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Subsidiary Body for Scientific and Technological Advice

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Item X of the provisional agenda

Views on carbon dioxide capture and storage in geological formations as clean development mechanism project activities

Submissions from Parties

1. The Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol, by its decision 7/CMP.6, paragraph 4, invited Parties to submit to the secretariat, by 21 February 2011, their views on how the issues referred to in paragraph 3 of that decision can be addressed in the modalities and procedures referred to in paragraph 2 of the same decision.

2. The secretariat has received ten such submissions from Parties. In accordance with the procedure for miscellaneous documents, these submissions are attached and reproduced* in the language in which they were received and without formal editing.

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* These submissions have been electronically imported in order to make them available on electronic systems, including the World Wide Web. The secretariat has made every effort to ensure the correct reproduction of the texts as submitted.

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* This submission is supported by Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro, Serbia and Turkey.

** Party to the Convention and observer State to the Kyoto Protocol.

Paper no. 1: Australia

Submission under the Cancun Agreements | February 2011

Modalities and procedures for carbon dioxide capture and storage in geological formations as Clean Development Mechanism project activities | SBSTA

I. Overview

This submission contains the views of the Australian Government on the elaboration of modalities and procedures for carbon dioxide and storage (CCS) in geological formation as project activities under the Clean Development Mechanism (CDM), as requested under paragraph 4 of Decision -/CMP.6 on *Carbon dioxide capture and storage in geological formations as clean development mechanism project activities* (the Cancun CCS Decision).

Australia welcomes the inclusion of CCS as an eligible project activity under the CDM, and the opportunity to submit its views to the Subsidiary Body for Scientific and Technological Advice (SBSTA). Australia also draws attention to its previous submissions on CCS in the CDM.[1] In overview, Australia considers:

- There are sufficient established technical and scientific data and analysis, methods and expert advice to address the issues identified in paragraph 29 of Decision 2/CMP.5.
- The elaboration of modalities and procedures for CCS project activities requires consideration as to whether existing CDM modalities and procedures are sufficient, or the extent to which additional modalities and procedures are needed to accommodate CCS project activities.
- CCS project activities will be unique in some respects and therefore will require tailored modalities and procedures including specific requirements relating to: host Party governance; site selection and operation; accounting for potential non-permanence; transboundary seepage paths and potential impacts; and proper accreditation for designated operational entities (DOEs).

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[1] FCCC/SBSTA/2010/MISC.2; FCCC/SBSTA/2009/MISC.11; <http://climatechange.gov.au/en/government/initiatives/unfccc/~/media/submissions/international/ccs-as-cdm-project-activities.ashx>.

II. Benefits of CCS Project Activities

Australia emphasises the importance of CCS as a mitigation strategy for greenhouse gas emissions. It reiterates the International Energy Agency's (IEA) *Energy Perspectives Report*,[2] which concluded that CCS will need to contribute one-fifth of the necessary emissions reduction to achieve stabilisation in the most cost-effective manner.

Australia has also referred to the IEA's *Technology Roadmap: Carbon Capture and Storage*,[3] which identified that CCS projects must be funded from carbon market mechanisms to provide sufficient incentives for the innovation and diffusion of CCS technologies in developing countries.

CCS project activities will provide an important financial incentive that will assist to offset the incremental cost for developing countries wishing to deploy this technology. While large-scale deployment in developing countries is still expected to be some time away, CCS project activities will provide potential investors with improved certainty for long-term and large-scale CCS projects.

Australia recognises that the CDM is technology-neutral and that modalities and procedures for CCS project activities will support developing countries' access to technologies consistent with their preferred development path. It will also provide developing countries access to the economic incentives that are available for other emission abatement technologies.

III. Elaborating modalities and procedures

Australia advocates a pragmatic approach for elaborating modalities and procedures for CCS project activities in the CDM. It considers that the existing CDM modalities and procedures should apply to CCS project activities where appropriate.

Australia reiterates the view that there are sufficient established technical and scientific data and analysis, methods and expert advice to address the issues identified in paragraph 29 of Decision 2/CMP.5. SBSTA should assess existing modalities and procedures to determine whether existing CDM modalities and procedures are sufficient to accommodate CCS project activities, or the extent to which additional provisions are required. This will include assessments of:

- definitions;
- the role of the Conference of the Parties serving as the meeting of the Parties;
- accreditation and designation of DOEs;
- the role of DOEs;
- participation requirements;
- validation and project registration;

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[2] IEA, *Energy Technology Perspectives* (2008), <http://www.iea.org/techno/etp/index.asp>.
[3] IEA, *Technology Roadmap: Carbon Capture and Storage* (2009), <http://www.iea.org/papers/2009/CCS_Roadmap.pdf>, p.35.

- monitoring during project operation and following project closure;
- verification and certification; and
- means to address the risk of non-permanence of carbon dioxide.

Australia recognises that CCS project activities will be unique in some respects to other CDM project activities. CCS project activities may therefore require tailored CDM modalities and procedures. Nonetheless, Australia considers that the issues raised in paragraph 3 of the Cancun CCS Decision can be adequately addressed by including specific requirements for CCS project activities.

The remaining sections of this submission outline Australia's position on the specific requirements relating to CCS project activities. Australia considers that SBSTA should move quickly to draft modalities and procedures to enable a decision to be taken at COP 17. The primary objective of the technical workshop should be to develop near final draft modalities and procedures for CCS project activities.

IV. Host Party governance

Key to the effective deployment of CCS project activities will be the establishment of relevant governance arrangements in the host Party. Australia considers that the modalities and procedures for CCS project activities should require the host Party to design and implement appropriate regulatory and governance arrangements for the deployment of CCS technologies and ensure that CCS project activities comply with these.

These requirements could be incorporated into host Party participation requirements; and the validation and registration procedure. In practice, the Host Party could indicate in the letter of approval that the project was compliant with their domestic regulations.

SBSTA may wish to elaborate upon necessary requirements for host Party regulatory and governance arrangements. This may help to identify whether a host country has established a governance framework, and that there are effective resources employed in the host country to promote compliance with the governance framework. However, Australia emphasises that CDM modalities and procedures should not seek to replace or prescribe law in host Parties. Australia respects the national sovereignty and territorial integrity of all Parties to the Convention and recognises the prerogative of all Parties to design and implement policies that are most effectively tailored to their national circumstances.

Australia expects that the Host Party regulatory regime will provide for the approval and oversight of the operation of the project, including covering the construction and operation of the capture plant, transport system and storage operation, safe sealing and abandonment of the reservoir, environmental and social impacts of the project, health and safety, property rights and systems for assigning liability. Australia recognises the need for capacity building in developing countries to facilitate the design and implementation of appropriate governance procedures.

Australia further considers that the issue of the determination and apportionment of liability for damage caused by a CCS CDM project should also be a matter for the domestic law of the host Party. The laws that will apply in the event of damage caused by a CCS project activity will in most cases be the body of law already existing in the host country.

It may be impractical to prescribe the detailed requirements of a liability regime at the international level, as the extent to which this can be implemented in practice will depend on the legal system in the host country. Therefore, in response to paragraph 3(m) of the Cancun CCS Decision, Australia considers that host Parties should examine the extent to which their domestic laws can be applied to effectively apportion liability between CCS project participants, and create new laws, if necessary.

Similarly, many countries have implemented environmental legislation establishing mechanisms for remediation of environmental damage resulting from industrial activities. Therefore, Australia considers that the provision for restoration of damaged ecosystems and full compensation for communities affected by a release of carbon dioxide from CCS project activities, within paragraph 3(o) of the Cancun CCS Decision, should be treated in the same way as other large-scale industrial activities, under national or local laws, as appropriate.

V. Site selection and operation

Australia recognises the importance of good site selection and operation of CCS project activities. Australia considers that the geological storage site selection must be made with the objective of permanent storage of the carbon dioxide injected.

The modalities and procedures for CCS project activities should include site selection criteria. Site selection criteria for CCS project activities could be addressed through specific validation and registration requirements in the CDM. In recognition of the unique geological circumstances of each storage site, Australia notes that different technical factors will have to be considered in each case. As a result, the site selection criteria should be objective-based, rather than prescriptive in nature.

Australia also considers that the geological storage site selection should not be undertaken in isolation from the operation plan specific to that site. Good site management is integral to the permanence of storage, and will require ongoing monitoring and reporting of site operations. Therefore, Australia considers that all project participants and host Parties should implement a site management plan. This plan should identify procedures for addressing identified risks, including for safe sealing and abandonment of the reservoir.

Australia considers that the project design document for CCS activities will need to adequately cover all aspects of the project activity, including site selection, risk analysis, storage site operation plan, a plan for monitoring the behaviour of the stored carbon dioxide, and a monitoring and measuring plan to account for carbon dioxide captured, transported, injected and stored or emitted, noting that all these aspects need to be fully integrated at the design stage.

A comprehensive risk assessment of potential CCS storage sites and operations should be undertaken prior to the deployment of a CCS project. It should identify risks together with possible consequences. This could be incorporated into the CDM through additional validation and registration requirements. Australia notes that the International Standards Organization has developed standards for risk management,[4] and

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[4] ISO 31000:2009

considers that these could provide basic methodologies for risk analysis. Australia further recognises that risk assessment should be an ongoing activity of CCS deployment, and fully integrated with storage site selection, proposed site management, and monitoring.

Tailored requirements during the monitoring procedure could provide for project participants to continually monitor storage operations against the site management plan for the duration of the CCS project activity. While agreeing that reservoir pressure should be continuously measured, there are a range of other factors relevant to the measurement of the stored substance, which may vary in applicability from site to site. Australia considers that the decision on the appropriate monitoring methods to be used should be integral with the storage site selection and the management plan.

Additional provisions could require project proponents to adapt their site management plans in response to the observed behaviour of the stored carbon dioxide. While such monitoring programs will be site-specific, they should be designed to detect any incidents of non-permanence or deviations from predicted behaviour in the reservoir in a timely fashion. Design of a storage site monitoring plan should also have due regard to the risk profile of that site. The monitoring plan should be subject to periodic review.

Following completion of the injection phase of the project, host Parties could be required to monitor the storage site against a longer-term management plan. In particular, Australia emphasises long-term monitoring for potential non-permanence, which must reflect risks on a project-by-project basis. This would continue until evidence demonstrates that the site has achieved long-term stability. Australia considers that it will be necessary for CDM modalities and procedures to reflect that such monitoring must extend to the period following the injection phase of storage operations. The DOE could then verify the accuracy of these monitoring reports.

Consistent with existing CDM modalities and procedures it will be essential that project proponents define the project boundary. Currently this is a requirement within the validation and registration process. SBSTA may like to consider the appropriate definition of the boundary. Australia considers that the boundary should include all above-ground and underground installations and storage sites, as well as potential sources of carbon dioxide that can be released into the atmosphere, involved in the capture, treatment, transportation, injection and storage of carbon dioxide, and any potential migratory pathways of the carbon dioxide plume, including any pathways resulting from dissolution of carbon dioxide in underground water or other fluids.[5]

Australia considers, in response to paragraph 3(n)(ii) of the Cancun CCS Decision, that multiple project proponents should not be permitted to share the same storage reservoir where there is any prospect of adverse consequences from this interaction. However, carbon dioxide from multiple sources may be stored in a single storage operation. Should a proportion of this stored carbon dioxide emanate from non-CDM accredited projects, then the emissions must be allocated in advance between the accredited and non-accredited projects.

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[5] Decision 3/CMP.1, Annex, para. 52; *CDM-PDD*, <http://cdm.unfccc.int/Reference/PDDs_Forms/PDDs/PDD_form04_v03_2.pdf>.

VI. Accounting for potential non-permanence

Australia recognises the risk of non-permanence of emission reductions from CCS project activities due to the potential for seepage. It reiterates that the risk of leakage in well-selected sites with appropriate site selection and operation is very low.[6]

Nonetheless, Australia considers that SBSTA should recommend modalities and procedures to account for the potential for non-permanence of emissions reductions from CCS project activities. It emphasises that any release of carbon dioxide from the project boundaries must be monitored and accounted for, including over the longer-term.

Australia is open to further consideration of all options that will promote environmentally effective and efficient abatement through CCS technologies. It notes that the International Energy Agency (IEA)[7] and an expert report prepared for the CDM Executive Board[8] have canvassed options to address non-permanence. Australia has referred to a number of these options in its submission to SBSTA 32.[9] Existing CDM rules require that certified emissions reductions (CERs) resulting from a project activity be calculated after adjusting for leakage.[10] The requirement for project participants to monitor removals and reversals during the issuance of CERs is also standard practice in certain CDM project activities.[11] It may be useful to establish similar requirements for CCS project activities.

Following project closure, host Parties of CCS project activities would need to monitor the site for potential reversal of emissions reductions, that is, seepage. Measures would need to be put in place to account for those emissions to ensure the ongoing permanence of issued CERs from the CCS project activity.

Australia reiterates that there are a number of potential options that could be considered. For example, a discount factor could be applied at issuance so that a proportion of CERs are not issued, accounting for any future reversal. Alternatively a proportion of CERS could be surrendered to a ‘confidence buffer’ at the time of issuance and retired in the event of future seepage. These options would require that the possibility or risk of seepage be assessed and adjusted over time, as the monitoring results would provide confidence of permanence over time.

Measures to address potential non-permanence would require specific modalities and procedures. These could be included as specific requirements during the issuance of CERs. Further requirements would be needed to operationalise any ‘confidence buffer’. Consideration would also need to be given to surplus units held that were generated by storage sites that have achieved long-term stability.

Australia further submits that uncertainty in accurately quantifying non-permanence can be reduced by ensuring adequate and accurate collection of baseline environmental data. This includes the carbon dioxide content of the atmosphere, soil and water in the vicinity of the storage site. Combined with effective monitoring of the behaviour of stored carbon dioxide, this data will provide the most effective basis for

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[6] FCCC/SBSTA/2010/MISC.2, pp. 6-7.

[7] IEA, *CO_2 Capture and Storage – A key carbon abatement option* (2008).

[8] <http://cdm.unfccc.int/EB/049/eb49annagan4.pdf>.

[9] Above n 6, pp. 7-9.

[10] Decision 3/CMP.1, para. 59, 62(f).

[11] Decision 5/CMP.1.

addressing uncertainties in quantifying leakage from the storage site. This data should also be an integral part of the storage site management plan.

VII. Potential transboundary impacts

Australia recognises the possibility of transboundary seepage or leakage of carbon dioxide from CCS project activities. Host Parties would need to identify and establish appropriate arrangements to ensure that project proponents address any transboundary seepage paths and potential impacts are addressed in accordance with applicable international obligations. Australia notes that existing CDM modalities and procedures require project participants to submit documentation relevant to transboundary impacts, and if deemed significant, undertake an environmental impact assessment according to the laws of the host Party.[12]

Nonetheless, it may be necessary for Parties to agree additional validation and registration requirements for CCS project activities. Australia considers modalities and procedures for CCS CDM projects approval procedures should require host countries to, *inter alia:*

- establish governance arrangements for the deployment of carbon dioxide capture and storage;
- establish measures to identify and address any trans-boundary seepage paths and/or potential impacts; and
- declare that, where trans-boundaries issues exist, the measures to address the issues have been agreed with all countries concerned consistent with applicable international obligations.

VIII. Designated operational entities

Australia considers that DOEs be properly accredited to validate and verify CCS project activities. It may be appropriate for SBSTA to elaborate upon additional requirements for the accreditation and designation of DOEs involved in CCS project activities.

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[12] Decision 3/CMP.1, para. 37(c).

Paper no. 2: Grenada on behalf of the Alliance of Small Island States (AOSIS)

Submission by Grenada on behalf of the Alliance of Small Island States (AOSIS)

Views On Matters Relating To The Use Of Carbon Capture And Storage In Geological Formations As Clean Development Mechanism Project Activities.

February 2011

Grenada welcomes the opportunity to present the views of the 43 member States of the Alliance of Small Island States (AOSIS), in response to the invitation to Parties to submit to the Secretariat, their views relating to the use of carbon capture and storage in geological formations as Clean Development Mechanism project activities in response to paragraph 4 of decision -/CMP.6, taken at CMP.6.

Decision -/CMP.6 "Recogniz[ed] that Parties have registered concerns regarding the implications of the possible inclusion of carbon dioxide capture and storage in geological formations as clean development mechanism project activities and have highlighted issues which need to be addressed and resolved in the design and implementation of carbon dioxide capture and storage in geological formations, in order for these activities to be considered within the scope of the clean development mechanism."

The CMP requested SBSTA to develop modalities and procedures for inclusion of carbon dioxide capture and storage in geological formations as clean development mechanism activities with a view to recommending a decision to the CMP at its seventh session. These modalities and procedures should address the unresolved issues referred to in 2/CMP.5. These unresolved issues include, inter alia,

a. Non-permanence, including long-term permanence;
b. Measuring, reporting and verification;
c. Environmental impacts;
d. Project activity boundaries;
e. International law;
f. Liability;
g. The potential for perverse outcomes;
h. Safety;
i. Insurance coverage and compensation for damages caused due to seepage or leakage;

AOSIS recognises the potential of CCS technology as part of the global mitigation effort to keep the average increase in global temperatures to less than 1.5°C above pre-industrial levels. However, AOSIS has been consistent in emphasizing that offsetting mechanisms do not contribute to global emission reductions, and therefore inclusion of CCS in the CDM would remove the mitigation benefit of this technology completely, in the absence of equivalently-deeper, legally-binding quantified emission reduction commitments by Annex I Parties to the Kyoto Protocol.

AOSIS has also been consistent in its view that eligibility of CCS as a CDM activity is conditional upon the resolution of several legal, technical and environmental issues. The SBSTA has been requested to address these unresolved issues that are summarised in decision 2/CMP5.

Eligibility Criteria: At CMP.6 in Cancun, the Parties confirmed a principle that AOSIS has always maintained – all technologies are NOT automatically eligible as CDM activities. There are criteria or provisos that must be met before eligibility is granted. This confirmation is clearly reflected in the first paragraph after the preamble:

1. *"Decides* that carbon dioxide capture and storage in geological formations is eligible as project activities under the clean development mechanism, provided that the issues identified in decision 2/CMP.5, paragraph 29, are addressed and resolved in a satisfactory manner;"

Perverse Outcomes: In the preamble of the CMP.6 decision, the issue of perverse outcomes is addressed as follows:

"Emphasizing that the inclusion of carbon dioxide capture and storage project activities in geological formations in the clean development mechanism should not provide perverse outcomes"

AOSIS submits that the issue of perverse outcomes would need to be explicitly addressed in any CCS modalities and procedures to be outlined by SBSTA. There are at least four examples of how CCS as a CDM activity may potentially lead to more GHG emissions than would have occurred under the baseline scenario to provide the same level of service.

a. CCS technology requires that greater than 15% of the energy produced from the combustion of the fossil fuel is required to capture, transport and store the CO2. As a result, A CCS plant will be required to burn >15% additional fuel to provide the same level of service as a conventional plant.
b. If CCS were used in combination with Enhanced Oil Recovery (EOR), the potential emissions from the additional hydrocarbons brought to the surface would need to be accounted. These tonnes also represent an additional source of revenue, which would need to be taken into consideration in any analysis of additionality.
c. Investments in CCS technology that are linked to coal-fired or gas-fired power generation represent long-term investments not made in renewable energy production or energy efficiency measures, which increases dependency on fossil fuels.
d. Use of storage capacity for CCS combined with fossil-fuel technology reduces the remaining storage capacity available for combining CCS with modern BioEnergy (BECCS). As confirmed by the UNEP Emissions Gap report in 2010, large-scale application of BECCS technology is required to achieve global net-negative CO2 emissions in the latter half of the 21st century, which in turn is crucial for achieving a 1.5°C temperature target (and even a 2°C target), unless deep and immediate emission cuts are achieved before 2020.

