2 plume spreads out over a large area.

73. In terms of procedures for defining liability, one Party and two organizations referred to the IEA GHG report, which suggests that contingent liabilities associated with potential future emissions of stored CO_2 could be established. Such liabilities could be established either multilaterally via a standardized procedure developed within a CDM methodology, or bilaterally between developer and host country, through a local environmental impact assessment permit-issuing procedure. The same report also suggests that whatever the approach, a cap on these liabilities would be needed for the approach to be commercially workable. Several Parties supported this view by proposing that specific details defining liability could be worked out by each host country, in the same way as host countries presently define the sustainable development criteria for CDM project activities (see also para. 26 above). Such processes (e.g. environmental impact assessment or host country approval) are unlikely to be sufficient, according to one organization, because they are often carried out before the project starts, are time limited and often define impacts in terms of specific limits which are defined in other areas of legislation. There was support in several organizations’ submissions for the use of rules that define accountability for actual releases occurring, which should be defined by the liability regime applied to CCS through contracts, for example. However, these may all need to be defined as part of permit-issuing decisions.

74. A suggestion was made by one Party that liability arrangements could be modelled on existing legal systems (e.g. the Superfund approach applied to remediation contaminated sites in the United States of America), with project proponents being required to pay a host country to regulate the long-term monitoring and remediation for the site. The Party mentioned that greater detail on the legal issues affecting CO_2 storage is provided in an IEA/CSLF study.[25] Another submission drew an analogy with nuclear waste management (e.g. in Germany or the United States), under which governments take on

[25] IEA. 2007. *Legal Aspects of Storing CO_2: Update and Recommendations.* Paris: IEA.

some of the liability, but operators are required to take out private insurance and also contribute to an industry trust fund to cover liabilities up to the amount of the government liability cap.[26]

VI. Policy issues

A. Scope of chapter and links with other chapters

75. The following issues raised in decision 1/CMP.2 are relevant to this chapter on policy issues: accounting options for any long term seepage from reservoirs (para. 21 (e)); and long-term physical leakage (seepage) levels of risks and uncertainty (para. 21 (a)).

76. It is important to note that options for accounting for any long-term seepage should be considered in conjunction with issues presented by long-term responsibility for monitoring and remediation measures and long-term liability for storage sites as reviewed under chapter V D above. This is because decisions either by the CMP or at national level could have ramifications for long-term accounting by either:

(a) Coupling liability to CERs generated by a CCS project activity, via a policy decision on modalities and procedures for CCS accounting (e.g. by the CMP) that is based on the "buyer liability" model as described above (see para. 68 above). This would mean that an Annex I Party buyer of CERs would be liable for any emissions that occur; or

(b) Decoupling liability from CERs generated by a CCS project activity, via the creation of laws (e.g. at a national level) that define host country liability for stored CO_2 within its territory. This would mean that any emission that could occur would be the responsibility of the host country, and thus decoupled from the CERs.

77. Deciding on acceptable long term seepage risks and uncertainties and on what level of environmental impact could be tolerated is considered to be a policy issue (covered in chapter III F above), because these may need to be compared with the risk of not deploying CCS.

B. General points

78. One Party noted that climate change is linked with efforts in development and poverty reduction, observing that current patterns of energy supply and demand threaten to cause severe climate change. Changing this pattern through the use of existing technologies that make it possible for countries to move straight to a low-carbon economy is a must, and CCS is one of the technologies that could facilitate such a change. One organization argued that poverty reduction will require the full range of low-carbon technologies, including CCS. Frequent references were made to the work of the IPCC, the IEA *World Energy Outlook 2006* reference scenario, the Stern Review[27] and the IEA report *Energy Technology Perspectives 2006*: *Scenarios and Strategies to 2050*,[28] all of which highlight the vital role that CCS plays – second only to improving energy efficiency – in CO_2 mitigation; the *Stern Review* suggested that CCS could provide as much as 20 per cent of all reductions needed by 2050. One organization noted that an EU commitment to reduce GHG emissions by 20 per cent of 1990 levels by 2020 will only be possible with the application of CCS.

79. Several Parties and organizations expressed clear support for the inclusion of CCS in the CDM, contingent on the development of rules for its technically safe and environmentally sound deployment. Reasons given for supporting its inclusion were:

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[26] It also notes that liability must be capped, as no insurance company would be willing to bear the full costs.
[27] Stern N. 2007. *The Economics of Climate Change*: *The Stern Review*. Cambridge: Cambridge University Press.
[28] IEA. 2006. *Energy Technology Perspectives: Scenarios and Strategies to 2050*. Paris: IEA.