AOSIS is of the opinion that these potentially perverse outcomes can be addressed by stipulations in the modalities and procedures. First, to require that the project developer compensate for the additional energy usage to provide the same service (same electrical energy to the grid) by incorporating the use of renewable energy or energy efficiency measures within the same project boundary. To ensure the environmental integrity of any CERs, the scale of this additional energy usage would have to be monitored on a project-project basis, and monitored and verified during the course of project activities. These calculations would to be conservative, erring on the side of over-compensating for this excess energy usage.

For example, if a 1000 MW CCS plant were planned to be built with only 800 MW to be exported and 200 MW used to capture, transport and store the CO_2 and the developer wished to register the plant as a CDM activity; then he would need to incorporate a renewable energy project or energy efficiency interventions (generation or distribution) to "recover" the lost 200 MW. Second, if EOR were to be used in conjunction with the CDM project activity, the GHG emissions of all downstream activities from the recovered hydrocarbons would have to be accounted for in the prescribed methodology.

It is AOSIS' view that perverse incentives should be discouraged by making the eligibility for participation by Annex I (AI) Parties in activities relating to CCS in the CDM conditional on their meeting a defined percentage of their commitments domestically. For unilateral CDM projects in non-Annex 1 (NAI) countries, part of the proceeds from the sale of CERs arising from CCS projects, additional to the 2% that goes to the Adaptation Fund, should be used for funding the development of renewable and energy efficiency projects in those and other developing countries as part of the eligibility criteria. Additionally, a further part from all CCS projects in the CDM should be dedicated to funding climate insurance for small island developing states given their vulnerability. The limitation of reservoirs to depleted oil wells might also address certain perverse incentives.

Site selection and monitoring plan criteria: It is noted that section 3(d) of the CMP.6 decision requires CMP approval of the site selection and monitoring plan criteria recommended by SBSTA. The preamble for decision CMP.6 states:

"*Emphasizing* that the deployment of carbon dioxide capture and storage in geological formations shall be environmentally safe and shall have as an objective the avoidance of any seepage,"

AOSIS notes the use of the words "*shall*" and "*any*" in the above quote and regard this clause in the preamble as setting the standard for site selection and monitoring plan criteria.

AOSIS recognizes that the site selection is one of the most critical and important aspects that will determine the feasibility of a project activity. Therefore, it is of utmost importance that addressing this area be given one of the highest priorities.

Short, medium and long-term liability: It is noted that there is no quantitative definition of short, medium and long-term liability in the decision text. AOSIS is of the view that long-term for CCS in geological formations should be in the context of geological time.

Further, the issue of liability ought to be placed in the context of the benefits to be derived by Annex I parties from activities giving rise to any ensuing risk and should be an underlying principle of CCS projects in the CDM. Accordingly, AOSIS is of the firm view that given the technical, technological and financial resources of Annex I parties, any liability arising from CCS projects should be vested in the respective Annex I party or entity investing in such projects.

Related issues for discussion include the appropriate placement and channelling of liability to private and public actors in the event of seepage or accidental release (to the Annex I project proponent, Annex I investor government, or CER purchaser?), responsibility for remediation in the event of seepage or accidental release in the pre- and post-closure phases, and responsibility for site closure, post-closure monitoring and post-closure releases (Annex I project proponent, Annex I investor government, or CER purchaser?). Consideration might be given to whether an international law framework should be developed to address the unique liability issues raised by the possible inclusion of CCS in the CDM, given the implications that possible CO2 releases in host countries have for the international accounting system, in the absence of developing country emission reduction commitments.

Legal and regulatory frameworks: SBSTA should also consider the scope of the legal and regulatory frameworks required to be in place in host countries to account for, monitor and report emissions captured and stored. Because seepage and accidental releases will undermine the environmental integrity of the CDM if not all emissions are reported and accounted for, host country frameworks should be as stringent in these areas as developed country obligations for CCS monitoring and reporting.

International Law: Other legal issues that warrant discussion and resolution include the relationship of CO2 capture, transport and storage to other international law frameworks, including, among others, those addressing: waste transport and management; marine pollution; transport and liability; access to information, public participation and access to justice; water; liability for transboundary impacts; and nature conservation. Many developing country Parties are party to international law frameworks in these areas and it is important that any projects are consistent with both domestic legislation and relevant international law.

Use of modelling vs. direct measurement: Section 3(c) of the decision refers specifically to the limitation of using models. Section 3(g) also requires measurement of any CO2 releases from the project boundary rather than the use of models to estimate seepage. AOSIS also notes the requirement for CERs to be real, measurable and verifiable and re-emphasises that whilst modelling can be supplemental, it should not be allowed in the modalities and procedures to be used as the primary or only means of quantifying emission reductions and/or seepage (including the potential dissolution of C02 in underground water).

Insurance/financial security: SBSTA should detail the nature, and form of financial security required to be held to cover all obligations and liabilities, including remediation of any seepage and accidental releases during capture, transport and storage, closure and post-closure requirements and post-closure monitoring requirements.

Transboundary CCS projects & shared reservoirs: SBSTA has been requested to consider the appropriateness of transboundary CCS projects and the potential use of a geological reservoir by more than one project proponent. See paragraphs 3(h) and 3(n)(ii). AOSIS is of the view that the following elements would be needed for consideration of transboundary CCS projects, among others:

- Any CDM project boundary would have to encompass all countries with the shared reservoir. DNA approval, access for verification of monitoring plans etc from both countries would be required.

- Procedures would have to be in place for verification of the amount of CO2 stored and for remediating seepage and any accidental releases where a reservoir is shared by more than one developer (CDM or non-CDM) or more than one country.
- Legal and regulatory regimes would have to be in place in both countries, addressing CCS project environmental impact assessments, risk assessments, responsibility for accounting and monitoring, responsibility for site closure, post-closure monitoring, and the maintenance of financial security to address these issues.

Required skill sets of any consultants: AOSIS recognises that SBSTA may seek to request the secretariat to assist it in preparing possible recommendations to the CMP. AOSIS respectfully suggests that the following diverse knowledge and experience skill sets would be required of any consultants engaged for such purpose;

- How the CDM operates in particular methodology development.
- CCS technology.
- International law frameworks relevant to CCS activities, as well as those relating to: waste management, marine pollution, climate change; transport and liability; access to information; public participation and access to justice; water; liability for transboundary impacts; and nature conservation.
- Options for the assignment and channelling of liability to public and private actors.
- Risk assessments, including the modelling of potential climactic impacts from the massive and catastrophic release of CO2.
- Geology, hydrogeology and seismology.
- Public health
- Aquatic and terrestrial ecosystem management
- Social and environmental impact analysis

It is unlikely that such skill sets will be found in one individual or company. Therefore, it is respectfully suggested that if any procurement process takes place, the terms of reference for the consultancy is divided into components (e.g. legal, engineering, environmental) and separate consultants hired to address the individual components.

Impacts on the market: At a time when the international community is challenged in establishing a sufficiently robust market price to induce investment in low-carbon technologies, it would be counter-productive to flood the market with inexpensive carbon credits. Therefore, in considering the possible inclusion of CCS project activities in the CDM, a study should be undertaken on the potential scale of CERs that might be produced, and their impact on carbon pricing. Because an additional concern with the inclusion of CCS in the CDM is the possible diversion of these investment funds from renewable energy and energy efficiency projects, this study might also consider the impact of investments in CCs in this regard, with and without the incentive of CERs from inclusion in the CDM.

AOSIS views the resolution of this issue in the context of the role that it can play in allowing Parties to undertake deeper, more ambitious emission reductions in order to ensure that temperature increases are kept as close as possible to 1.5 degrees Celsius. Therefore, the members states are ready to do all that they can to assist the SBSTA in this regard.

Paper no. 3: Hungary on behalf of the European Union and its member States

Submission by Hungary and the European Commission on behalf of the European Union and its Member States

This submission is supported by Albania, Bosnia and Herzegovina, Croatia, the Former Yugoslav Republic of Macedonia, Montenegro, Serbia and Turkey.

Budapest, 15 February 2011

Subject: **Carbon dioxide capture and storage in geological formations as clean development mechanism project activities (SBSTA)**

Submission from Parties - on views on how different issues can be addressed in modalities and procedures

1. At COP/MOP 6 in Cancun, draft Decision -/CMP.6 invited Parties to make submissions to the secretariat, by 21 February 2011, on views on how different issues (referred in paragraph 3 of this decision) regarding carbon dioxide capture and storage (CCS) in geological formations as clean development mechanism (CDM) project activities can be addressed in modalities and procedures. The EU welcomes the opportunity to submit its views on this important issue and looks forward to discussions at SBSTA 34 and COP/MOP 7.

2. This submission should be considered in conjunction with our previous submissions, most recently that of March 2010.

3. The CCS in CDM should not serve as an incentive to increase the share of fossil fuel power plants in the host countries. Its development should not lead to a reduction of efforts to support energy saving policies, renewable energies and other safe and sustainable low carbon technologies, both in research and financial terms. In particular, as CCS is an end-of-pipe technology, it should ensure that downstream technologies (eg: boilers) are applying the best technologies available or at least that the crediting baselines are set at this BAT level. Any risk for the human health and the environment resulting from CCS should be avoided.As the EU places high priority on environmental integrity and safety the assessment of CCS in CDM project activities should be done in a conservative manner, reflecting the specificities of such activities. The following sections elaborate the basis of a set of comprehensive and stringent modalities and procedures against which the Executive Board (EB) assesses that proposals for CDM project activities involving CCS adequately address specific issues referred in draft Decision -/CMP.6.

4. A suitable national obligatory and regulatory framework for the environmentally safe capture, transport and geological storage of CO2 should be established before the CCS project can be implemented in the host country. The purpose of environmentally safe geological

storage of CO2 is permanent containment of CO2 to prevent and, where this is not possible, eliminate as far as possible negative effects and any risk to the environment and human health. The obligatory and regulatory framework needs to contain a permitting system for storage site operators. It should be ensured that no site is operated without such permit and there is only one operator for each storage site. Such permit should at least contain the name and address of the operator, proof of the technical competence of the potential operator, the precise location and delimitation of the storage site and storage complex, the requirements for storage operation, the total quantity of CO2 authorised to be geologically stored, the reservoir pressure limits, and the maximum injection rates and pressures, the requirements for the composition of the CO2 stream, the approved monitoring plan, the requirement to notify the competent authority in the event of leakages or significant irregularities, the approved corrective measures plan and the obligation to implement the corrective measures plan in the event of leakages or significant irregularities, the conditions for closure, any provisions on changes, review, updating and withdrawal of the storage permit, the requirement to establish and maintain the financial security.

5. Terminology throughout the submission is contained in Annex III "Definitions".

I. Selection of the storage site

6. This section addresses the issues raised in point (a) paragraph 3 of draft Decision -/CMP.6.

7. The secretariat should, drawing on external technical expertise as needed, elaborate draft criteria on site selection which will need to be met by national obligatory and regulatory frameworks before projects are approved. This should have regard to the issues discussed in paragraphs 9 to13.

8. A DOE with appropriate expertise should independently assess each project to verify both that regulations which meet the criteria referred to above are in place and that the project meets these regulations.

9. CO_2 storage in the water column, including storage on the sea ground, should be explicitly excluded from the scope. The suitability of a geological formation for use as a storage site under the CDM shall be determined through a characterisation and assessment of the potential storage complex and surrounding area pursuant to the criteria specified in Annex I. The selection of the appropriate storage site is crucial to ensure that the stored CO2 will be completely and permanently contained.

10. A geological formation shall only be selected as a storage site under the CDM, if under any conditions of use there is no significant risk of leakage, and if in any case no significant environmental or health risks exist.

11. Injection of CO2 streams for storage purposes into geological formations, which are not permanently unsuitable for other purposes shall be prohibited. This means that the storage of CO2 in freshwater aquifers or potential underground sources of drinking water shall be prohibited.

12. Storage reservoirs should not affect the development of renewable sources of energy and have to consider other energy-related options for the use of a potential storage site, including options which are strategic for the security of the host State's energy supply.

II. Stringent monitoring plan

(a) Monitoring

13. This section addresses the issues raised in points (b), (g) and (i) paragraph 3 of draft Decision -/CMP.6.

14. The monitoring shall be based on a monitoring plan designed by the project operator. This will need to meet criteria to be elaborated by secretariat which should have regard to the requirements laid down in Annex II and the issues raised in paragraphs 16 to 31.

15. Attention must be given to potential seepage during the pre-injection (CO2 capture and transportation), injection, and post-injection (operation, closure, post-closure) phases of a CCS project. All those operational phases should be monitored appropriately. Monitoring of injection facilities is done for the purpose of comparison between the actual and modelled behaviour of CO2 and formation water, in the storage site, detecting significant irregularities, detecting migration of CO2, detecting leakage of CO2, detecting significant adverse effects for the surrounding environment, including in particular on drinking water, for human populations, or for users of the surrounding biosphere, updating the assessment of the safety and integrity of the storage complex in the short and long term.

16. The plan should be submitted to and approved by a DOE with appropriate expertise to verify both that the monitoring plan meets the criteria referred to above and that the plan is being adhered to.

17. The plan shall be updated pursuant to the requirements laid down in Annex II and in any case every five years to take account of changes to the assessed risk of leakage, changes to the assessed risks to the environment and human health, new scientific knowledge, and improvements in best available technology. Updated plans shall be re-submitted for approval to a DOE.

18. In the case of geological storage under the seabed, monitoring shall further be adapted to the specific conditions for the management of CCS in the marine environment. Operational procedures and monitoring methodologies shall be determined in accordance with industry best practice and the recommendations of the IPCC.

19. Monitoring of the sealing performance of wells is necessary after storage operations are completed.

20. Appropriate quality control and quality assurance regulations are fundamental to ensure sustainable operation of storage sites without setting the environment and human health at risk.

21. A CO2 stream shall consist overwhelmingly of carbon dioxide. To this end, no waste or other matter may be added for the purpose of disposing of that waste or other matter. However, a CO2 stream may contain incidental associated substances from the source, capture or injection process and trace substances added to assist in monitoring and verifying CO2 migration. Concentrations of all incidental and added substances shall be below levels that would: (a) adversely affect the integrity of the storage site or the relevant transport infrastructure; (b) pose a significant risk to the environment or human health; or (c) breach the requirements of applicable national legislation.

22. A DOE shall verify that the operator: (a) has carried out an analysis of the composition of the CO2 streams (including corrosive substances) and the risk and safety assessment, and if the risk and safety assessment has shown that the contamination levels are in line with the conditions; (b) keeps a register of the quantities and properties of the CO2 streams delivered and injected, including the composition of those streams.

23. A DOE shall verify that the project operator carries out monitoring of the injection facilities, the storage complex (including the CO2 plume), and the surrounding environment for the purpose of: (a) comparison between the actual and modelled behaviour of CO2 and formation water, in the storage site; (b) detecting significant irregularities; (c) detecting migration of CO2; (d) detecting leakage of CO2; (e) detecting significant adverse effects for the surrounding environment, including in particular on drinking water, for human populations, or for users of the surrounding biosphere; (f) updating the assessment of the safety and integrity of the storage complex in the short and long term, including the assessment of whether the stored CO2 will be completely and permanently contained.

24. Before authorizing any CCS CDM project activity, the EB should develop specific criteria tailored for accreditation of DOEs that will guarantee a high level of expertise, competencies and independency of the DOE. The accreditation of a DOE expires automatically after 3 years and can be renewed. All DOEs responsible for validation and verification of CCS project activities shall have all proper experiences relevant to CCS.

(b) Reporting by the project operator

25. At least once a year, the monitoring report shall contain (1) all results of the monitoring in the reporting period, including information on the monitoring technology employed; (2) the quantities and properties of the CO2 streams delivered and injected, including composition of those streams, in the reporting period; (3) proof of the putting in place and maintenance of the financial security; (4) any other information a DOE considers relevant for the purposes of assessing compliance with storage requirements and increasing the knowledge of CO2 behaviour in the storage site.

(c) DOE inspections

26. DOEs shall organize in cooperation a system of routine and non-routine inspections of all storage complexes for the purposes of checking and promoting compliance with the requirements and of monitoring the effects on the environment and on human health.

27. Inspections should include activities such as visits of the surface installations, including the injection facilities, assessing the injection and monitoring operations carried out by the operator, and checking all relevant records kept by the operator.

28. Routine inspections shall be carried out at least once a year until three years after closure and every five years until transfer of responsibility to the competent authority of the host country has occurred. They shall examine the relevant injection and monitoring facilities as well as the full range of relevant effects from the storage complex on the environment and on human health.

29. Non-routine inspections shall be carried out: (a) if one DOE has been notified or made aware of leakages; (b) to investigate complaints related to the environment or human health; (c) in other situations where any DOE or the EB considers this appropriate.

30. Following each inspection, a DOE shall prepare a report on the results of the inspection. The report shall evaluate compliance with the requirements and indicate whether or not further action is necessary. The report shall be communicated to the project operator concerned and shall be publicly available within two months of the inspection.

III. Risk and safety assessment

31. This section addresses the issues raised in points (j), (k) and (l) paragraph 3 of draft Decision -/CMP.6.

32. The secretariat should elaborate on a risk and safety methodology in the modalities and procedures having regard to the issues raised in paragraphs 34 to 44.

33. At a minimum, the risk and safety assessment shall comprise the elements specified in Step 3.3 of the Annex I.

34. The risk and safety assessment shall address the potential for leakage during operations as well as over the long term (i.e. after closure of the storage site).

35. The development and implementation of a risk and safety management and risk and safety communication plan shall be included in the risk and safety assessment.

36. The risk and safety assessment should help identify priority locations and approaches for enhanced monitoring activities.

37. The risk and safety assessment should provide the basis for mitigation/ remediation /corrective measures plans for response to unexpected events; such plans should be developed and submitted to the DOE in support of the proposed monitoring plan.

38. The risk and safety assessment should determine relevant operational data, including setting an appropriate injection pressure that will not compromise the integrity of the confining storage complex.

39. Periodic updates to the risk and safety assessment every 3 years shall be conducted throughout the project life cycle based on updated monitoring data and revised models and simulations, as well as knowledge gained from ongoing research and operation of other storage sites.

40. The risk and safety assessment should include site-specific information, such as the terrain, potential receptors, proximity of drinking water resources, faults, and the potential for unidentified borehole locations within the project extend.

41. The risk and safety assessment should include non-spatial elements or non-geologic factors (such as population, land use, or critical habitat) that should be considered in evaluating a specific site.

42. Pipelines located in vulnerable areas (populated or ecologically sensitive, areas) require extra due diligence by project operators to ensure safe pipeline operations. Options for increasing due diligence include among other things: decreased spacing of mainline valves, greater depths of burial, increased frequency of pipeline integrity assessments and monitoring for leaks.

43. The risk and safety assessment and all essential information shall be made public in order to guarantee a broad public participation in the decision making process.

IV. Socio-environmental impacts assessment

44. This section addresses the issues raised in points (j) and (l) paragraph 3 of draft Decision -/CMP.6.

45. The secretariat should elaborate on criteria for this socio-environmental impact assessment having regard to the issues raised in paragraphs 47 to 52.

46. Full socio-environmental impact assessment in accordance with relevant regional and international legal instruments as applicable shall be carried out for CO2 capture installations, CO2 storage sites and CO2 transport pipelines.

47. A DOE with appropriate expertise should undertake an assessment of each project based on the criteria referred to in paragraph 46 and provide a report to the EB.

48. For CO2 capture plants, as a minimum, the comprehensive socio-environmental impacts assessment shall analyze thoroughly and exhaustively air emissions (NOx, SOx, dust, Hg, PAHs, etc.), solid waste generation, and water use associated with current CO2 capture technologies.

49. In all cases, the socio-environmental impact assessment shall ensure that best available techniques are well applied and achieve a high level of protection for the environment as a whole.

50. The socio-environmental impact assessment shall include at least a comprehensive analysis of impacts on peoples living conditions in the possibly affected area, regardless of any boarders or other administrative frontiers.

51. In order to guarantee a broad public participation, project operators have to ensure that all relevant information is made available to the public and to stakeholders and that they are extensively involved in the decision making process, in line with relevant regional and international legal instruments as applicable,.

V. Short-, medium- and long-term liability

(a) General considerations

52. This section addresses the issues raised in points (m), (n) and (o) paragraph 3 of draft Decision -/CMP.6.

53. An effective national obligatory and regulatory framework has to be developed and implemented which covers liability before the CCS project can be authorised in the host country.

54. The secretariat should elaborate criteria on liability which will need to be consistent with national obligatory and regulatory frameworks before projects are approved. This should have regard to the issues discussed in paragraphs 56-73.

55. A DOE with appropriate expertise should assess each project to verify both that regulations are in place which meet the criteria referred to paragraph 55 and that the project is consistent with these regulations.

56. A general subsidiary responsibility and liability for the CCS complex lies with the host country. Before a transfer of responsibility each storage site should at all times be under the responsibility of only one entity (project operator or competent authority of the host country) for monitoring, preparedness, response, and remediation measures.

57. In cases of transboundary transport of CO2, transboundary storage sites or transboundary storage complexes, the project is only eligible as long as there is clear assignment of responsibilities and liabilities, and effectual accounting for emission reductions and any seepage according to solutions for reporting of cross border CCS projects put forward in the 2006 IPCC Guidelines; notwithstanding that the objective should be to avoid any seepage.

58. Before authorizing the CCS CDM project in the host country, the national obligatory and regulatory framework needs to contain closure and post-closure obligations, including provisions as mentioned in paragraphs 60-63.

59. A storage site shall be closed: (a) if the essential conditions stated in the permit have been met; (b) at the substantiated request of the operator, after authorisation of the competent authority of the host country; or (c) if the competent authority of the host country so decides after the withdrawal of a storage permit.

60. After a storage site has been closed pursuant to points (a) or (b) of paragraph 60, the project operator remains responsible for monitoring, reporting and corrective measures, and for all obligations relating to the accounting of emission reductions in case of leakages until the responsibility for the storage site is transferred to the competent authority of the host country. The project operator shall also be responsible for sealing the storage site and removing the injection facilities.

61. The obligations referred to in paragraph 61 shall be fulfilled on the basis of a post-closure plan designed by the operator based on best practice and in accordance with the requirements laid down in Annex II.

62. After a storage site has been closed pursuant to point (c) of the paragraph 60, the competent authority of the host country shall be responsible for monitoring and corrective measures, and for all obligations relating to the accounting of emission reductions in case of leakages. The post-closure requirements shall be fulfilled by the competent authority of the host country on the basis of the post-closure plan referred to in paragraph 62, which shall be updated as necessary.

63. Before authorizing the CCS CDM project in the host country, the national obligatory and regulatory framework in place has to demonstrate that there are adequate provisions guaranteeing in the long-term a means of redress for Parties, communities, private-sector entities and individuals affected by the release of injected CO2 or any other adverse health and environmental impact from the CCS project, including restoration of damaged ecosystems and full compensation for affected communities.

64. Storage sites, CO2 pipelines and potential seepage locations which cross national borders will potentially have additional legal implications and might be a source of dispute between States. A cooperation mechanism between countries together with an international organism to solve potential disputes might be created in the framework of the UNFCCC and/or international jurisdiction.

(b) Transfer of responsibility

65. Project Design Document (PDD) and monitoring plan should include clear and explicit assignment of long-term liability for monitoring and site-management, including remediation; they should clearly specify details of any transfer of liabilities, including evidence of agreements on such transfers; PDD and Monitoring Reports/Verification Reports should also

include clear evidences of the compliance with financial and organizational provisions to ensure the continuing viability of the storage operation and monitoring beyond the crediting period.

66. Before authorizing the CCS CDM project in the host country, the national obligatory and regulatory framework in place has to demonstrate that there are adequate provisions guaranteeing that after closing the storage site, all legal obligations relating to monitoring and accounting of emissions in the event of leakages, have been transferred to the competent authority of the host country on its own initiative or upon request from the project operator.

67. When the competent authority of the host country endorses this responsibility, it shall notify it to the EB.

68. After the transfer of responsibility, DOE inspections can cease and monitoring may be reduced to a level which allows for detection of leakages or significant irregularities which imply the risk of leakage if the following conditions are met: (a) all available evidence indicates that the stored CO2 will be completely and permanently contained; (b) a minimum period since the closure, to be determined by the competent authority of the host country, has elapsed. This minimum period shall be no shorter than 20 years, unless the competent authority and the DOE are convinced that the criterion referred to in point (a) is complied with before the end of that period; (c) the operator has paid a financial contribution to cover possible cost resulting from the transfer of responsibility (incl. corrective measures), at least the costs for monitoring for 30 years; (d) the site has been sealed and the injection facilities have been removed. If any leakages or significant irregularities which imply the risk of leakage are detected, the competent authority of the host country shall notify it to the EB and monitoring shall be intensified as required to assess the scale of the problem and the effectiveness of corrective measures.

(c) Measures in case of leakages or significant irregularities which imply the risk of leakage

69. At any time in the short-, medium- and long-term, in cases of leakages and significant irregularities which imply the risk of leakage, the entity responsible (i.e. project operator or competent authority of the host country) shall notify the EB and take the necessary corrective measures, including measures related to the protection of human health. Moreover, the entity responsible has to verify and notify to the EB the amount of CO2 still stored safely in the relevant reservoir.

70. Before authorizing any CCS CDM project activity, the CMP/EB shall elaborate provisions to guarantee that leakage of any ton of CO2 in the atmosphere is compensated, including through the removal of the same amount of credits from the market and/or by remediation.

(d) Financial security

71. The project operator must demonstrate a financial security or any other equivalent in order to ensure that all obligations during project operation as well as closure and post-closure

requirements can be met. This financial security shall be valid and effective before the registration of the CCS CDM project.

72. The regulatory framework for the financial security shall be periodically adjusted by the EB to take account of changes in the assessed risk of leakage and the estimated costs of all obligations.

73. The financial security or any other equivalent shall remain valid and effective after a storage site has been closed, until the responsibility for the storage site is transferred to the competent authority of the host country.

ANNEX I: CRITERIA FOR THE CHARACTERISATION AND ASSESSMENT OF THE POTENTIAL STORAGE COMPLEX AND SURROUNDING AREA

The characterisation and assessment of the potential storage complex and surrounding area shall be carried out in three steps according to best practices at the time of the assessment and to the following criteria. Derogations from one or more of these criteria may be permitted by the DOE provided the project operator has demonstrated that the capacity of the characterisation and assessment to enable the determinations is not affected.

Step 1: Data collection

Sufficient data shall be accumulated to construct a volumetric and three-dimensional static (3-D)-earth model for the storage site and storage complex, including the caprock, and the surrounding area, including the hydraulically connected areas. This data shall cover at least the following intrinsic characteristics of the storage complex:

(a) geology and geophysics;

(b) hydrogeology (in particular existence of ground water intended for consumption);

(c) reservoir engineering (including volumetric calculations of pore volume for CO2 injection and ultimate storage capacity);

(d) geochemistry (dissolution rates, mineralisation rates);

(e) geomechanics (permeability, fracture pressure);

(f) seismicity;

(g) presence and condition of natural and man-made pathways, including wells and boreholes which could provide leakage pathways.

The following characteristics of the complex vicinity shall be documented:

(h) domains surrounding the storage complex that may be affected by the storage of CO2 in the storage site;

(i) population distribution in the region overlying the storage site;

(j) proximity to valuable natural resources;

(k) activities around the storage complex and possible interactions with these activities (for example, exploration, production and storage of hydrocarbons, geothermal use of aquifers and use of underground water reserves);

(l) proximity to the potential CO2 source(s) (including estimates of the total potential mass of CO2 economically available for storage) and adequate transport networks.

Step 2: Building the three-dimensional static geological earth model

Using the data collected in Step 1, a three-dimensional static geological earth model, or a set of such models, of the candidate storage complex, including the caprock and the hydraulically connected areas and fluids shall be built using computer reservoir simulators. The static geological earth model(s) shall characterise the complex in terms of:

(a) geological structure of the physical trap;

(b) geomechanical, geochemical and flow properties of the reservoir overburden (caprock, seals, porous and permeable horizons) and surrounding formations;

(c) fracture system characterisation and presence of any human-made pathways;

(d) areal and vertical extent of the storage complex;

(e) pore space volume (including porosity distribution);

(f) baseline fluid distribution;

(g) any other relevant characteristics.

The uncertainty associated with each of the parameters used to build the model shall be assessed by developing a range of scenarios for each parameter and calculating the appropriate confidence limits. Any uncertainty associated with the model itself shall also be assessed.

Step 3: Characterisation of the storage dynamic behaviour, sensitivity characterisation, risk and safety assessment

1. The characterisations and assessment shall be based on dynamic modelling, comprising a variety of time-step simulations of CO2 injection into the storage site using the three-dimensional static geological earth model(s) in the computerised storage complex simulator constructed under Step 2.

Step 3.1: Characterisation of the storage dynamic behaviour

At least the following factors shall be considered:

(a) possible injection rates and CO2 stream properties;

(b) the efficacy of coupled process modelling (that is, the way various single effects in the simulator(s) interact);

(c) reactive processes (that is, the way reactions of the injected CO2 with in situ minerals feedback in the model);

(d) the reservoir simulator used (multiple simulations may be required in order to validate certain findings);

(e) short and long-term simulations (to establish CO2 fate and behaviour over decades and millennia, including the rate of dissolution of CO2 in water).

The dynamic modelling shall provide insight into:

(f) pressure and temperature of the storage formation as a function of injection rate and accumulative injection amount over time;

(g) areal and vertical extent of CO2 vs time;

(h) the nature of CO2 flow in the reservoir, including phase behaviour;

(i) CO2 trapping mechanisms and rates (including spill points and lateral and vertical seals);

(j) secondary containment systems in the overall storage complex;

(k) storage capacity and pressure gradients in the storage site;

(l) the risk of fracturing the storage formation(s) and caprock;

(m) the risk of CO2 entry into the caprock;

(n) the risk of leakage from the storage site (for example, through abandoned or inadequately sealed wells);

(o) the rate of migration (in open-ended reservoirs);

(p) fracture sealing rates;

(q) changes in formation(s) fluid chemistry and subsequent reactions (for example, pH change, mineral formation) and inclusion of reactive modelling to assess affects;

(r) displacement of formation fluids;

(s) increased seismicity and elevation at surface level.

Step 3.2: Sensitivity characterisation

Multiple simulations shall be undertaken to identify the sensitivity of the assessment to assumptions made about particular parameters. The simulations shall be based on altering parameters in the static geological earth model(s), and changing rate functions and assumptions in the dynamic modelling exercise. Any significant sensitivity shall be taken into account in the risk and safety assessment.

Step 3.3: Risk and safety assessment

The risk and safety assessment shall comprise, inter alia, the following:

3.3.1. Hazard characterisation

Hazard characterisation shall be undertaken by characterising the potential for leakage from the storage complex, as established through dynamic modelling and security characterisation described above. This shall include consideration of, inter alia:

(a) potential leakage pathways;

(b) potential magnitude of leakage events for identified leakage pathways (flux rates);

(c) critical parameters affecting potential leakage (for example maximum reservoir pressure, maximum injection rate, temperature, sensitivity to various assumptions in the static geological Earth model(s));

(d) secondary effects of storage of CO2, including displaced formation fluids and new substances created by the storing of CO2;

(e) any other factors which could pose a hazard to human health or the environment (for example physical structures associated with the project).

The hazard characterisation shall cover the full range of potential operating conditions to test the security of the storage complex.

3.3.2. Exposure assessment — based on the characteristics of the environment and the distribution and activities of the human population above the storage complex, and the potential behaviour and fate of leaking CO2 from potential pathways identified under Step 3.3.1.

3.3.3. Effects assessment — based on the sensitivity of particular species, communities or habitats linked to potential leakage events identified under Step 3.3.1. Where relevant it shall include effects of exposure to elevated CO2 concentrations in the biosphere (including soils, marine sediments and benthic waters (asphyxiation; hypercapnia) and reduced pH in those environments as a consequence of leaking CO2). It shall also include an assessment of the effects of other substances that may be present in leaking CO2 streams (either impurities present in the injection stream or new substances formed through storage of CO2). These effects shall be considered at a range of temporal and spatial scales, and linked to a range of different magnitudes of leakage events.

3.3.4. Risk characterisation — this shall comprise an assessment of the safety and integrity of the site in the short and long term, including an assessment of the risk of leakage under the proposed conditions of use, and of the worst-case environment and health impacts. The risk characterisation shall be conducted based on the hazard, exposure and effects assessment. It shall include an assessment of the sources of uncertainty identified during the steps of characterisation and assessment of storage site and when feasible, a description of the possibilities to reduce uncertainty.

ANNEX II: CRITERIA FOR ESTABLISHING AND UPDATING THE MONITORING PLAN AND FOR POST-CLOSURE MONITORING

1. Establishing and updating the monitoring plan

The monitoring plan shall be established according to the risk and safety assessment analysis carried out in Step 3 of Annex I, and updated with the purpose of meeting the monitoring requirements according to the following criteria:

1.1. Establishing the plan

The monitoring plan shall provide details of the monitoring to be deployed at the main stages of the project, including baseline, operational and post-closure monitoring. The following shall be specified for each phase:

(a) parameters monitored;

(b) monitoring technology employed and justification for technology choice;

(c) monitoring locations and spatial sampling rationale;

(d) frequency of application and temporal sampling rationale.

The parameters to be monitored are identified so as to fulfil the purposes of monitoring. However, the plan shall in any case include continuous or intermittent monitoring of the following items:

(e) fugitive emissions of CO2 at the injection facility;

(f) CO2 volumetric flow at injection wellheads;

(g) CO2 pressure and temperature at injection wellheads (to determine mass flow);

(h) chemical analysis of the injected material;

(i) reservoir temperature and pressure (to determine CO2 phase behaviour and state).

The choice of monitoring technology shall be based on best practice available at the time of design. The following options shall be considered and used as appropriate:

(j) technologies that can detect the presence, location and migration paths of CO2 in the subsurface and at surface;

(k) technologies that provide information about pressure-volume behaviour and areal/vertical distribution of CO2-plume to refine numerical 3-D simulation to the 3-D-geological models of the storage formation;

(l) technologies that can provide a wide areal spread in order to capture information on any previously undetected potential leakage pathways across the areal dimensions of the complete storage complex and beyond, in the event of significant irregularities or migration of CO2 out of the storage complex.

1.2. Updating the plan

The data collected from the monitoring shall be collated and interpreted. The observed results shall be compared with the behaviour predicted in dynamic simulation of the 3-D-pressure-volume and saturation behaviour undertaken in the context of the security characterisation pursuant to Annex I Step 3.

Where there is a significant deviation between the observed and the predicted behaviour, the 3-D model shall be recalibrated to reflect the observed behaviour. The recalibration shall be based on the data observations from the monitoring plan, and where necessary to provide confidence in the recalibration assumptions, additional data shall be obtained.

Steps 2 and 3 of Annex I shall be repeated using the recalibrated 3-D model(s) so as to generate new hazard scenarios and flux rates and to revise and update the risk and safety assessment.

Where new CO2 sources, pathways and flux rates or observed significant deviations from previous assessments are identified as a result of history matching and model recalibration, the monitoring plan shall be updated accordingly.

2. Post-closure monitoring

Post-closure monitoring shall be based on the information collected and modelled during the implementation of the monitoring plan.

ANNEX III: DEFINITIONS

1. "geological storage of CO2" means injection accompanied by storage of CO2 streams in underground geological formations;

2. "storage site" means a defined volume area within a geological formation used for the geological storage of CO2 and associated surface and injection facilities;

3. "geological formation" means a lithostratigraphical subdivision within which distinct rock layers can be found and mapped;

4. "leakage" means any release of CO2 from the storage complex;

5. "storage complex" means the storage site and surrounding geological domain which can have an effect on overall storage integrity and security; that is, secondary containment formations;

6. "CO2 stream" means a flow of substances that results from CO2 capture processes;

7. "CO2 plume" means the dispersing volume of CO2 in the geological formation;

8. "migration" means the movement of CO2 within the storage complex;

9. "significant irregularity" means any irregularity in the injection or storage operations or in the condition of the storage complex itself, which implies the risk of a leakage or risk to the environment or human health;

10. "significant risk" means a combination of a probability of occurrence of damage and a magnitude of damage that cannot be disregarded without calling into question the purpose of this Directive for the storage site concerned;

11. "corrective measures" means any measures taken to correct significant irregularities or to close leakages in order to prevent or stop the release of CO2 from the storage complex;

12. "closure" of a storage site means the definitive cessation of CO2 injection into that storage site;

13. “post-closure" means the period after the closure of a storage site, including the period after the transfer of responsibility to the competent authority.

Paper no. 4: Indonesia

SUBMISSION BY INDONESIA

Proposal by the Government of Indonesia on

Carbon Dioxide Capture and Storage in Geological Formations as Clean Development Mechanism Project Activities

The Meeting of Parties serving as the 6th Conference of the Parties to the Kyoto Protocol (CMP-6) held in Cancun in December 2010 in its Decision -/CMP.6 has decided that carbon dioxide capture and storage in geological formations (CCS) is eligible as project activities under the Clean Development Mechanism (CDM), provided that the issues identified in Decision 2/CMP.5, paragraph 29, are addressed and resolved in a satisfactory manner.

The Government of the Republic of Indonesia welcomes the adoption of Decision -/CMP6. It believes that the decision is a critical step forward in promptly deploying CCS at a global scale, including in developing countries, as required to avoid dangerous climate change in a responsible and safe manner.

Pursuant to the Decision -/CMP.6, paragraph 4, Parties are invited to submit their views on how to elaborate modalities and procedures for the inclusion of carbon dioxide capture and storage in geological formations as project activities under the clean development mechanism. The Government of the Republic of Indonesia, consistent with its previous submission as contained in FCCC/SBSTA/2010/Misc.2, welcomes this opportunity.

In that regard, the Government of the Republic of Indonesia:

a. Reiterates that inclusion of CCS in the CDM does not imply any obligation whatsoever to any developing countries to deploy CCS. Yet it provides options and financial support for those developing countries that wish to do so according to their respective national circumstances;

b. Believes that the process of drafting modalities and procedures related to CCS in CDM as stated in paragraph 2 of Decision -/CMP.6 in addressing important issues listed in paragraph 3 needs to take into consideration the existing works undertaken by credible international and specialized organizations experiences by Parties with knowledges in the engineering, geological, legal, social and enivironmental as well as financial aspects of CCS representing different geographies, including country's report on carbon dioxide capture and storage in geological formations in order to have wide spectrum of CCS value chain;

c. Notes that the following key documents are essential in addressing the important issues listed in paragraph 3 of Decision -/CMP6: (i) Intergovernmental Panel on Climate Change (IPCC) Special Report Carbon Dioxide Capture and Storage (2005); (ii) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, particularly elaboration on Tier 3 Methodology; (iii) London Protocol 2009; (iv) Implications of the

Inclusion of Geological CO2 Capture and Storage as CDM Project Activities, A report for the UNFCCC, UNFCCC/EB50 Annex 1 (2009); and (iv) European Union Directive on the Geological Storage of Carbon Dioxide 2009;

d. Emphasizes that the modalities and procedures developed for CCS in CDM should be credible, robust, and practical with clear distinction of responsibilities between the host government, Designated Operational Entity (DOE), CDM Executive Board, and Project Developer;
e. Welcomes the Secretariat to conduct a technical workshop with relevant technical and legal experts as stipulated in paragraph 5 of Decision -/CMP.6 after the thirty-fourth session but prior to the thirty-fifth session of the SBSTA, and this technical workshop was suggested in the previous submission FCCC/SBSTA/2010/Misc.2.

Furthermore, in order to address important issues as contained in paragraph 3 of Decision -/CMP.6, the Government of the Republic of Indonesia herewith put forward its views asssociated with key elements under technical aspects and CDM issues that should be taken into account in the establisment of modalities and procedures related to CCS in CDM.