(a) That CCS is a critical bridge towards a low-carbon future as part of a portfolio of measures for confronting climate change, because of its large potential to reduce GHG emissions. Reference was made to the support in the SRCCS for this view,[29] and also the support in the SRCCS for the view that CCS is appropriate in both developed and developing countries in the twenty-first century. Some organizations suggested that CCS is complementary to policy measures for other technologies (e.g. renewable energy), rather than in conflict with them;

(b) That including CCS in the CDM would assist the development of the technology, its transfer to developing countries, and the availability and provision of financial flows needed for CCS in the mid- to long-term. All supportive Parties felt that inclusion of CCS in the CDM is critical to the transfer of CCS technology and expertise to developing countries. One Party noted that the report on the dialogue on long-term cooperative action to address climate change by enhancing implementation of the Convention[30] suggests that a significant proportion of additional CCS-related investment will be required in developing countries;

(c) That exclusion of CCS from the CDM might reduce storage potential and limit technology transfer to countries not included in Annex I to the Convention;[31]

(d) That CCS supports the objective of the Convention in delivering emission reductions at the lowest cost.

80. Several organizations and one Party argued against inclusion of CCS in the CDM. Their reasons included:

(a) That at present CCS is not yet a mitigation technology that is as safe and cost-efficient as renewable energy and energy efficiency projects, and as a consequence, inclusion in the CDM can only be an *additional* incentive to further develop and deploy CCS;

(b) That CCS does not contribute to sustainable development, and the long-term liability might contradict the sustainable development element of the CDM;

(c) That the cost of CCS is beyond the means of many developing countries;

(d) That CCS could divert investment away from energy efficiency and renewable energy;

(e) That CCS-enabled facilities require more fuel than non-CCS facilities, which is a barrier owing to energy security and supply efficiency concerns in many developing countries.

81. It was suggested by one Party that industrialized countries will need to take the lead on climate change mitigation, but given the size of the challenge and projected increases in emissions in developing countries, it is important that capacity to deploy low-carbon technologies including CCS on a commercial scale is developed within developing countries within the next decade.

82. An opposing organization gave the following preconditions for revising its view on the inclusion of CCS in the CDM: demonstration of CCS in developed countries (on a large scale); reconciliation of the 21-year crediting period and potential seepage horizons; development of legal systems; civil society

[29] See section 8.3.3, pages 352–359, and the Summary for Policy Makers, paragraph 19, page 12 of the SRCCS.
[30] FCCC/CP/2007/4 and Add.1.
[31] Based on analysis presented in: Bode S and Jung M. 2005. *Carbon Dioxide Capture and Storage (CCS) – liability for non-permanence under the UNFCCC.* HWWA Discussion Paper 325. Hamburg: Hamburg Institute of International Economics.

involvement; mandatory environmental impact assessment; evidence of sustainable development benefits; assessment of the effects of CCS inclusion in the CDM on emission reduction technologies in Organisation for Economic Co-operation and Development (OECD) countries; and clear portrayal of the role of CCS after 2012.

83. The suitability of the CDM in its present form was discussed in two submissions. One organization suggested that on the basis of the large cost of CCS projects, some form of modified (unspecified) clean development mechanism may be required in order to attract new forms of industry participation and enable technical assistance, which could appraise site licensing and assessment requirements. Another organization proposed that a more effective, less bureaucratic way of making CCS work in developing countries may be to create joint partnerships and/or bilateral government ventures. On the other hand, one Party believes that delaying a decision on the possible inclusion of CCS in the CDM is affecting its ability to contribute to achieving the objective of the Convention.

84. One organization predicted that the number of CERs from CCS projects under the CDM within the first commitment period of the Kyoto Protocol would be only a small fraction of the total CERs, as the revenues generated at the current price of CERs will be sufficient to fund only a small number of projects where costs are modest. Another organization shared this view, suggesting that the amount of money mobilized by the CDM is too small to have an impact on energy systems. Another organization noted the possible effects of CCS on the CDM market, suggesting that analogies with HFC-23 project activities are unwarranted as the technology applied in those cases was proven in OECD countries and was known to be cheap, whereas CCS is expensive and not yet fully developed. This organization suggested that, according to figures from the SRCCS, approximately 360 Mt CO_2 per year could be available for CCS from low-cost opportunities, such as natural gas sweetening, and in the same submission also provided another estimate of around 200 Mt CO_2 per year of emission reductions for less than USD 20 per tonne.

C. Accounting options for any long-term seepage

85. This section should be considered in conjunction with chapter V D regarding long-term responsibility and liability for storage site monitoring and remediation.

86. It was considered important by some Parties to ensure that CERs resulting from CCS project activities be considered permanent and fungible compared with CERs from other CDM project activities, underpinned by sound site selection and long-term monitoring. A view was expressed by one Party and one organization that the guiding principle for accounting rules for CCS project activities under the CDM should be consistency with current approaches under the Kyoto Protocol. These ensure that the actual effect of a project on the atmosphere is reflected in the number of Kyoto units issued and accounted over time. Based on this principle, one Party’s position is that it does not support the use of temporary CERs (tCERs) or long-term CERs (lCERs) for CCS project activities, indicating that these were specifically designed to deal with the issue of non-permanence by afforestation and reforestation (A/R) project activities. Most organizations felt that long-term leakage potential should not be handled through temporary crediting or discounting approaches, as seepage cannot be effectively predicted, even through computer simulation modelling (although such modelling can help). All agreed that good site characterization is fundamental to managing the risk of seepage.

87. One Party recommended that the question of liability should be resolved by a decision on long-term liability that extends the crediting and project period. Similarly, one organization suggested that as CCS has specific characteristics that distinguish it from other CDM project activities, it should have its own specific modalities and procedures, in the same way that A/R and small-scale project activities have. This should take account of the relative permanence of CCS reductions compared with, for example, A/R or fuel switching.

D. Levels of risk and uncertainty

88. A number of Parties indicated that the work undertaken to date has shown that geological CO_2 storage is technically proven under full-scale operation, and secure. Several of them cited a conclusion from the SRCCS that "the fraction of stored CO_2 retained in appropriately selected and managed geological reservoirs is very likely (a probability of 90-99%) to exceed 99% over 100 years, and is likely (a probability of 66-90%) to exceed 99% over 1000 years", and "that over 5000 years, all the CO_2 injected into the Weyburn Oil Field will dissolve or be converted to carbonate minerals within the storage formation", noting that in this case "the caprock and overlying formations have an even greater capacity for mineralization making it unavailable for leakage."

89. Several Parties clearly indicated that retention of CO_2 in geological storage sites is dependent on naturally occurring physical and geochemical trapping mechanisms, including structural trapping, hydrodynamic trapping and geochemical trapping (these issues are also described in the context of site selection, in chapter IV C above).

90. A submission from an organization noted that once CO_2 leaves a well and enters the subsurface formation, it is out of human control and characterized by a higher degree of uncertainty. According to this submission, the possibility that a reservoir might "leak" seems a certainty; the unknown element is the rate at which it might "leak". Another organization acknowledged the risk of leakage in the long term, but claimed that the risk would be mitigated by residual CO_2 trapping, solubility and mineral trapping.

91. An organization suggested that experience to date has been too little and monitoring too limited to permit direct empirical conclusions about the long-term performance of geological storage. One Party also reported that there is limited experience in, and uncertainty associated with, monitoring, verification and reporting, but noted also that work is under way to address these issues.

92. In contrast, it was suggested in another submission that although there are remaining unknowns, existing knowledge in the fields of site selection and characterization, risk assessment and management, and monitoring techniques is substantial. One organization suggested that the levels of risk presented by CCS projects are comparable with those of other projects already implemented under the CDM.

VII. Summary

93. On technical issues, there is broad agreement among Parties and organizations that:

(a) CCS is subject to four types of emissions: fugitive emissions; indirect emissions; seepage; and storage site breach, which can arise through a variety of potential leakage and seepage pathways;

(b) There is a need for both computer modelling, to understand and predict CO_2 behaviour and storage performance of the reservoir, and comprehensive monitoring, as an early warning system for impending seepage and to provide information on CO_2 movement.

94. Few comments were made relating to environmental impacts, although issues raised include the potential effects of leaking CO_2 on benthic organisms and considerations of CO_2 purity. One Party suggested that procedures set down in decision 3/CMP.1 should be sufficient for considering environmental impacts of CCS project activities under the CDM.