1. **Site Selection Criteria** (relating to paragraph 3(a) and 3(d) of the Decision)

There are several technical aspects involved, namely:

- Establishment of CCS Best Practices, which consists of site selection and good site characterization procedures based on geologic characteristic of the associated site, including its criteria to ensure permanent storage of CO_2 within the geological formation and take into consideration other key issues related to liability. They also include injection guidelines, the international legal framework and environmental impacts, including transboundary impacts.
- As an integral part of the site characterization and selection, site specific risk assessment needs to be conducted, since CCS Best Practices for site selection should include criteria to guide the risk and safety assessment of the potential CO_2 storage sites.
- Stringent and robust criteria for the selection of the storage site are strongly required for any consideration of CO_2 capture and storage

Given the above technical aspects, CDM related issues are:

a. CCS Best Practices for site selection that will be used by CCS Project Developers should be adopted by CMP in order to establish “CMP-CCS Best Practices”.
b. In the application of CMP-CCS Best Practices, complete information on site characterization and site selection activities of the agreed site selection with the DNA, should be provided by Project Developer including: (i) site development programmes which includes site preparation and well construction, (ii) operating and maintenace programmes and management, (iii) management of the end storage project: site closure and post-closures, and (iv) its associated time frame that should be included in the Project Design Document (PDD).
c. In assessing the site selection in the PDD, the Project Developer must demonstrate that it has taken into account CMP-CCS Best Practices and any specific requirement imposed by DNA.

d. DNA may provide additional considerations and requirements when assessing site selection of a project, in addition to CMP-CCS Best Practices. Such requirements must be explicit, clear and transparent.
e. For the purpose of project validation, DOE makes an assessment based on the information available in the PDD.
f. Registration decison by CDM Executive Board should refers to the CMP-CCS Best Practices.

2. **Monitoring Plan** (relating to paragraph 3(b) and 3(d) of the Decision)

There are several technical aspects involved, namely:

- The objective of monitoring should be to confirm that the CO_2 stored underground is permanently sequestered within the geological formation of the agreed selected site.
- Establishment of a guideline on monitoring covering key monitoring parameters that need to be monitored, reporting plans including monitoring criteria. It should also lays down procedures to ensure that monitored data are collected/recorded, reported and stored, which enables independent verification, if required.
- In order to have a complete scope of the monitoring plan, monitoring system should also covers capture and transportation facilities.
- The monitoring plans need to be site-specific, based on the most suitable methodology and technology for the selected site and implemented over the life of CCS project in order to reduce the risk to the environmental integrity of CCS in geological formations.
- The data used in developing monitoring plan must be consistent with the data and insights from the site selection process.
- The monitoring plan must include the entire injection period (i.e. the CDM crediting period) and post injection period and the storage that has been closed (i.e. the CDM post-crediting period).

Hence, CDM related issues are:

a. A guideline on monitoring and reporting plans that is consistent with 2006 IPCC Guidelines for National GHG Inventories (Volume 2, Chapter 5) should be adopted by CMP.
b. Site-specific monitoring plan proposed by Project Developer should be agreed upon by DNA. DNA is required to provide its agreement of the monitoring plan after due consideration by the relevant government agencies.
c. In assessing the monitoring plan in the PDD, Project Developer must demonstrate that it has implemented the guideline adopted by the CMP and any specific requirement imposed by DNA.
d. DNA may provide additional consideration and requirement when assessing site selection of a project, in addition to the guideline adopted by the CMP. Such requirements must be explicit, clear and transparent.
e. For the purpose of project validation, the DOE, if required, can make assessments of the monitoring plan based on the information available in the PDD, and to check whether the CMP monitoring plan criteria were applied accordingly.
f. For the purpose of periodic project verification, whether the agreed monitoring plan has been applied by Project Developer and the amount of emission reductions was achieved by the CCS project that has been provided by the monitoring system should be confirmed by DOE.

g. Registration decison by CDM Executive Board refers to CMP monitoring plan criteria.

3. **The Role of Modeling** (relating to Paragraph 3 (c) of the Decision)

There are several technical aspects involved, namely:

- Computer models are required to support important task for site characterization, site selection, risk assessment and monitoring plans, but they should be complemented by other techniques, consistent with 2006 IPCC Guidelines for National GHG Inventories (Volume 2, Chapter 5).
- Computer models need to be continuously improved and learnings between projects are encouraged to be shared.

Hence, CDM related issues are:

a. The PDD must provide and define the type of computer modeling it uses, including its caveats and limitations.
b. The PDD must demonstrate that the techniques used to complement the computer modeling address the limitations of the computer modeling.
c. The agreement of the CCS project between Project Developer and DNA for CCS project development is not based only on the assessment of the techniques used, it shall combine with modelling, measurement and monitoring which is consistent with 2006 IPCC Guidelines for National GHG Inventories (Volume 2, Chapter 5).
d. For the purpose of project validation, based on the information available in the PDD, DOE makes an assessment to evaluate the appropriateness of the techniques that has been used for the site selection, development and operating programmes.
e. For the purpose of periodic project verification, the appropriateness of the techniques used is assessed by DOE.
f. CDM Executive Board makes registration decision accordingly.

4. **Project Boundaries** (relating to Paragraph 3 (e), 3 (f), and 3 (g) of the Decision)

There are several technical aspects involved, namely:

- The project boundary should include the entire chain of a CCS project from the capture, transport, and storage of the CO_2, covering both above-ground and subsurface boundaries.
- The subsurface boundary must includes the potential migratory pathways of the sequestered CO_2.
- Develop associated criteria that will be used to evaluate whether an accurate physical boundary has been established.
- The monitoring plans must cover the entire project boundary.

Hence, CDM related issues are:

a. Project boundary proposed by Project Developer needs to be agreed with DNA, and providing clear descriptions including its associated data.

b. The PDD must define the project boundary and demonstrate that robust analysis was conducted when determining potential migratory pathways.
c. For the purpose of project validation and periodic project verification phase, DOE will make an assessment to check whether the project boundary fulfil the guideline on monitoring and reporting plans adopted by CMP.
d. CDM Executive Board makes registration decision accordingly.

5. **Transboundary** (relating to Paragraph 3 (h) of the Decision)

There are several technical aspects involved, namely:

- CCS project will require transboundary arrangements where the CO_2 captured need to be transported to a storage site across the border.
- To reach optimization of shared infrastructure and cost efficiency as well as implementation of international standards, CCS transboundary projects in some regions may be inevitable. Under this specific condition, liability regime arrangements needs to be established which based on with the nature of the CCS transboundary project and in line with 2006 IPCC Guidelines for National GHG Inventories.

Hence, CDM related issues are:

a. It's preferable that CCS project under CDM must be prioritized for projects that fall under a national border rather than CCS transboundary project.
b. Transboundary arrangements need to be agreed in advance, including but not limited to provisions of liability regime arrangements which covers respective responsibility of all the related host governments/DNA of all participating countries.
c. CCS transboundary project can be registered further if the national approval of each related countries has been confirmed officially by all the related host governments/DNA of all participating countries.
d. Reporting of emissions from CCS transboundary projects must be consistent with 2006 IPCC Guidelines for National GHG Inventories.

6. **Accounting for Project Emissions** (relating to Paragraph 3 (i) of the Decision)

There are several technical aspects involved, namely:

- Clear statement from Paragraph 3 (i), "Any project emissions associated with the deployment of carbon dioxide capture and storage in geological formations shall be accounted for as project or leakage emissions and shall be included in the monitoring plans, including an ex-ante estimation of project emissions".
- Monitoring plan for CO_2 accounting at least has three components: (i) to detect loss of containment from the storage formation, (ii) to detect and locate leakage at the surface, and (iii) to quantify leakage.
- 2006 IPCC Guidelines for National GHG Inventories (Volume 2, Chapter 5) can be considered to be used as a reference in which provides a complete description and a comprehensive approach to accounting for project emissions.

Hence, CDM related issues are:

a. 2006 IPCC Guidelines for National GHG Inventories (Volume 2, Chapter 5) must be used accounting for project emissions.
b. For the purpose of periodic project verification, (i) project emissions , and (ii) leakage emissions should be accounted and determined.

7. **Risk and Safety Assessment** (relating to Paragraph 3 (j), 3 (k), and 3 (l) of the Decision)

There are several technical aspects involved, namely:

- Risk and safety assessment must form the basis of the approval of site selection and monitoring plans.
- Risk and safety assessment must include the entire project boundary (above-ground and subsurface) and its immediate surroundings when relevant.
- Proposed projects that fail to demonstrate proper risk and safety assessment should not be considered.

Hence, CDM related issues are:

a. A clear, robust, and criteria for risk and safety assessment in the site selection criteria need to be adopted by CMP.
b. CCS projects developed under CDM and should include an assessment of the risks and safety of the development and operation of the full CCS chain.
c. Environmental Impact Assessment needs to be conducted according to the standard CDM practice.
d. As stipulated in paragraph 3 (j), risk and safety assessment, as well as a comprehensive socio-environmental impacts assessment, shall be undertaken by independent entity(ies) prior to the deployment of CCS in geological formations.
e. Prior to conducting risk and safety assessment, its works plan in detail shall be endorsed by DNA, and further its result shall be approved by DNA.
f. The results of risk and safety assessment shall be used for storage site selection, and need to be agreed by DNA.
g. The PDD must demonstrate that the identified risks are mitigated and will be properly monitored.
h. Risk assessment criteria during validation phase and identified risks level need to be confirmed by DOE.

8. **Liability** (relating to Paragraph 3 (m), 3 (n), and 3 (o) of the Decision)

There are several technical aspects involved, namely:

- Liability of a CCS project involves liability in the event of the stored of CO_2 seeps to the atmosphere and liability for any impacts to the immediate surroundings caused by CO_2 seepage.
- Liability on the impact to immediate surroundings caused by CO_2 seepage, such as damage to environment, property, or population (i.e. public health) are national issues and should be addressed as provisions in the agreed liability arrangement between Project Developer and the

Host Country which is legally binding agreement by using national law and regulation of the Host Country as governing law.

- Project Developer is responsible and liability on the CO_2 seepage should be hold by Project Developer, and should be remediated by Project Developer during the operating phase (injection phase). Seepage of CO_2 should be monitored and accounted as project emissions.
- During the post-closure phase, Project Developer: (i) should continue to hold the liability for the project, (ii) will continue to monitor the stored CO_2 including any seepage that may be occured, (iii) continue to be responsible for any remediation, and (iv) responsible to compensate the same amount of CO_2 that were seeped taking from the CERs.
- If there is an option for transfering the responsibility to the Host Country in which Project Developer has no further liability for the stored CO_2, it is required that the predetermined criteria based on performance should be agreed by Project Developer and the Host Country when issuing the injection permit through establishment of legally binding agreement by using national law and regulation of the Host Country as governing law.
- The host country takes over the liability once the project developer has met the predetermined criteria that the CO_2 is safely and considered permanently stored.
- The predetermined criteria may differ between Host Countries.

Hence, CDM related issues are:

a. The liability arrangements should cover the CCS life-cycle and define clear responsibility for the liabilities to participating entities.
b. The liability arrangements and its agreement between Project Developer and Host Country, including the predetermined criteria for liability handover and compensation mechanisms must be made clear in the PDD.
c. Seepage of CO_2 during crediting period should be accounted as project emissions.

Jakarta, 21 February 2011

Paper no. 5: Japan

Submission by Japan on modalities and procedures for the inclusion of CCS in geographical formations as project activities under the CDM

Japan welcomes the decision adopted at the sixth session of the COP/MOP (decision 7/CMP.6) which has clarified that carbon dioxide capture and storage in geological formations (hereinafter referred to as ‘CCS’) is eligible as project activities under the CDM. Japan supports the adoption of modalities and procedures for the inclusion of CCS as project activities under the CDM (hereinafter referred to as CCS-CDM) at the seventh session of the COP/MOP, on the basis of the recommendation to be made by the SBSTA at its thirty-fifth session. Japan also welcomes the opportunity to submit its views on these modalities and procedures.

1. Importance of promoting CCS-CDM

(1) CCS technology is essential to achieving large-scale CO2 emission reductions in an effective manner, while at the same time ensuring energy security. The IPCC Special Report on Carbon Dioxide Capture and Storage reiterates that CCS has the potential to reduce overall mitigation costs and increase flexibility in achieving greenhouse gas emission reductions.

(2) The Technology Roadmap for carbon capture and storage, which was published by the International Energy Agency in 2009, highlights the need for, in addition to CCS efforts to be led by developed countries, rapid spread of CCS technology to developing countries. CCS-CDM will enable the effective transfer of technological, human, and financial resources from developed countries to developing countries, which will contribute to the safe and stable implementation of CCS projects in developing countries.

(3) A CCS project requires an enormous amount of initial investment, and it is very difficult to recover those costs without revenues from the sale of CERs. The CDM therefore provides financial incentives for the implementation of CCS projects.

(4) A CCS project will generate employment during its construction phase as well as its operation phase. Project participants for CCS-CDM may use the revenues from sales of CERs for local community development. Thus, CCS-CDM is compatible with the purpose of the CDM to assist the sustainable development of developing countries.

2. Modalities and procedures for CCS-CDM

(1) General

(a) For proper implementation of CCS-CDM, it is of paramount importance that long term site management plans and monitoring plans be established by project participants, and that CCS-CDM be implemented in accordance with these plans. The modalities and procedures for CCS-CDM need to provide guidance to participants to help them establish such plans in a robust and timely manner.

(b) The modalities and procedures need to address issues identified in paragraph 3 of decision 7/CMP.6 in an appropriate and pragmatic manner. In this context, modalities and procedures should be flexible enough to accommodate a variety of site conditions that are necessary for the proper implementation of CCS-CDM. These conditions depend on the circumstances of each storage site and boundary.

(c) It is Japan’s view that some elements need to be added to the issues identified in decision 7/CMP.6 in order to adequately address the unique characteristics of CCS-CDM in the modalities and procedures. Examples of such elements will include eligibility requirements of host countries, consideration of possible non-permanence of the CO2 storage, and requirements to be fulfilled by designated operational entities.

(d) In terms of the format of modalities and procedures, those related to afforestation and reforestation project activities under the CDM (decision 5/CMP.1) may serve as a good reference, although the method of addressing non-permanence should differ between CCS and afforestation/reforestation.

(2) Individual issues

(a) Issues identified in paragraph 3 of decision 7/CMP.6 can be classified based on their nature into the following five categories:

(i) Criteria for storage site selection;

(ii) Monitoring (including in relation to the use of models, leakage and seepage);

(iii) Boundaries;

(iv) Risk and safety assessment; and

(v) Liability.

(b) The modalities and procedures for CCS-CDM need to address the issues noted above in an appropriate and pragmatic manner, taking into account the following points:

(i) Criteria for storage site selection

A number of studies on CCS indicate that there is no doubt regarding the importance of proper site selection in connection with the stable long-term storage of CO2. In selecting storage sites, it is critical to conduct detailed analyses, covering a wide range of aspects related to geological and hydrogeological formations and structures, using proper models, including regional (conceptual) models and detailed (numerical simulation) models.

Criteria for site selection need to be developed for elements including, but not limited to, the following:

a) Existence of sufficient reservoir volumes and cap rocks which prevent stored CO2 from being released into the atmosphere;

b) Absence of any large-scale fault in the reservoir region or its vicinity, where the stored CO2 is expected to permeate and spread or discharge subsurface fluids;

c) The possibility of injecting CO2 at a designed rate and storing the designed volume based on reservoir simulations using detailed models and analysis of relevant data;

d) The cap rock which exists over the reservoir retaining necessary sealing capability and avoiding breakdown under the planned CO2 injection pressure;

e) Seismicity in the vicinity being determined not to be high, based on results of geology and stratigraphy studies in the vicinity of the storage site, as well as the results of historical analysis of seismic activity.

(ii) Monitoring

In order to ensure the environmental integrity and safety of the storage site and its vicinity, it is necessary to conduct rigorous monitoring during the crediting periods and beyond in accordance with an adequately established monitoring plan. The monitoring plan should clearly define what items need to be monitored, as well as how and how often monitoring should be performed at the time of, and after, CO2 injection.

Items to be monitored at the time of CO2 injection include, among others, pressure and temperature at the bottom-hole of the injection well, injection rate/pressure/temperature of CO2 at the head of the injection well, concentration of CO2 and impurities, and microseismicity at the storage site and its vicinity.

There is no argument regarding the need to carefully monitor CO2 seepage from the storage site. It is generally understood that the area around the wells has the highest risk of seepage. It is therefore crucial to assess the adequacy of the injection well, exploration well(s), other wells drilled for the project in question, and wells drilled for other projects.

In addition to the monitoring activities noted above, simulation of CO2 behavior also needs to be undertaken using numerical simulation models established based on a wide variety of data, including data on geological formations and structures, which must be acquired before CO2 is injected. Comparison between the simulation results and actual monitoring results contributes to better site selection and improvement of the monitoring plan. In this context, it is indispensable to make the best use of models and continuously improve them, taking into account the degree of uncertainty associated with the models, which is to be estimated before using them.

It is also necessary to monitor, as part of leakage emissions, CO2 emitted by each aspect of a CCS project, namely, isolation, capture, treatment, transportation, injection, and storage of CO2. This helps complete the CO2 accounting (additions and removals of CO2) associated with CCS-CDM.

(iii) Geographical boundaries

As with other types of CDM project activities, geographical boundaries of CCS-CDM need to be defined before the start of project activities. As described in decision 7/CMP.6, the boundaries need to include all above-ground and underground installations and storage sites, as well as all potential sources of CO2 that can be released into the atmosphere, involved in the capture, treatment, transportation, injection, and storage of CO2, and any potential migratory pathways of the CO2 plume, including a pathway resulting from dissolution of the CO2 in underground water.

Transboundary CCS-CDM should be accepted in a manner consistent with existing CDM rules and practices. These project activities could include those under which the capture of CO2 and its storage occur in different countries, as well as those under which the storage site spreads into multiple countries. For all these cases, liability issues among countries involved need to be addressed before project initiation, in order to avoid legal problems.

(iv) Risk and safety assessment

Results of a risk and safety assessment, including a socio-environmental impact assessment, need to be contained in a PDD for CCS-CDM. The assessment needs to be accompanied by adequate site selection, use of various techniques to prevent CO2 seepage, vigorous monitoring, and timely action to be taken in the event of any irregularities being discovered.

According to the IPCC Special Report on Carbon Dioxide Capture and Storage, routes of CO2 seepage may be classified into (a) along the injection well or abandoned well, (b) along a fault or fracture, (c) along the storage formation stratum, and (d) through the cap rock. Actual seepage occurs via a combination of these routes. While (c) and (d) may constitute part of a long-term seepage scenario, (a) and (b) may constitute part of a short-term scenario. In undertaking the environmental impact assessment of CO2 seepage, the routes, scenarios, and seepage driving forces, such as buoyancy or pressure, corresponding to the scenario need to be considered.

Examples of items to be assessed in the environmental impact assessment could include:

a) Air quality (CO2, SOx, NOx, dust);

b) Noise;

c) Vibration;

d) Water quality (shallow groundwater) (pH, HCO3, contamination, water temperature);

e) Chemical properties of seawater (CO2 concentration index, hydrogen ion concentration, concentration of hazardous substances); and

f) Organisms and ecosystem, scenery, waste, soil contamination (to be selected as appropriate, based on the site situations).

Before undertaking CCS-CDM, it is important to confirm the natural fluctuation of assessment targets in order to more accurately assess the impact of the project activity on the environment.

The CCS risk and safety assessment needs to be carried out by independent assessors with sufficient expertise in that field. The expertise could relate to ISO standards on risk management.

Risk and safety assessment is a new challenge, for which little experience has accumulated. It also has the characteristics that (a) the existence or degree of the environmental impact of CO2 seepage is not clearly known; (b) the impact could appear after a very long time has elapsed since CO2 injection; and (c) there are no recognized international guidelines on how the assessment is to be carried out. Taking these characteristics into account, the sharing of information and experience could be very useful. A technical workshop, which is referred to in decision 7/CMP.6, could provide a good venue for this purpose.