95. On methodological issues, there is broad agreement among Parties and organizations that:

(a) Flexibility is required to allow for improvements in the knowledge of and experience in CCS, and to accommodate different geological conditions with distinct storage characteristics;

(b) Project boundaries would be defined by the emissions sources, as described in the context of emissions sources and potential leakage pathways;

(c) Factors for site selection include depth; the vertical and lateral extent of the formation(s); the physical and chemical nature of the geological trapping mechanisms; the homogeneity, heterogeneity, permeability, fluid migration rate and storage volume of the formation; geological stability; and local environmental conditions;

(d) Steps for site selection include detailed site characterization; assessment of the effects of injecting CO_2 in the formation; assessment and analysis of possible leakage pathways; assessment of the sensitivity of the local environment; and consideration of neighbouring countries;

(e) Site characterization and selection are the most critical elements in ensuring long-term or permanent CO_2 emission reductions from CCS, and should provide the basis for ensuring that fugitive emissions, seepage or storage site breach are unlikely to occur. Thus, the main objective of site characterization is to identify the ability of the geological formation to structurally, physically or chemically trap CO_2;

(f) Short- and long-term computer modelling can provide the basis for collecting relevant information on factors and steps for selecting a site, and in order to facilitate decisions regarding site selection and approvals, the CDM-EB could develop such procedures;

(g) There is a strong link between site characterization and monitoring, and a monitoring programme should be used to verify whether the site is performing as forecast in computer modelling. The results of monitoring should be used to recalibrate any models applied and to further assist in the identification of seepage, updated in the light of new findings from monitoring;

(h) The 2006 IPCC Guidelines outline a suitable approach to site characterization.

96. On legal issues, there is broad agreement among Parties and organizations that:

(a) Site selection is critical and needs rigorous and consistent application of procedures, irrespective of project location;

(b) Some sort of fund, insurance or financial bonds could be used to support liability arrangements and longer term monitoring and remediation costs;

(c) Some comments were made in respect of projects which cross national boundaries, although it was suggested that crossing natural boundaries does not pose any additional challenges from a project boundary perspective as the full life cycle emissions would need to be accounted for. It was also mentioned that the 2006 IPCC Guidelines provides guidance on accounting responsibilities between countries involved with CCS projects.

97. Conflicting views on legal issues were apparent among Parties and organizations on:

(a) Whether a national regulatory regime for CCS should be a prerequisite for CCS project activities in a host country, or whether implementing CCS in the CDM could contribute to the development of legal systems by countries concerned with a particular project;

(b) Whether short-term liability or long-term liability is the more complex;

(c) Whether ultimate liability for any long-term seepage emissions needs to be with the host country (i.e. the “seller/host country” liability model) or with the holder of CERs generated by a CCS project (i.e. the “buyer/user country” liability model). More Parties and organizations were supportive of the former than of the latter. No strong views on the other options were expressed in submissions;

(d) Whether specific details of liability arrangements could be defined by each host country in the same way that host countries presently define sustainable development criteria for CDM project activities, or whether such a process would be insufficient.

98. On policy issues, there is broad agreement among Parties and organizations that:

(a) In respect of accounting, CERs resulting from CCS project activities should be considered as permanent and fungible compared with CERs from other project activities, underpinned by sound site selection and long-term monitoring;

(b) “Discounting” approaches are not a suitable way of handling long-term seepage.

99. Conflicting views were apparent among Parties and organizations on whether CCS should be included in the CDM. The following reasons were given in favour:

(a) CCS is a critical bridge towards a low-carbon future as part of a portfolio of measures;

(b) CCS would provide an important contribution to the development of the technology and its transfer to developing countries;

(c) Exclusion of CCS might reduce storage potential and limit technology transfer to non-Annex I countries;

(d) CCS supports the objective of the Convention in delivering emission reductions at the lowest cost.

100. The following reasons were given against including CCS in the CDM:

(a) CCS is not yet a mitigation technology that is as safe and cost-efficient as renewable energy and energy efficiency;

(b) CCS does not contribute to sustainable development, and the long-term liability might contradict the sustainable development element of the CDM;

(c) The cost of CCS is beyond the means of many developing countries;

(d) CCS could divert investment away from renewable energy and energy efficiency and energy security concerns.

101. A number of other divergent comments are made by Parties and organizations including that:

(a) Industrialized countries need to take the lead in developing climate change mitigation policy;

(b) It is important that capacity to deploy low-carbon technologies, including CCS on a commercial scale, is developed within developing countries during the next decade;

(c) A modified (unspecified) clean development mechanism may be required in order to attract new forms of industry participation;

(d) Delaying a decision on whether to include CCS in the CDM is affecting some Parties' ability to contribute to achieving the objective of the Convention;

(e) The expected number of CERs from CCS projects under the CDM within the first commitment period of the Kyoto Protocol would be only a small fraction of the total CERs, as the revenues generated at the current CER price will be sufficient to fund only a small number of projects where costs are modest.

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