(v) Liability

Liability issues, including those relating to the harmful effects of CO2 seepage on the human body, the environment, and social infrastructure, should be handled in accordance with the legislation and laws of each country involved. However, the manner in which liability issues are handled needs to be defined and agreed upon in advance by all countries involved, and clearly described in a PDD.

The treatment of the issue of non-permanence of CO2 storage should be properly addressed, and needs to be discussed further, although it is not desirable to take the same approach as with afforestation and reforestation project activities under the CDM, which have introduced provisions for the expiry of CERs. Such an approach would make it difficult for project participants to manage the investment costs of CCS-CDM, and will discourage their involvement. CERs from CCS-CDM should be treated in the same way as normal CERs, and should not lose validity even after a certain period of time.

Paper no. 6: Norway

Submission from Norway on

Carbon Capture and Storage in Geological Formations as project activities in the Clean Development Mechanism

At the sixth session of the Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol, the Decision -/CMP.6 invited Parties to submit their views related to carbon dioxide capture and storage in geological formations as a mitigation technology.

Norway welcomes the confirmation of the eligibility of carbon dioxide storage in geological formations as project activity in the Clean Development Mechanism. We further welcome the opportunity to present our views on appropriate modalities and procedures for this type of project activity. This submission should be considered in conjunction with our previous submissions on this issue.

1. Definitions

- Carbon dioxide capture and storage - a process consisting of the separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere.
- Leakage - the net change of anthropogenic emissions by sources of greenhouse gases which occurs outside the project boundary, and which is measurable and attributable to the CDM project activity.
- Physical leakage/seepage – CO_2 released from the storage site to the atmosphere.

2. General comments

If we are to reach our global long-term goal as stated in article 2 of the Framework Convention on Climate Change, we need to use a broad and comprehensive portfolio of mitigation options. Such a portfolio should include a variety of mitigation options. According to the IPCC, CCS has, after energy efficiency, the second largest potential for global emission reductions. In light of its vast potential of reducing emissions,
Norway sees carbon capture and storage in geological formations as an imperative part of such a broad and comprehensive mitigation portfolio.

The Intergovernmental Panel on Climate Change (IPCC) defines carbon capture and storage (CCS) as “a process consisting of the separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere”. CCS in general should not be viewed as a distinct technology, but rather as a vital mitigation option, consisting of various technological options, many of which are already individually commercially viable and proven.

Due to the importance of the energy sector as source of GHG emissions, most attention has so far been paid to capturing CO_2 from power generation. However, the most attractive conditions for capturing could be found in industrial sectors where plants generate gas streams with high concentrations of CO_2. Such streams are found in the chemical processes used to produce ammonia of hydrogen, in coal-to-liquids and gas-to-liquids processes, in blast furnaces and cement kilns and in the processing of natural gas. For dominating industrial sectors, such as cement, iron and steel production, ammonia production and refineries, CO_2 storage could therefore contribute to significant emission reductions.

The Executive Board (EB) of the Clean Development Mechanism (CDM) has approved methods that are relevant for parts of a CCS CDM project. Norway recommends using existing CDM rules and modalities where appropriate. Exception is to be made for the CCS specific issues not covered by the CDM rules and modalities. The text in this submission is therefore a general description in areas where existing rules and modalities may be applicable and more specific in areas where new may be needed.

3. Storage site selection criteria

According to the IPCC Special Report on CCS, a retention time of CO_2 for several thousand years can be obtained for well-selected, designed and managed geological storage sites. It is also most likely that the CO_2 may gradually be immobilised by various trapping mechanisms, so that it will be stored for up to millions of years. Thus, the selection of appropriate storage sites for CCS projects is of fundamental importance to ensure long-term permanence and the environmental integrity of the projects; and consequently, the selection of a storage site should be based on stringent and robust criteria.

The examination of possible storage reservoirs in geological formations should be based on e.g. best available scientific knowledge, knowledge obtained by intergovernmental and national governmental institutions, industry and research institutions.

The suitability of a geological formation for use as a storage site shall be determined through a characterisation and assessment of the potential storage complex and surrounding area pursuant to the criteria specified below. A geological formation shall only be selected as a storage site, if there is under the proposed conditions of use no significant risk of leakage, and if no significant environmental or health risks exist.

The following criteria should form the basis for storage site selection. The EB should ensure that storage sites proposed for CCS projects in the CDM have been thoroughly characterised and analysed, and that the documentation is a part of the Project Design Document (PDD).

1: No projects in international waters

Norway would not recommend projects using geological formations in international waters or projects that cross into international waters due to the legal complexities associated with such projects.

2: No significant risk of physical leakage

The long-term risk for physical leakage or seepage has to be minimised and only projects designed with a high expectation of no seepage should be approved.

The IPCC Special Report on Carbon Dioxide Capture and Storage states that “the proportion of CO_2 retained in appropriately selected and managed sites is […] likely to exceed 99% over 1,000 years”. Over time, it is also possible that the CO_2 will be immobilised by various trapping mechanisms.

3: Thorough analysis and assessment of geology and geophysics

The PDD should include thorough data analysis and assessment of the storage site's geology and geophysics.

4: Thorough analysis and assessment of hydrogeology

The PDD should include thorough data analysis and assessment of the hydrology and particularly any existence of drinkable ground water.

5: Thorough analysis and assessment of the geochemistry

The PDD should include thorough data analysis and assessment of the geochemistry, e.g. calculation and modelling of the CO_2 dissolution rates and mineralisation rates.

6: Thorough analysis and assessment of the geomechanics

The PDD should include thorough data analysis and assessment of the geomechanics, e.g. permeability, and fracture pressure.

7: Thorough analysis and assessment of the seismicity

The PDD should include thorough data analysis and assessment of the seismicity of the area surrounding the project.

8: Thorough analysis and assessment of potential pathways for physical leakage or seepage

The PDD should include thorough data analysis and assessment of the potential pathways for physical leakage or seepage. This includes all subsurface components such as wells and all other potential direct pathways that may lead to seepage of physical leakage, e.g., injection, observation of abandoned wells, mineshafts and boreholes.

9: Thorough analysis and assessment of the storage capacity

The PDD should include a thorough analysis and assessment of the storage capacity of the formation.

4. Risk & safety assessment

The modalities and procedures for CDM project activities require that the project participants shall develop a risk and safety assessment. A thorough risk assessment is therefore an integral part of any CCS CDM project activity and the assessment should include all relevant above-ground and subsurface installations and the storage site. The risk and safety assessment and the analysis will form the basis for determining the project boundary and for developing the monitoring plan.

Assessment of the risks and safety of a project should be based on international criteria and standards, like ISO31000 standard[13], and best industry practices and standards. Under the OSPAR Convention, it is developed Guidelines for Risk Assessment and Management of Storage of CO_2 Streams in Geological Formations offshore. These guidelines provide a generic guidance for CO_2 storage project activities in general, not directly related to CDM project activities. However, they cover many of the topics listed in Decision 2/CMP.5 and Decision -/CMP.6.

The risk and safety assessment of the storage site should include, inter alia:

i. Containment risks:
ii. Capacity and injectivity risks:
iii. Measurement, verification, accounting and reporting risks

The project participants should document the risk and safety assessment results in full and submit this with the PDD.

During the closure phase, a final risk and safety assessment should be carried out to establish that the risk levels are acceptable before storage site is relinquished to the host country.

5. Socio-environmental impacts assessment

An assessment of the possible impacts, both positive and negative, that the project may have on the environment shall be undertaken following the existing rules and modalities of the Clean Development Mechanism.

The Social-Environment Impact Assessment should cover, inter alia, how domains surrounding the project boundary may be affected by the project, possible effects of potential physical leakage or seepage of the stored CO_2, effects potentially induced seismicity or geological or any other potential consequences for the environment (both local ecosystems and the global climate), property, public health or global effects to the climate directly attributable to the clean development project activity during and beyond the crediting period.

6. Monitoring plan

Stringent monitoring plans shall be in place and be applied during and beyond the crediting period in order to reduce the risk to the environmental integrity of carbon dioxide capture and storage in geological formations.

The modalities and procedures for CDM project activities require that the monitoring plan for a project activity provides for e.g. the collection and archiving of all relevant data necessary for estimating greenhouse gas emissions and determination of project baselines. Identification of all potential sources of increased emissions outside the project boundary that are significant and attributable to the project activity during the crediting period should also be included. A monitoring plan is to be developed by the project participants and included in the PDD. The monitoring plan should be consistent with the existing modalities and procedures for CDM as well as the requirements of IPCC 2006 GHG Inventory Guidelines, relevant parts of the IPCC Special Report as well as available best industry practices. It is important that monitoring plan encompass and incorporate all site specific issues identified during site selection and the risk and safety assessment.

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[13] ISO31000: Risk management – Principles and guidelines

Proper monitoring of the storage site is required to ensure that any seepage/physical leakage from the site will be detected, accounted for and brought under control. It is important that the monitoring plan covers the CO_2 storage and addresses any possible seepage/physical leakage pathways. These pathways would have been identified during the analysis of the storage site (see 3. Storage site selection criteria) and the risk and safety assessment (see 4. Risk & safety assessment).

Modelling is a vital part of the different stages in the development of CCS projects. The models used build on extensive experience from the petroleum industry and other industries. Monitoring technologies and methods for environmentally sound storage of CO_2 are available and in use by industry. Valuable information on adaptation of these methods and techniques to CCS CDM project activities could be drawn from existing CCS projects and ongoing research projects. This includes well-known seismic as well as gravimetric techniques.

At appropriate intervals during the project, the fate of the CO_2 plume should be monitored, verified, accounted for and reported and the risk and safety assessment updated. This will require robust baseline data and the quantification of associated uncertainty ranges for the appropriate monitoring technologies to be established prior to CO_2 injection and a risk and safety assessment performed to provide assurance that the maximum risk during operation is acceptable. During the closure phase, a final risk and safety assessment should be carried out to establish that the risk levels are acceptable before storage site is relinquished to the host country.

The monitoring should go far beyond the crediting period (10 years or 7 years, with the possibility to be renewed twice). The responsibility for monitoring in the post crediting, post closure period, must be clearly defined and agreed between the project participants and the host country and this must be clearly addressed in the PDD (see 8. Liability).

7. Project boundary

According to the modalities and procedures for the CDM, “the project boundary shall encompass all anthropogenic emissions by sources of greenhouse gases under the control of the project participants that are significant and reasonably attributable to the CDM project activity”.

The project boundary of the CCS CDM project activity should comprise of any potential greenhouse gas emissions resulting from the three separate processes; capture, transportation, and injection/storage of CO_2. This includes, inter alia, fugitive emissions, indirect emissions resulting from the use of electrical and other energy sources required for the project and potential seepage.

As physical and geochemical properties of geological formations may vary, the definition of project boundary should be project specific to make sure all potential project-related emissions are accounted for. Items that should be properly addressed in the project boundary include:

i. The above ground components, e.g., the installation where the CO_2 is generated, the capture facility, any additional CO_2 treatment facilities, the compression facility, the transportation equipment and booster stations along a pipeline or offloading facilities in the case of transportation by ship, any reception facilities or holding tanks at the injection site, and the injection facility. These components present similar technical elements to any CDM project. Emissions from these components can therefore be calculated using techniques and approaches applied in other CDM project activities.

ii. Subsurface components and all other potential direct pathways that may lead to seepage of physical leakage, e.g., injection wells, observation of abandoned wells, mineshafts and boreholes. These potential seepage pathways will need to be monitored as part of the overall project monitoring plan.

iii. The formation where the CO_2 is stored. Site characterisation and storage performance assessment studies carried out in advance of CO_2 injection operations will define the boundary for the storage site.

iv. The geology surrounding the storage site such as the cap-rock or spill points at the lateral edges of a geological structural trap.

Cross-border projects

Cross-border projects are allowed under the CDM and do not pose any additional challenges from a project boundary perspective, with respect to CO_2 transported from one country to be stored in another or where two(or more) countries share storage sites. It does, however, pose the question of determining liabilities in the post-closure post crediting period of the project, and would entail resolving legal responsibility and liabilities for the involved countries.

8. Liability

The emission reductions resulting from each project activity under the CDM shall, according to Kyoto Protocol, contribute to real, measurable and long-term benefits to the mitigation of climate change. As stated earlier, it is vital for Norway that CERs from CCS projects are considered as solid as CERs from other CDM emission reduction projects.

On this basis we see a need for clearly defined liability for the short, medium and long-term liability of stored CO_2.

In the PDD, the participants should demonstrate procedures for the proper and safe sealing and abandonment of the storage. It should also demonstrate all available evidence indicates that the stored CO_2 will be completely and permanently contained within the formation.

Furthermore the PDD should show how binding regulatory provisions will be in place to permit, regulate and control the CCS project, including in the post closure post crediting period. Thus the PDD must clearly define: short-term, medium-term, and long-term liabilities; accounts for any seepage and the remediation required in the different periods.

The short to medium-term liability should as a rule rest with the project participants. Post-closure/ medium-term and long-term liability should be agreed upon between the host country and the project participants.

The EB should ensure that the issue of liability is appropriately addressed in the PDD.

Cross-border projects and liability

If cross-border projects are to be registered in the CDM, the PDD shall include clearly defined and agreed liability between the involved host countries. The PDD shall also be approved by all the involved host countries’ DNAs.

9. Reporting, accounting and verification

Norway recommends using existing CDM rules and modalities where appropriate. .

Capture, transportation and injection processes will require additional energy. Any emissions due to this should be accounted for and be subtracted from the amount of CO_2 stored.

The total amount of CO_2, including emissions from the additional energy consumption necessary to operate the capture, transportation and injection processes, can be estimated by using the methods and guidance in the IPCC 2006 GHG Inventory Guidelines. The capture processes are well defined in space and time, and their emissions (from additional energy use, fugitives etc.) are covered by the Guidelines. For estimation purposes, the reduced CO_2 emissions should be determined by measuring the amount of CO_2 stored and deducting it from the total amount of CO_2 produced.

The location of guidelines for compiling inventories of emissions from the CO_2 capture and compression system depends on the nature of the CO_2 source:

- Stationary combustion systems (mainly electric power and heat production plants): Volume 2, Chapter 2, Section 2.3.4.
- Natural gas processing plants: Volume 2, Section 4.2.1.
- Hydrogen production plants: Volume 2, Section 4.2.1.
- Capture from other industrial processes: Volume 3 (IPPU) Chapter 1, Section 1.2.2, and specifically for
  (i) Cement manufacture: IPPU Volume, Section 2.2
  (ii) Methanol manufacture: IPPU Volume, Section 3.9
  (iii) Ammonia production: IPPU Volume, Section 3.2
  (iv) Iron and steel manufacture: IPPU Volume section 4.2

Volume 2, Chapter 5 covers carbon dioxide transport, injection and geological storage.

10. The potential for perverse outcomes

There have been concerns raised about the possibility that emissions reductions from CCS activities would overflow the global CDM market. To our knowledge this argument is not based on factual figures as far as the near and mid-term is concerned.

It is unlikely that potential CCS-projects will have a large crowding-out effect on other CDM project activities, due to the long lead times for implementation and relative high technology costs. The potential market effect of any specific technology or project activity in subsequent commitment periods under the Kyoto Protocol will depend on the ambition level and content of these commitments, and should not have any impact on rules and modalities for CDM projects.

11. International regulations, guidelines etc.

Other conventions have addressed issues and adopted guidelines relevant to the international regulation of the application of carbon dioxide capture and storage, including risk assessment, environmental impact assessment and legal aspects: e.g. the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and the OSPAR Convention.

Under the OSPAR Convention Guidelines for Risk Assessment and Management of Storage of CO_2 Streams in Geological Formations have been developed. These guidelines provide a generic guidance for offshore CO_2 storage activities in general, not directly related to CDM project activities. However, they cover many of the topics listed in Decision 2/CMP.5 and Decision -/CMP.6.

The OSPAR Convention is the current legal instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic. Work under the Convention is managed by the OSPAR Commission, made up of representatives of the Governments of 15 Contracting Parties and the European Commission, representing the European Community. The mission of the OSPAR Convention*” is to conserve marine ecosystems and safeguard human health in the North-East Atlantic by preventing and eliminating pollution; by protecting the marine environment from the adverse effects of human activities; and by contributing to the sustainable use of the seas.”*

In 2006, amendments to the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Protocol) were adopted. The amendments regulate the sequestration of CO_2 streams from CO_2 capture processes in sub-seabed geological formations, for permanent isolation, thereby creating a basis in international environmental law to regulate this practice. Guidelines on how to store CO_2 in sub-seabed geological formations were adopted by the Parties to the London Protocol in 2007. These guidelines address how to store CO_2 in a manner that meets all the requirements of the London Protocol and is safe for the marine environment, over both the short- and long-term. The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972, the "London Convention" for short, is one of the first global conventions to protect the marine environment from human activities and has been in force since 1975. Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter. In 1996, the London Protocol was agreed to further modernise the Convention and, eventually, replace it. Under the Protocol all dumping is prohibited, except for possibly acceptable wastes on the so-called "reverse list". The Protocol entered into force on 24 March 2006.

Similarly to the Guidelines under the OSPAR Convention, the regulations and guidelines under the London Protocol do not directly apply to CDM project activities, but provide an environmentally safe framework for storage of CO_2. Offshore CCS CDM projects in countries which are Party to the London Protocol will need to follow these regulations and guidelines when they enter into force. The Parties to the Kyoto Protocol may chose to build on or use elements in the existing regulatory work developed and adopted by other Conventions.

12. Fully fungible Certified Emission Reductions

For Norway it is important that Certified Emission Reductions (CER) resulting from environmentally sound CCS project activities under the CDM be considered as solid and viable as CERs from other CDM project activities.

Paper no. 7: Qatar

SUBMISSION BY THE STATE OF QATAR

Decision -/CMP.6: Carbon dioxide capture and storage in geological formations as clean development mechanism project activities

(21 February 2011)

1. The State of Qatar welcomes decision -/CMP.6 which sanctions carbon dioxide capture and storage in geological formations (CCS-GF) as project activities under the clean development mechanism (CDM) provided that the outstanding issues referred to in decision 2/CMP.5 (section 29) are properly addressed. These issues which continue to constrain and limit the use of CCS-GF under the CDM include: (a) Non-permanence, including long-term permanence; (b) Measuring, reporting and verification; (c) Environmental impacts; (d) Project activity boundaries; (e) International law; (f) Liability; (g) The potential for perverse outcomes; (h) Safety; (i) Insurance coverage and compensation for damages caused due to seepage or leakages.

2. Qatar is pleased to respond to the invitation contained in decision -/CMP. 6 to submit views on how to address the issues, referred to in the above section, in the modalities and procedures stated in paragraph 2 of the decision.

3. Qatar understands that the Subsidiary Body for Scientific and Technological Advice will consider the Parties' views while elaborating the required modalities and procedures needed to include CCS-GF as project activities under the CDM.

4. Despite the climate change mitigation potential and the possible contribution to sustainable development in developing country Parties as CDM project activities, CCS-GF deployment at the present, is best suited for Annex 1 Parties and few developing countries, particularly those who already managed to establish the needed legal and regulatory CCS framework. Moreover, CCS-GF deployment in host countries requires capacity and know-how to assess the various issues listed above, some of which are detrimental to human health, safety and environmental protection for most developing countries. These constraints constitute significant barriers to

host CCS-GF projects particularly for some developing countries such as Qatar. The challenges include: (i) ability to use tier 3 methodologies for monitoring, accounting and verification of GHGs; (ii) capacity to use modeling and inherent uncertainty of models to assess project boundary, project emissions, leakage and adequacy of infrastructure including long term permanence of carbon dioxide storage, and the capacity of the geological formation to trap CO2 physically and chemically; and (iii) support to develop needed CCS technology.

5. Qatar remains committed, in principle, toward CCS as a useful instrument to mitigate emissions in the coming decades.
6. Currently, Qatar supports a number of research and technology initiatives to investigate and understand the major challenges relating to deployment of CCS-GF locally.

Paper no. 8: Saudi Arabia

SUBMISSION BY SAUDI ARABIA

February 21, 2011

Views on Carbon Capture and Storage in Geological Formations as Clean Development Mechanism Project Activities

Saudi Arabia welcomes the opportunity to submit it's on views on how the issues referred to in Paragraph 3 of Document FCCC/KP/2010/L.10 to address the modalities and procedures referred to in paragraph 2 of the same document.

Saudi Arabia strongly supports the Decision at Cancun to make carbon dioxide capture and storage in geological formations eligible as project activities under the clean development mechanism. All studies related to CCS, including IPCC assessment reports and the special report on CCS, stressed that CCS provides great potential for mitigating greenhouse gases. CCS technology alone can reduce up to 45% of total global emissions. CCS also helps many developing countries to contribute to global mitigation efforts to achieve common goals. The acceptance of eligibility of CCS under CDM will help in the faster deployment and dissemination of the technology and the reduction of costs associated with it.

CCS technology has been proven through a number of demonstration and well as large scale projects in different countries, some of which have been in operation for significant number of years. Results from all these projects conclude that CCS is the most effective win-win technology for combating greenhouse gas emissions, win to reducing emissions and win for reducing impacts on developing countries. All initiatives to promote and deploy this technology under through CDM are important.

All concerns related to CCS and modalities of implementation can easily be resolved. There are number of existing intergovernmental multilateral bodies and institutions, including, IPCC that already produced significant work in that regards. This is in addition to the existing and ongoing work from many respected research institutions. Such work can be easily captured to provide specific modalities and procedures for the CCS under CDM.

Addressing issues from Decision-/CMP.16 paragraph 3 of Documents FCCC/KP/2010/L.10.

- ### Site selection criteria (Para. 3.a & d)

In order to ensure a permanent storage of CO2 and manage the risk, site characterization accurate procedures need to be followed as indicated in IPCC SR, IPCC GHG Inventory Guidelines 2006, CSLF and London Protocol, Risk Assessment and Management Framework for CO2 Sequestration in Sub-Seabed Geological Structures.

This is most important to ensure that CCS provides real, measurable, long-term emissions reductions and is compatible with the current Modalities and Procedures of the CDM. Criteria based on the above work should be provided to the EB for them to assess site selection in proposed CCS projects.

- ### Monitoring plans (Para. 3.b)

There are current available techniques, equipment and processes that are in use in number of projects to monitor and assess the integrity of the storage site as indicated in IPCC 2005, Special Report on CCS, IPCC 2006 GHG Inventory Guidelines and London Protocol, Risk Assessment and Management Framework for CO2 Sequestration in Sub-Seabed Geological Structures. Criteria based on the above work should be provided to the EB for them to assess monitoring plans in proposed CCS projects.

- ### Modelling (Para. 3.c)

Climate Change science, impacts and all variables, depend on the modeling; smaller modeling is an important tool used to support work undertaken during the site characterization and selection phases, as well as the risk assessment and the development and implementation of the site monitoring plans. The use of modelling in combination with monitoring is very important to ensure that CCS provides real, measurable, long-term emissions reductions and is compatible with the current Modalities and Procedures of the CDM.

- ### CCS boundaries and Transboundary (Para. 3.e, f, g&h)

Project boundaries for the storage would be defined by the site characterization, site selection and risk assessment exercise. Any release of CO2 emissions from the project boundaries will be determined by the site specific monitoring. Many UN bodies developed and adapted guidelines, such as the 2006 IPCC GHG Guidelines, that provide methodologies for estimating CCS project-related emissions, also offering guidance on instances where more than one country utilize a common storage site, and in the case where a storage site occurs in more than one country. These guidelines could be followed for defining different new projects; in addition to London Protocol, Risk Assessment and Management Framework for CO2 Sequestration in Sub-Seabed Geological Structures guidelines.

- Accounting for project or Leakage emissions (Para. 3.i)

All emissions under the control and attributable to a CCS project activity can easily be accounted for. Such accounting for total redactions from CCS projects should not be different from other redaction projects under the CDM.

There are many reference to this is issues can be referred to such as:

- IPCC 2006 Guidelines approach to accounting for project emissions
- The definition of the leakage under the CDM

- Risk and safety assessment (Para. 3.j,k ,l& o)

Environmental Impact Assessment (EIA) will be developed for each CCS project before implementation; such EIA includes an assessment of risks and safety. IPCC and other international bodies have faithfully established EIA guidelines that address such issues. In addition to appropriate site selection based on available subsurface information, as well as monitoring programmes to detect problems if they occur, and a regulatory system including the appropriate use of remediation methods to stop or control CO2 releases.

Corrective measure from unintended consequences associated with CCS projects should be explored as more experience is gained from a wider application of CCS projects.

- Liability (Para. 3.m & n)

Liability should not be used as an obstacle for hindering progress on projects for which Environmental Impact Assessment (EIA) have been completed. Risk and safety issues were addressed within the EIA where any mater related to liability can be further explored and elaborated. The main liability issue can be associated with possible small leakage. It should however be noted that the IPCC concluded that on the fraction of injected CO2, it is very likely that projects can exceed 99 per cent long-term permanence.

Appropriate site selection, modelling, risk assessment, operation, and monitoring are of the upmost importance to ensure the long term permanence of the CO2 and minimize liability. The detail on how to implement liability for damage to the environment, property or public health should be left to host country regulations. Further guidance is provided on treatment of short and long term liability with respect to the Modalities and Procedures in the Implications Report to UNFCCC Sections 2.3.1 and 5.1 (2009).

References

Implications of the Inclusion of Geological CO2 Capture and Storage as CDM Project Activities, A report for the UNFCCC, UNFCCC/EB50 Annex 1 (2009), (http://cdm.unfccc.int/EB/050/eb50annagan1.pdf)

- IPCC SR CCS 2005
- IPCC GHG Guidelines 2006
- London Protocol (various 2004-2009)
- OSPAR (2007)

Paper no. 9: United Arab Emirates

Contents

Executive Summary

CO_2 capture and storage in deep geological formations (e.g., depleted oil and gas reservoirs, aquifers, salt domes, etc.) has emerged as one of the most viable and promising technologies for effective large scale reduction of CO_2 emissions. World-wide experience with CCUS projects has been gaining momentum and proves that CO_2 can be stored safely and permanently without significant leakage. There are around 80 large scale integrated projects at various stages of the asset lifecycle, and a total of almost 200 active projects at various scales and stages of the CCS chain globally. The vast majority of these are in developed countries.[14]

The eligibility of Carbon Capture and permanent Storage (CCS) projects as CDM projects is critical in meeting GHG emissions reductions targets to mitigate climate change, providing energy security and economic stability, and ensuring that this important technology is successfully transferred to developing countries.

A summary of the responses to the issues raised by the CMP regarding the acceptance of CCS in the CDM follows:

- **The importance of site selection and characterization**
  The importance of site selection and site characterization in order to ensure safe CO_2 storage and long-term permanence of containment is widely recognized. These issues are addressed by a variety of guidance documents, including the recently issued EU Directives and DNV's CO2QUALSTORE best practice guidelines. We would suggest the EB use these guidelines to inform the development of their own site selection criteria. Furthermore, the undertaking of such challenges is well within the capabilities of National Oil Companies, such as the Abu Dhabi National Oil Company (ADNOC). Geological CO_2 storage can be safely and securely accomplished in a variety of geological settings such as depleted gas fields, depleted or active oil fields, deep saline aquifers, deep coal seams, caverns, salt domes and organic rich shales. As a requirement, the selected geological sites should have good CO_2 injectivity, adequate storage capacity, good sealing cap rock, and stable geological settings/environment.

- **The scope and role of risk assessments in CCS projects**
  A wide-scope, dynamic, continuously refined and updated dynamic risk management and mitigation (DRMM) strategy should be developed and integrated throughout the CCS project lifecycle as a requirement. DRMM should commence at a very high level during the first stages of site screening, and should include safety, social, environmental and economic factors. DRMM should be further refined as the site selection process progresses, ultimately resulting in site-specific performance-assessment-based frameworks that quantify adverse consequences and event likelihood while keeping track of key uncertainties. Besides shaping the ultimate storage site selection, the final DRMM assessment should form the basis of the monitoring and measurement program, as well as shape the corrective measures strategy.

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[14] Global CCS Institute. "The Status of CCS Projects: Interim Report." 2010.

- **Strict monitoring requirements**
  A comprehensive quantitative understanding of the reservoir is required prior to, during, and after the injection of CO_2. By combining model predictions and concrete measurements one can be in a position to generate predictions (CO_2 migration path and CO_2 process performance) that are physically realistic and also consistent with field data. CCUS projects require multiple types of observations, each sensitive to different physical and chemical properties acting over different spatial and temporal scales. The procedure linking monitoring data and models will be an ensemble data assimilation algorithm that will use the models to generate a set of possible system descriptions, all consistent with monitoring observations. This makes it possible to provide a cost-benefit analysis of the importance of different data types, as well as to design robust operating and monitoring strategies that can work well over a range of conditions.

- **The applicability of modeling for CCS projects**
  Development of a reliable modeling framework (analytical models and an accurate and robust coupled compositional fluid flow and geomechanics simulator) is the most critical scientific and engineering challenge that must be tackled and resolved in order to be able to make realistic and accurate subsurface performance forecast of CO_2 utilization and permanent sequestration processes. Modeling is an essential part of any risk based project and is routinely used in oil and gas field management and decision making. Modeling *complements*, and does not replace monitoring.

- **Project boundaries**
  CCS project boundaries should include all surface facilities as well as an extended portion of the subsurface. It is important to note that an element of flexibility should be maintained with respect to the lateral boundaries of the subsurface in case CO_2 migrates across such lateral boundaries but remains safely contained.

- **Accounting for seepage**
  Geochemical and surface monitoring must be performed in order to detect, measure, and account for any CO_2 seepage from the storage.

- **Liability**
  Overall liability should be with the project proponent especially throughout the project life cycle, followed by long term liability under host country responsibility.

1. Introduction

The United Arab Emirates welcomes the decision of the Conference of the Parties to include CCS under the clean development mechanism as stated in the CMP.16 on carbon dioxide capture and storage in geological formations as clean development mechanism project activities, providing that issues raised and identified in decision 2/CMP.5 paragraph 29 are addressed and resolved in a satisfactory manner. The United Arab Emirates also welcomes the invitation to address these issues. Accordingly, we hereby submit our views and recommendations on how to address them in the modalities and procedures.

As noted by the IEA (World Energy Outlook 2010[15], and Energy Poverty Report[16]), the need to keep pace with rising global energy demand means that fossil fuel will continue to play a central role in the global energy mix for the foreseeable future. CCS is therefore an indispensible component of a broader strategy to tackle the challenge of climate change and limit the global average temperature rise to 2 degrees Celsius above pre-industrial levels. The use of CCS can and should complement other approaches to to ensuring a balanced energy portfolio, such as increased efficiency and the promotion of renewable energy. This balance is essential to addressing climate change while still providing reliable, affordable energy for the developing world.

Yet CCS projects still face considerable barriers, particularly barriers related to cost. The inclusion of CCS under the CDM will help to address these cost-related and other barriers, paving the way for the transfer of this important technology to developing countries.

Many governments have perceived an immediate need to start taking measures to reduce CO_2 emission into the atmosphere. One such measure is carbon capture from power generation stations and storage in geological structures such as oil and gas reservoirs or aquifers.

The United Arab Emirates (UAE), as a result of its rapid population and economic growth, has one of the highest carbon footprints per capita in the world. The Abu Dhabi government has established an ambitious plan to capture CO_2 from a wide range of large carbon emitting industrial plants, and transport it through pipelines to inject it for enhanced oil recovery and/or subsurface storage in geological formations. This is one way in which the UAE and, especially, Abu Dhabi, is taking steps towards reducing greenhouse gas emissions and, ultimately, achieving carbon neutrality. Indeed, carbon capture use and storage (CCUS) has emerged as a critical enabling technology for the continued use of fossil fuels in a carbon constrained world with minimizing the carbon footprint of this energy source.

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[15] International Energy Agency. “World Energy Outlook.” 2010.

[16] International Energy Agency. “Energy Poverty Report.” 2010.

1.1. Purpose /scope of submission

This submission considers the issues raised in **Decision -/CMP.6 on "Carbon dioxide capture and storage in geological formations as clean development mechanism project activities"** at *The Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol*, *Recalling* decisions 7/CMP.1, 1/CMP.2, 2/CMP.4 and 2/CMP.5, *Taking into account* Article 12, paragraph 5(b) and 5(c), of the Kyoto Protocol.

Our comments focus mainly on the subsurface storage issues related to carbon capture and storage. We believe that issues related to the capture and transportation components of the CCS chain can be addressed under the already existing modalities and procedures under the CDM.

2. Issues listed in the Draft decision -/CMP.16 to be addressed by the CDM modalities and procedures

2.1.2. Site Selection

2.1.2. Description of technical issue to be addressed

Site selection of CCS projects is determined by the suitability of a geological formation for use as a storage reservoir. Suitability is determined by a site's geology, tectonic regime, depth of burial, surface characteristics, likely trapping mechanisms, and anticipated seepage pathways.

A geological formation should only be selected as a storage reservoir if, under the proposed conditions of use, no significant risk of either seepage or contamination exists. We recommend the development of a standard definition of what constitutes "significant risk."

Draft Decision Paragraph 3 Subparagraph (a): The selection of the storage site for carbon dioxide capture and storage in geological formations shall be based on stringent and robust criteria in order to seek to ensure the long term permanence of the storage of carbon dioxide and the long-term integrity of the storage site; **Subparagraph (d)** The criteria for site selection and monitoring plans shall be decided upon by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol and may draw upon relevant guidelines by international bodies, such as the 2006 IPCC Guidelines for National Greenhouse Gas Inventories;

2.1.2. Recommendations on addressing site selection in modalities and procedures

Because each site is unique, a project proponent applying for a CCS project under the CDM should be required to include a comprehensive and clear explanation of the suitability of their proposed site. Following the suggestion made by the IPCC in their Special Report on Carbon

Dioxide Capture and Storage, at minimum, sites must (1) have adequate capacity and injectivity, (2) include a satisfactory sealing caprock or confining unit and (3) consist of a sufficiently stable geological environment to avoid compromising the integrity of the storage site.

CDM project participants engaging in CCS activities should also be required follow state-of-the-art site selection procedures which follow guidance set out by national or international standards or legislation. The Executive Board (EB) should refer to the selection criteria set out in the EU Directive on the geological storage of carbon dioxide[17] or as described in the guidelines prepared by DNV in CO2QUALSTORE [9] as examples of "best practice" as they undertake the development of their own guidelines on site selection.

For each site, a site selection assessment should be undertaken, and should include a risk assessment as well as a risk mitigation plan. Minimum site criteria should be met, and uncertainty with respect to seepage should be addressed in more stringent monitoring requirements. The EB should develop a standardized definition of minimum site criteria, and establish an uncertainty threshold below which the application of more stringent monitoring requirements are applied. Overall, the UAE believes that significant seepage is unlikely if CCS projects are selected carefully, operated in strict adherence to regulations, and responsibly monitored over long time frames.

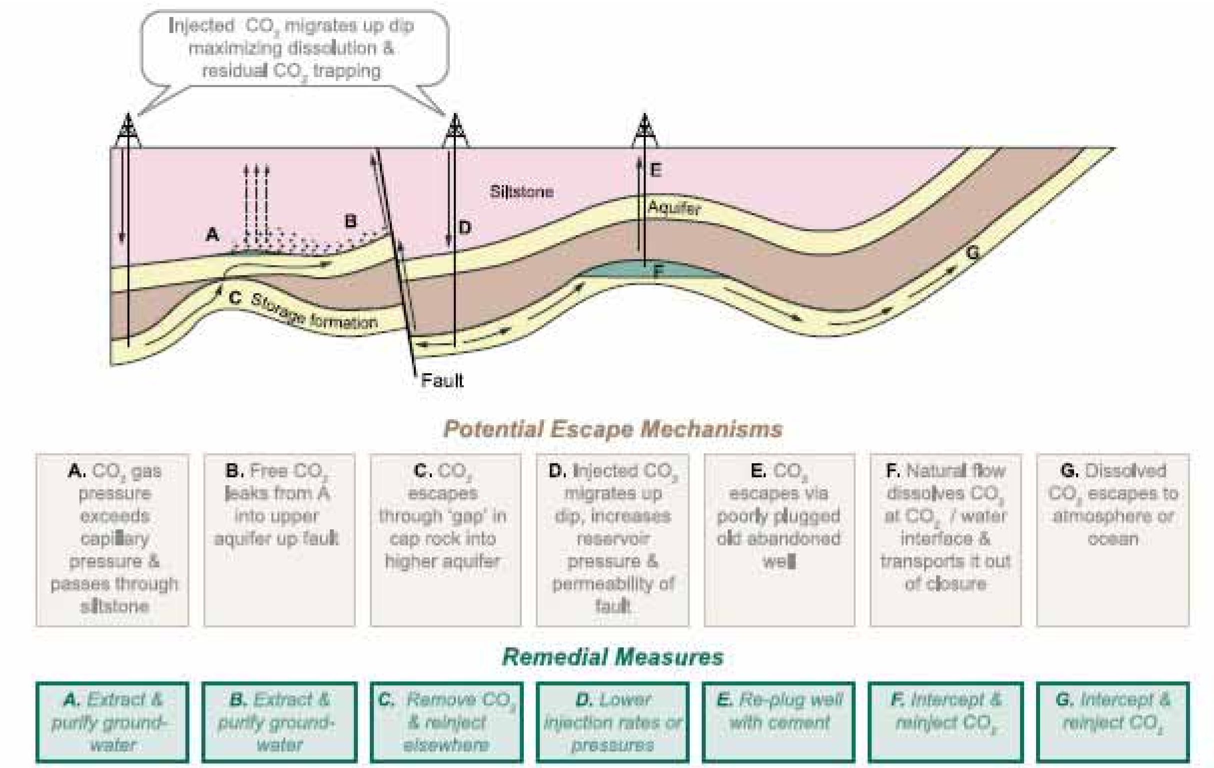

Fig. 1: Potential escape routes for CO_2 injected into saline formations, and remedial measures (from IPCC, 2005)[18]

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[17] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide.

[18] IPCC Special Report on Carbon Dioxide Capture and Storage. 2005.

In addition, any site assessment should have to be approved by a national authority relevant to the sector, before it is submitted to the UNFCCC and considered as CDM project.

The UAE recommends that site selection be addressed in the CDM modalities and procedures by using the methodology proposed below.

Proposed Site Selection Methodology

Information Input Requirements

i. Geologic information including descriptions of the geologic units above and within the reservoir, locations of mapped faults, and information about the regional tectonics including the regional stress field.

ii. Geophysical information including 3D seismic surveys, interpretations of processed results from the 3D surveys, and information about regional and local seismicity. Both raw and processed active seismic data will be needed to assess the continuity and thickness of the cap rock, existence of faults within the reservoir and caprock, and reservoir heterogeneity. Velocity models to be used for migration and any updated information about the velocity model, particularly for the reservoir and caprock regions will be essential for conducting future seismic and geomechanical modeling. Sonic logs taken above and within the reservoir will be useful for calibrating seismic data and as complementary information for use in interpretation of other geological and geophysical data.

iii. Geomechanical information that can be used to infer the state of stress within the reservoir and caprock. This information may be obtained from borehole data such as breakouts inferred from caliper and televiewer logs, minifrac results, or information about fracture anisotropy within the reservoir, and mud loss events. Any data from boreholes needs to have associated wellbore location information.

iv. Rock/fluid properties information will be needed about properties of both reservoir and caprocks, as well as fluid properties. Rock properties include permeability, porosity, and mineralogy, which are essential to determine the injectivity of the formation and the containment properties of the caprock. Fluid properties include salinity of the brine, which is key to assessing dissolution trapping. Both geological descriptions and results of geophysical measurements will be essential for evaluating the candidate sites.

v. Locations and information about all existing wells will be needed to assist in the interpretation of the geophysical and geological data. Wellbore trajectories will be helpful for placing well information within a 3D model of the reservoir region. In addition, this information will help to determine which wellbores can be used in monitoring of injections into the reservoir. Information about well completions will help to better characterize the likelihood of existing wells as potential seepage pathways for injected CO_2.

Individual Site Characterization Tasks[19]

i. **Compiling all available data** for each proposed site, evaluating data quality, and making recommendations for new data that needs to be collected. The goal is to ensure that all background information is available for studies that need to be conducted to both characterize the reservoir and determine possible mechanisms for escape of CO_2.
ii. **Conduct evaluation of available data** to make a preliminary assessment of storage capacity as well as discussing the challenges related to monitoring each site.
iii. **Delineation of the reservoir architecture** including known and inferred structures within the reservoir and caprock that will act as barriers or facilitators for migration of injected fluids. This will likely involve further analysis of active seismic data and evaluation of changes in the reservoir that have accompanied previous production from the reservoir.
iv. **Evaluation and ranking of potential target formations.** This will build upon the initial ranking performed by the project participant/project operator. The most important criterion is seepage risk, which depends upon the integrity of the seal, and injectivity. Capacity is also important, especially to ensure the ability to ramp up CCS operation over the next few decades.

In addition, in line with the recommendations set out in the external assessment report for the UNFCCC[20] and in the annotations of EB 50, we recommend that a CCS Working Group under the UNFCCC should be established to further elaborate and fully describe:

- Minimum criteria for CO_2 storage site characterization;
- Procedures for site selection, risk assessment, and mitigation plans, drawing on the existing knowledge base such as the EU directive, and DNV guidelines for site selection[21];
- A Code of Conduct for the operation and monitoring of reservoirs;
- In the case of CCUS projects, a requirement for a percentage of “breakthrough” to be recovered and re-injected in the reservoir in addition the CO_2 injected in the base case.

We would also suggest that suitable site selection for long-term permanence would benefit from the development of an international (or host country) environmental regulatory framework that

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[19] Abu Dhabi National Oil Company recommended guidelines.

[20] Implications of the Inclusion of Geological Carbon Dioxide Capture and Storage as CDM Project Activities, http://cdm.unfccc.int/EB/050/eb50annagan1.pdf

[21] CO2QUALSTORE – Guideline for Selection and Qualification of Sites and Projects for Geological Storage of CO_2, DNV, 2010; http://www.dnv.com/binaries/CO2QUALSTORE_guideline_tcm4-412142.pdf

provides guidance on storage security and includes clear criteria for site selection, risk assessment, monitoring, and long-term ownership.

2.2. Monitoring

2.2.1 Description of technical issue to be addressed

A project participant/project operator must sufficiently monitor their storage site to:

(i) detect seepage or contamination, and

(ii) estimate the flux of CO_2 released to the atmosphere or hydrosphere if such a release is detected.

Draft Decision Paragraph 3

Subparagraph (b) Stringent monitoring plans shall be in place and be applied during and beyond the crediting period in order to reduce the risk to the environmental integrity of carbon dioxide capture and storage in geological formations;

To enable this level of monitoring, the following types of measurements and assessments are important:

- Fluid pressures, displaced fluid characteristics, fluxes, and composition in injection for a sample of monitoring wells;
- Active seismic measurements ranging from cross-well, to VSP, to 4-D surface seismics;
- Passive seismic measurements, including measurements that rely on induced seismicity;
- Geodetic measurements, including data from existing or newly deployed GPS stations and InSAR surveys;
- Time-lapse microgravity and/or gradiometry measurements;
- Electrical resistance tomography;
- Geochemical and surface monitoring of atmospheric CO_2 concentrations;
- Detection of corrosion or degradation of the injection facilities;
- Comparison between the reported and forecast behavior of CO_2 in the storage complex; and
- Assessment of the effectiveness of any corrective measures taken.

A broad range of technologies and methods for monitoring CCS projects are available, and the decision of which to apply varies depending on the specific project site. We recommend as a reference guide Srivastava's comprehensive overview of various methods of monitoring CO_2 storage in deep geological formations (2009). His methods are subdivided into (i) atmospheric monitoring techniques, (ii) near surface monitoring techniques and (iii) subsurface monitoring techniques, and are explained in detail in the appendices I-III of Srivastava (2009) and Annex ii of EU directive[22].

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[22] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide.

2.2.2. Recommendations on addressing monitoring in modalities and procedures

Unlike existing CDM project activities, and their modalities and procedures, monitoring for carbon capture and storage activities should require three phases, namely (i) pre-project monitoring, (ii) monitoring during operation and injection and (iii) post injection operation. Monitoring will need to extend beyond the crediting period of the project; the appropriate length of that time period should be determined by the EB or CCS Working Group.

Monitoring plans will need to vary across each of these phases as well. There should be a requirement that the monitoring plan be updated frequently (at a minimum, every five years) to account for changes to the assessed risks, learning, technical developments, and the evolution of best practices; however, excessive administrative burden or cost should be avoided in the application of this requirement. Updated plans should be re-submitted to the Host country and EB for approval.

Reporting

In addition to existing requirements for CDM project monitoring, reporting and verification, it is recommended that for CCS CDM projects, the project participant/project operator be required to submit annually to the Host country and CDM-EB:

- Reports on the measurements and assessments listed above in section 2.2.1;
- The quantities and composition of the CO_2 streams captured in the reporting period;
- Proof of the maintenance of the sufficient funds to address both short and long term liabilities; and
- Other information the Host Country and CDM-EB reasonably considers relevant for the purposes of assessing compliance with relevant storage permit conditions.

Inspections

The Host Country and CDM-EB, or an independent verifier elected on their behalf, should have the authority to conduct routine and non-routine inspections of all storage reservoirs for the purposes of checking and promoting compliance. Inspections could include activities such as visits to the injection facilities, assessing the relevant injection and monitoring operations carried out by the project participant/project operator, and checking all relevant records kept by the project participant/project operator. Routine inspections should be required at least every 5 years, following at least one calendar month's prior written notice to the project participant/project operator. Non-routine inspections should also be carried out at the discretion of CDM-EB/host country, within the guidelines of reasonable frequency. Following each inspection, the inspector should be required to prepare a report on the results of the inspection. The report should evaluate compliance with the requirements of the storage permit and the project parameters as established in the Project Design Document (PDD), and indicate whether or not further action is necessary. The report must also be communicated to the project proponent/project operator concerned.

In line with the recommendations as set out in the external assessment report for the UNFCCC[23] and in the annotations of EB 50, page 15, we recommend further elaboration of, and commitment to, the following elements:

1) Monitoring methodologies should set overall objectives while leaving flexibility in the monitoring programme details, so as to allow the most appropriate monitoring techniques to be selected given specific geological situations.
2) For each project, the monitoring programme and techniques should be derived from the site characterisation and modelling for the particular site, and fully described in the PDD so that they can be assessed.
3) The EB might wish to consider developing criteria for the assessment of monitoring methodologies and plans for geological CO_2 storage.
4) Verification of monitored reductions in anthropogenic emissions of CCS CDM project activities requires a DOE with appropriate CCS expertise.
5) Impose a requirement that a country wishing to host a CCS CDM project activity must notify the UNFCCC that, conditional on the registration of a project, it will commit to the post-crediting period responsibility for monitoring.

(Source: implication of the Inclusion of Geological Carbon Dioxide Capture and Storage as CDM Project Activity (EB 50, Annotations, Annex 1, page 15)

Unlike the monitoring requirements under existing CDM modalities and procedures, which are limited to the credit period, we recommend including the provision of monitoring prior to and beyond the credit period. Furthermore, flexibility has to be given to the project participants to change and update the monitoring plan and obtain necessary approvals. The Executive Board should develop procedures to address changes to the monitoring plans, including an approval process via a DOE and a technical committee.

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[23] Implications of the Inclusion of Geological Carbon Dioxide Capture and Storage as CDM Project Activities, http://cdm.unfccc.int/EB/050/eb50annagan1.pdf.

2.3. Modeling

2.3.1 Recommendations on addressing modeling in modalities and procedures

Modeling is not, and should not be used as a tool to calculate emission reduction volumes. It does however have a crucial and complementary role to play in evaluating and assessing the behavior of CO_2 injection, storage, CO_2 plume movement and trapping in the given geological formation. Data derived from monitoring is invaluable to update numerical models and to improve existing or future storage operations and vice versa.

Draft Decision Paragraph 3

Subparagraph (c) Further consideration is required as regards the suitability of the use of modeling, taking into account the scientific uncertainties surrounding existing models, in meeting the stringency requirements of such monitoring plans, in particular taking into account the 2006 IPCC Guidelines for National Greenhouse Gas Inventories;

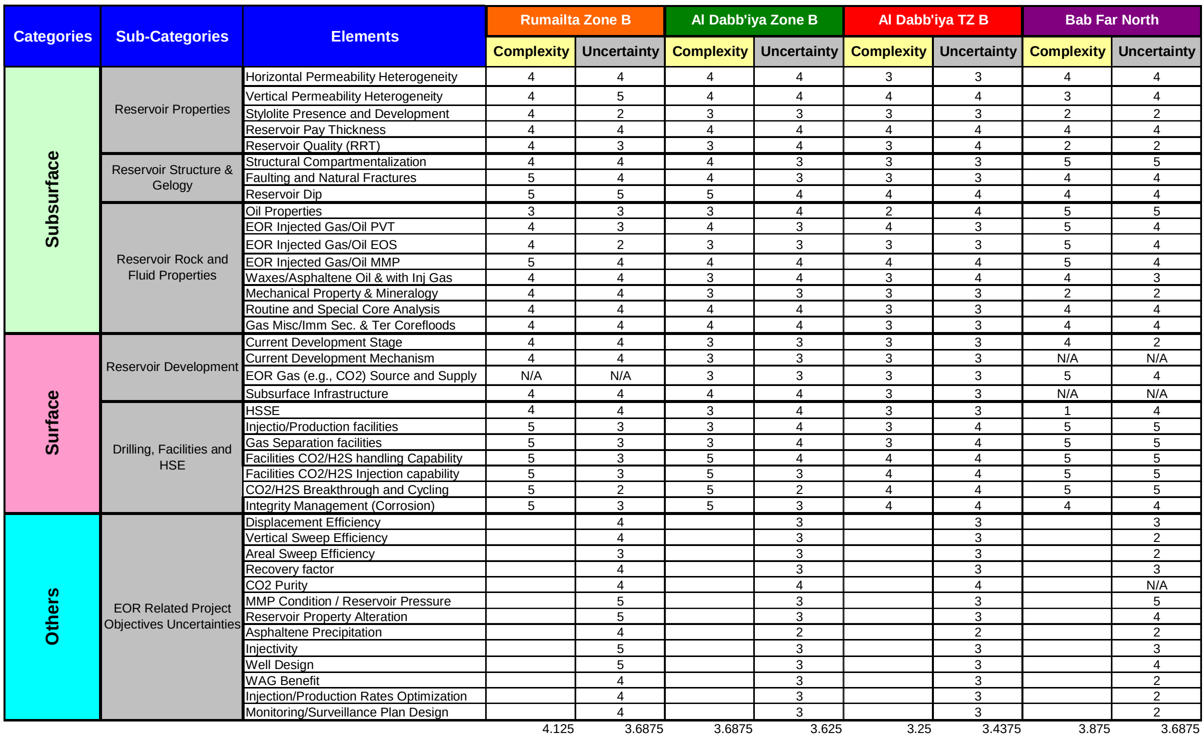
Modeling is not a substitution for monitoring but should be seen as a tool to predict the storage behavior of CO_2 for a short, medium and long term period. Modeling should be used as a "living" tool, and all monitoring data should flow back into newer modeling to (i) ensure the suitability of the modeling previously done, and (ii) re-adjust the modeling in case of large variations. Adjustment is necessary so that the model can reflect not just the predictions, but the real CO_2 behavior in the geological formation at that time.

In turn, modeling can be utilized in two important integration processes: (i) using models to merge and interpret data (a process often called "data assimilation"), and (ii) using models and data together to design cost-effective real-time monitoring strategies.

The key to the successful implementation of a modeling approach is the use of an integrated multi-disciplinary team which can leverage experience gained in the oil and gas industry in dealing with subsurface uncertainty. Such a team must in turn develop a transparent model which allows reviewers to appreciate and challenge the assumptions/inputs.

Examples for the use of monitoring in combination with models can be demonstrated by the activities undertaken by Abu Dhabi National Oil Company (ADNOC) in developing their CCUS project. ADNOC has further performed various laboratory studies, simulation and surface facilities studies to develop a suitable model and mitigate risks for their CCUS project. See Annex 1 for more details.

The result of these models can be the generation of a risk matrix that can be used as a dynamic tool for decision-making and review by the EB. An example of such a matrix resulting from modeling is demonstrated below.



Categories	Sub-Categories	Elements	Rumailta Zone B		Al Dabb'iya Zone B		Al Dabb'iya TZ B		Bab Far North	
			Complexity	Uncertainty	Complexity	Uncertainty	Complexity	Uncertainty	Complexity	Uncertainty
Subsurface	Reservoir Properties	Horizontal Permeability Heterogeneity	4	4	4	4	3	3	4	4
		Vertical Permeability Heterogeneity	4	5	4	4	4	4	3	4
		Stylolite Presence and Development	4	2	3	3	3	3	2	2
		Reservoir Pay Thickness	4	4	4	4	4	4	4	4
		Reservoir Quality (RRT)	4	3	3	4	3	4	2	2
	Reservoir Structure & Gelogy	Structural Compartmentalization	4	4	4	3	3	3	5	5
		Faulting and Natural Fractures	5	4	4	3	3	3	4	4
		Reservoir Dip	5	5	5	4	4	4	4	4
	Reservoir Rock and Fluid Properties	Oil Properties	3	3	3	4	2	4	5	5
		EOR Injected Gas/Oil PVT	4	3	4	3	4	3	5	4
		EOR Injected Gas/Oil EOS	4	2	3	3	3	3	5	4
		EOR Injected Gas/Oil MMP	5	4	4	4	4	4	5	4
		Waxes/Asphaltene Oil & with Inj Gas	4	4	3	4	3	4	4	3
		Mechanical Property & Mineralogy	4	4	3	3	3	3	2	2
		Routine and Special Core Analysis	4	4	4	4	3	3	4	4
		Gas Misc/Imm Sec. & Ter Corefloods	4	4	4	4	3	3	4	4
Surface	Reservoir Development	Current Development Stage	4	4	3	3	3	3	4	2
		Current Development Mechanism	4	4	3	3	3	3	N/A	N/A
		EOR Gas (e.g., CO2) Source and Supply	N/A	N/A	3	3	3	3	5	4
		Subsurface Infrastructure	4	4	4	4	3	3	N/A	N/A
	Drilling, Facilities and HSE	HSSE	4	4	3	4	3	3	1	4
		Injectio/Production facilities	5	3	3	4	3	4	5	5
		Gas Separation facilities	5	3	3	4	3	4	5	5
		Facilities CO2/H2S handling Capability	5	3	5	4	4	4	5	5
		Facilities CO2/H2S Injection capability	5	3	5	3	4	4	5	5
		CO2/H2S Breakthrough and Cycling	5	2	5	2	4	4	5	5
		Integrity Management (Corrosion)	5	3	5	3	4	4	4	4
Others	EOR Related Project Objectives Uncertainties	Displacement Efficiency		4		3		3		3
		Vertical Sweep Efficiency		4		3		3		2
		Areal Sweep Efficiency		3		3		3		2
		Recovery factor		4		3		3		3
		CO2 Purity		4		4		4		N/A
		MMP Condition / Reservoir Pressure		5		3		3		5
		Reservoir Property Alteration		5		3		3		4
		Asphaltene Precipitation		4		2		2		2
		Injectivity		5		3		3		3
		Well Design		5		3		3		4
		WAG Benefit		4		3		3		2
		Injection/Production Rates Optimization		4		3		3		2
		Monitoring/Surveillance Plan Design		4		3		3		2
			4.125	3.6875	3.6875	3.625	3.25	3.4375	3.875	3.6875

Table 1. Complexity and uncertainty matrix used in Abu Dhabi Company for Onshore Operations (ADCO) CCUS project screening (all facts and figures in the following figure are non representative and for demonstration purposes only).

As demonstrated by Table 1 above, a site can be characterized with associated risk. A CDM project could therefore be approved within the approved risk characterization limits.

For data collection and characteristics of a dynamic model, we refer to the EU Directive on the geological storage of carbon dioxide, especially Annex I, step2 and the following steps.

We recommend accepting modeling under the modalities and procedures as a tool for predicting behavior of CO_2 in project specific geological formations, and as a basis for risk assessment, taking into account uncertainties. Any change of the monitoring plan should be supported by the results of an updated model. The modeling method used by a project proponent should be agreed by a CCS Working Group under the EB (see also Section 3). The detailed requirements for modeling should be guided by the EU directive for geological formations[24]. We would also suggest that an international system be developed to regularly update the computational models available for

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[24] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide.

modeling CO2 storage. This would be an iterative way of generating and improving risk assessments of possible paths of the injected CO2 plume.

2.4. Boundaries

2.4.1 Description of technical issue to be addressed

The spatial boundaries of a CCS project should include all above-ground and underground installations and storage sites as described and mentioned by the subparagraph (e), paragraph 3 of FCCC/CMP/2010/L.10. However, due to the complexity of projects, and taking into account the various aspects of capture, transportation and storage over a long period of time, certain flexibility in setting boundaries is essential. In the early stages of a project, boundaries should include the above-ground facilities, including the capture, transportation, and injection components. This may not be applicable after the capture and injection components of the project cease. Furthermore, the potential migration pathways of the CO_2 plume might show a different behavior than originally projected. Therefore, we support allowing for a dynamic project boundary, which will change over time and project stage.

Draft Decision Paragraph 3

Subparagraph (e): The boundaries of carbon dioxide capture and storage in geological formations shall include all above-ground and underground installations and storage sites, as well as all potential sources of carbon dioxide that can be released into the atmosphere, involved in the capture, treatment, transportation, injection and storage of carbon dioxide, and any potential migratory pathways of the carbon dioxide plume, including a pathway resulting from dissolution of the carbon dioxide in underground water;

Subparagraph (f): The boundaries referred to in paragraph 3 (e) above shall be clearly identified;

This submission does not directly address trans-boundary issues or their resolution under current modalities and procedures. However, it should be in the interest of project owners/project participants to unambiguously clear their project of any trans-boundary-related issues upfront and to demonstrate that trans-boundary issues are not relevant to their specific project's geological formation, taking into account migration of the CO_2 plume, groundwater contamination, and seepage pathways.

2.4.2 Recommendations on addressing boundaries in modalities and procedures

In line with the recommendations set out in the external assessment report for the UNFCCC and in the annotations of EB 50, page 13, we recommend that following elements be incorporated into the CDM modalities and procedures:

1) Sub-surface, any project boundary described within a CCS CDM Approved Methodology would need to include a larger volume than just the storage reservoir so as to include potential secondary containment formations. This larger volume, referred to as a "storage complex," includes the storage site and surrounding geological domains which can have an effect on overall storage integrity and security, and thus be a potential source of anthropogenic emissions.

2) In the event that CO_2 does move out of a predefined determined project spatial boundary, the monitoring plan should be revised and reassessed by the DOE, with the option of changing the spatial boundary to ensure all potential seepage locations are included within the project boundary.

3) The validation of the project boundary requires a DOE with appropriate CCS expertise.

(Source: implication of the Inclusion of Geological Carbon Dioxide Capture and Storage as CDM Project Activity (EB 50, Annotations, Annex 1, page 13)

2.5. Seepage measuring and accounting

2.5.1 Description of technical issue to be addressed

CO_2 Seepage Measurement

Seepage should be monitored and quantified based on one or more of the following techniques:

- Monitoring reservoir properties that can indicate and quantify seepage, including continuous reservoir pressure measurement;
- Reservoir behavior through geological models;
- Monitoring well integrity;
- Shallow (sub)surface monitoring; and
- Atmospheric monitoring;
- Surface movement monitoring using satellite geodetic sensing;
- Permanent geophysical monitoring; and
- Any other technology that becomes available for this purpose.

Draft Decision Paragraph 3

Subparagraph (g): Any release of carbon dioxide from the boundaries referred to in paragraph 3 (e) above must be measured and accounted for in the monitoring plans and the reservoir pressure shall be continuously measured and these data must be independently verifiable;

Geochemical and surface monitoring must be performed in order to measure and account for any CO_2 seepage from the storage. Two of the primary CO_2 seepage monitoring techniques are:

1. Isotopic characterization of CO_2 for monitoring, and
2. Diode laser absorption sensors for continuous CO_2 surface monitoring (for more details see Annex 2).

In case of confirmed significant seepage detection (the definition of which should be agreed during the project permitting approval), CO_2 injection operations should be required to cease. In all cases, detailed investigations should be carried out by the project participant/project operator in order to:

- initiate corrective measures required to restore the storage integrity;
- take reasonable corrective measures to minimize any impact of the seepage on environment, human health and safety; and
- initiate actions to quantify seepage.

2.5.2 Recommendations on addressing seepage and accounting in modalities and procedures

Accounting for CO_2 seepage in monitoring plans

If seepage occurs during the crediting period, then the amount of seepage emissions should be quantified according to agreed/approved procedures, incorporating the most accurate and current technology, and considering uncertainties in the estimate. An amount equal to the mass of seepage quantified following these procedures should either be deducted from the entitlement for the respective period, or an equivalent amount should be surrendered to the CDM Registry Account.

If seepage occurs after the end of the crediting period, then the amount of seepage emissions shall be quantified and the equivalent amount of permanent emissions certificates returned to the CDM Registry Account.

3rd party verification

The monitoring plan should account for:

- Data to be collected and properly recorded
- Data to be readily available for 3rd party verification
- Retention period and security for data

Seepage and leakage should be a part of a long term monitoring plan, and subject to regular inspection. The EB may wish to define periodic measurement and reporting and independent inspection reporting guidelines.

Seepage could also be accounted and adjusted for with a buffer CER issuance mechanism and liability allocation.

2.6. Trans-boundary effects

2.6.1 Recommendations on addressing trans-boundary effects in modalities and procedures

Draft Decision Paragraph 3

Subparagraph (h): The appropriateness of the development of transboundary carbon dioxide capture and storage project activities in geological formations and their implications shall be addressed;

We are of the opinion that additional legal complexities will be associated with trans-boundary projects, and therefore such projects can be considered only after more experience is gained with the implementation of CCS projects. Therefore, any project proponent should initially be required to demonstrate that there is no trans-boundary effect associated with their project, until sufficient learning has been acquired to permit the inclusion of trans-boundary projects.

Draft Decision Paragraph 3

Subparagraph (i): Any project emissions associated with the deployment of carbon dioxide capture and storage in geological formations shall be accounted for as project or leakage emissions and shall be included in the monitoring plans, including an ex-ante estimation of project emissions;

2.7. Accounting of associated project emissions (Leakage)

2.7.1 Recommendations on addressing associated project emissions (Leakage) in modalities and procedures

All project-associated emissions should be calculated and included in an ex-ante estimate at the project design phase and included in the monitoring plan. The monitoring plan should periodically measure and verify actual associated emissions during the project life. This monitoring plan data should be verified by third parties.

The project emissions should include as a minimum:

- CO_2 Capture and separation activities
- CO_2 treatment and compression activities
- CO_2 transportation activities
- CO_2 injection activities

2.8. Risk and safety assessment

2.8.1 Description of technical issue to be addressed

Managing the risk of CO_2 injection in a subsurface storage (including existing oil and gas reservoir storage site) requires:

a) Assurance of safe operational integrity and containment of the retained/recycled CO_2 (utilization factor), and
b) Performance of dynamic risk management and mitigation (DRMM) to ensure risks and uncertainties are effectively managed throughout the project life-cycle.

Uncertainty can be analyzed and quantified, and if managed properly, reservoir development and risk mitigation can be improved as a result. Consequently, reservoir management, CO_2 injection, process physics, chemistry and ultimately modeling is essential to developing a risk assessment matrix correlated with a mitigation plan (see Table 2 below).

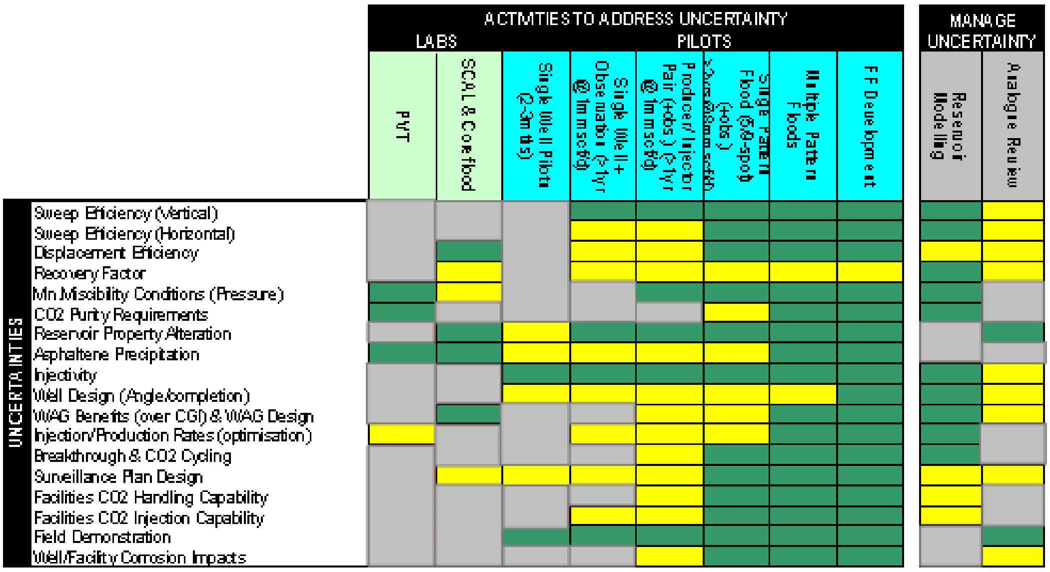
Significant capital expenditure and manpower are required to conduct these highly technical and state-of-the-art studies to address uncertainties as described below (conducted by Abu Dhabi National Oil Company).

Draft Decision Paragraph 3

Subparagraph (j): A thorough risk and safety assessment using a methodology specified in the modalities and procedures, as well as a comprehensive socio-environmental impacts assessment, shall be undertaken by independent entity(ies) prior to the deployment of carbon dioxide capture and storage in geological formations;

Subparagraph (k): The risk and safety assessment referred to in paragraph 3 (j) above shall include, inter alia, the assessment of risk and proposal of mitigation actions related to emissions from injection points, emissions from above-ground and underground installations and reservoirs, seepage, lateral flows, migrating plumes, including carbon dioxide dissolved in aqueous medium migrating outside the project boundary, massive and catastrophic release of stored carbon dioxide, and impacts on human health and ecosystems, as well as an assessment of the consequences of such a release for the climate;

Subparagraph (l): The results of the risk and safety assessment, as well as the socioenvironmental impacts assessment, referred to in paragraphs 3 (j) and (k) above shall be considered when assessing the technical and environmental viability of carbon dioxide capture and storage in geological formations;



UNCERTAINTIES	ACTIVITIES TO ADDRESS UNCERTAINTY								MANAGE UNCERTAINTY	
	LABS		PILOTS							
	PVT	SCAL & Core flood	Single Well Pilots (2-3mths)	Single Well + Observation (>1yr @ 1mmscfd)	Producer/Injector Pair (+obs) (>1yr @ 1mmscfd)	Single Pattern Flood (5/9-spot) (+obs) >2yrs @ 8mmscfd	Multiple Pattern Floods	FF Development	Reservoir Modelling	Analogue Review
Sweep Efficiency (Vertical)	⬜	⬜	⬜	🟩	🟩	🟩	🟩	🟩	🟩	🟨
Sweep Efficiency (Horizontal)	⬜	⬜	⬜	🟨	🟨	🟩	🟩	🟩	🟩	🟨
Displacement Efficiency	⬜	🟩	⬜	🟨	🟨	🟩	🟩	🟩	🟨	🟨
Recovery Factor	⬜	🟨	⬜	🟨	🟨	🟨	🟨	🟨	🟩	🟨
Min Miscibility Conditions (Pressure)	🟩	🟨	⬜	⬜	🟩	🟩	🟩	🟩	🟩	⬜
CO2 Purity Requirements	🟩	⬜	⬜	⬜	⬜	🟨	🟩	🟩	🟩	⬜
Reservoir Property Alteration	⬜	🟩	🟨	🟩	🟩	🟩	🟩	🟩	⬜	🟩
Asphaltene Precipitation	🟩	🟩	🟨	🟨	🟨	🟨	🟩	🟩	⬜	⬜
Injectivity	⬜	⬜	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨
Well Design (Angle/completion)	⬜	⬜	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟨
WAG Benefits (over CGI) & WAG Design	⬜	🟩	⬜	⬜	🟨	🟨	🟩	🟩	🟩	🟨
Injection/Production Rates (optimisation)	🟨	⬜	⬜	🟨	🟨	🟨	🟩	🟩	🟩	⬜
Breakthrough & CO2 Cycling	⬜	⬜	⬜	⬜	🟨	🟩	🟩	🟩	🟩	⬜
Surveillance Plan Design	⬜	🟨	🟨	🟨	🟨	🟩	🟩	🟩	🟨	🟨
Facilities CO2 Handling Capability	⬜	⬜	⬜	⬜	🟨	🟩	🟩	🟩	🟨	⬜
Facilities CO2 Injection Capability	⬜	⬜	⬜	🟨	🟨	🟩	🟩	🟩	🟨	⬜
Field Demonstration	⬜	⬜	🟩	🟩	🟩	🟩	🟩	🟩	⬜	🟩
Well/Facility Corrosion Impacts	⬜	⬜	⬜	⬜	🟨	🟩	🟩	🟩	⬜	🟨

Table 2. List of key CO_2 CCUS related uncertainties and mitigations considered for Abu Dhabi CCUS project

Analytical solutions permit rapid sampling of the uncertainty across all input parameters, and thus more robust risk assessment. This principle has been used recently to perform uncertainty quantification of seepage through hundreds of wells across several geologic layers [Nordbotten et al., 2009]. For each geologic basin, the risk assessment methodology should be broken down into four subtasks: (1) Sensitivity analysis on model parameters; (2) determination of probability distributions for parameters with greatest impacts; (3) uncertainty quantification; and (4) estimates of risk of CO_2 seepage. These simplified, quick, analytical forward models will also be instrumental in the design of monitoring techniques, as they provide first-order estimates of pressure evolution and CO_2 plume footprint.

2.8.2 Recommendations on addressing risk and safety assessment in modalities and procedures

Project proponents should be required to perform Health, Safety, and Environmental Impact Assessment Studies (HSEIA), commensurate with the project phase, through an independent qualified entity.

A "Terms of Reference" document outlining the HSEIA scope, objectives and methodology consistent with the CDM modalities and procedure requirement should also be submitted and approved by the local authorities and the CDM designated authority prior to performing the work.

HSEIA studies should use a probabilistic risk assessment methodology, and the HSEIAA study scope should cover the entire project boundary. The risk approach as proposed in the CO2QUALSTORE and CO2PIPETRANS Guidelines provide a good practice tool to ensure risks and uncertainties are effectively managed throughout a project's life-cycle.

Finally, risk and impact assessment outcomes should be reviewed by national authorities and the results should be reported to the Host country DNA.

2.9 Liability under the CDM scheme

2.9.1 Recommendation for the inclusion of liabilities under the CDM scheme into the modalities and procedures

Initially, all liability related to the project should rest with the project proponent, throughout the project life cycle and up until proper storage closure has been demonstrated.

The long term liability for the storage site should be transferred to the host country, either through national regulation or a negotiated agreement specific to the project.

Such long term liability schemes should be finalized during the project permitting stage and should address the conditions for transfer and the financial mechanism for meeting the liabilities.

Draft Decision Paragraph 3

Subparagraph (m): Short-, medium- and long-term liability for potential physical leakage or seepage of stored carbon dioxide, potential induced seismicity or geological instability or any other potential damage to the environment, property or public health attributable to the clean development mechanism project activity during and beyond the crediting period, including the clear identification of liable entities, shall:

i. Be defined prior to the approval of carbon dioxide capture and storage in geological formations as clean development mechanism project activities;
ii. Be applied during and beyond the crediting period;
iii. Be consistent with the Kyoto Protocol;

Subparagraph (n): When determining the liability provisions referred to in paragraph 3 (m) above, the following issues shall be considered:

i. A means of redress for Parties, communities, private-sector entities and individuals affected by the release of stored carbon dioxide from carbon dioxide capture and storage project activities under the clean development mechanism;
ii. Provisions to allocate liability among entities that share the same reservoir, including if disagreements arise;
iii. Possible transfer of liability at the end of the crediting period or at any other time;
iv. State liability, recognizing the need to afford redress taking into account the longevity of liabilities surrounding potential physical leakage or seepage of stored carbon dioxide, potential induced seismicity or geological instability or any other potential damage to the environment, property or public health attributable to the clean development mechanism project activity during and beyond the crediting period;

3 Provision for restoration of potential damages to ecosystems

3.1 Recommendation for the inclusion of provisions for restoration of potential damages to ecosystems into the modalities and procedures

There is a limit on the period of time over which project proponents will have responsibility for the liability associated with the CO_2 storage, since their lifetime is limited compared to the time-frame long term CO_2 storage requires.

Draft Decision Paragraph 3

Subparagraph (o): Adequate provision for restoration of damaged ecosystems and full compensation for affected communities in the event of a release of carbon dioxide from the deployment of carbon dioxide capture and storage in geological formations must be established prior to any deployment of related activities;

Project proponents should therefore make financial provisions to address any potential damage to the environment, human health and properties beyond the period of their direct short term liability. This financial provision should be transferred to an authorized body designated by the host country after the end of their short term liability period.

The financial provision covering the long term liability should be based on a long term probabilistic risk assessment, to be approved by the local authorities as per agreed international rules.

The liability transfer from the project proponent to the host country should be materialized by a bilateral agreement which sets the period of liability and conditions to consider the CO_2 storage as permanent. Host countries should accept the principal of transfer of liability during the initial stages of the project approvals and make sure that all technical and CDM issues are addressed before giving their approval.

The UAE supports the development of comprehensive environmental impact statements (EIS) for CCS projects, and believes that that the scope of an EIS for a CCS project should be expanded to include a compositional analysis of the CO2 stream and public participation.

3. Changes in roles and administrative procedures under the a new CCS Scheme

In addition to the recommendations already described in the previous chapter, we support the inclusion of following elements to the Modalities and Procedures.

3 .1. General administrative changes

Technical Committee/CCS Working Group

Most of the issues described above lead to a set of new modalities and procedure for carbon dioxide capture and storage in geological formations as clean development mechanism project activities. CCS activities encompass a complex set of technical, geological, legal requirements, as well as socio-environmental, modeling, hazard and safety aspects. This set of complex requirements have not had to be addressed in CDM projects so far. Expertise spanning across all these topics will therefore be required to ensure informed approval or rejection of methodologies for CCS, as well as for reviewing projects for CDM approval. We believe that the Executive Board needs the support from a CCS Working Group, similar to the Afforestation and Reforestation Working Group (ARWG). Like the ARWG, the mandate of the CCS Working Group would be to prepare recommendations in cooperation with the Methodologies Panel on submitted proposals for new baseline and monitoring methodologies for CDM CCS projects.

Additional to this task, the CCS Working Group should support the Registration and Issuance Team (RIT) and with it, the Executive Board in their CCS-CDM project activity appraisal.

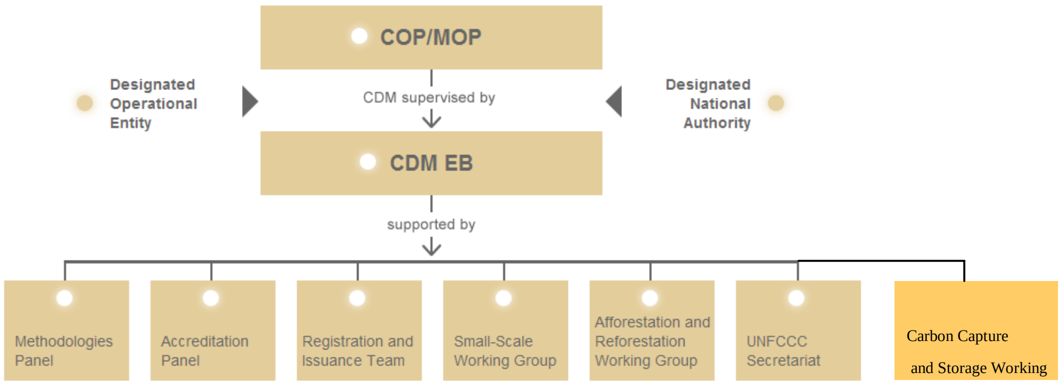


Fig. 3: Governance for CCS in CDM

Compliance and Compensation Fund

We would also recommend the establishment of a Compliance and Compensation Fund. This could be similar to approaches in the mining industry, and/or to the International Fund for Compensation of Oil Pollution Damage. It would also be in line with the already existing Adaptation Fund, which was established to finance adaptation projects and programmes in developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change. The Adaptation Fund is financed by a 2% levy on CERs issued by the CDM. Similar to the financial setup of the Adaptation Fund, a percentage levy on the CERs issued by the CDM from CCS projects should flow to this Compliance and Compensation Fund. The objectives for the compensation fund could be as follows:

- Covering accidents and compensating for any damage caused to the people and the environment as a result of CCS CDM projects;
- Monitoring and corrective actions, especially to cover long term liabilities in least developed countries associated with CCS CDM projects; and
- Covering seepage emissions and the release of carbon dioxide to the atmosphere from CCS CDM projects.

The establishment of the Compliance and Compensation Fund requires further elaboration, but the UAE expresses its support for the creation of such a Fund in principle.

3 .2. Roles of the Conference of the Parties

All provisions of section B of the CDM modalities and procedures, contained in the annex to decision 17/CP.7, should apply *mutatis mutandis* to carbon dioxide capture and storage in geological formations project activities under CDM. In addition, we recommend including the following aspects in the modalities and procedures:

- Assist in setting up a long-term compliance fund for CCS projects.
- Assist in setting up a CCS Working Group to support the EB in its appraisal procedures for methodologies and projects.
- Include carbon capture and storage in geological formations as a new sectoral scope (16).

3 .3. Roles of the Executive Board

All provisions of section C of the CDM modalities and procedures, contained in the annex to the decision 17/CP.7, should apply *mutatis mutandis* to carbon dioxide capture and storage in geological formations project activities under CDM. In addition, we recommend including following aspects in the modalities and procedures:

- Establish, develop and maintain a compensation fund, covering accidents, seepage avoidance, monitoring and corrective actions for long term risk mitigation and correction actions in least developed countries.

- Risk assessment and mitigation measures, including emergency response plans, should not be considered as proprietary or confidential.
- Establish and support the CCS Working Group.

3 .4. Participation requirements

All provisions of section F of the CDM modalities and procedures, contained in the annex to the decision 17/CP.7, should apply *mutatis mutandis* to carbon dioxide capture and storage in geological formations project activities under CDM. In addition, we recommend including following aspects into the modalities and procedures:

- A party not included in Annex I may host a carbon dioxide carbon capture and storage in geological formations as CDM project activity if the host country has designated these sites as potential storage sites and has undertaken an assessment of the storage capacity of their territory.
- The long term liability for the storage site has been evaluated by the host country; either national regulation is in place taking into account long term liability after post closure, or the project participant has an agreement in place with the host country clearly resolving liability.

3 .5. Roles of the DOE

All provisions of section E of the CDM modalities and procedures, contained in the annex to the decision 17/CP.7, should apply *mutatis mutandis* to carbon dioxide capture and storage in geological formations project activities under CDM. In addition, we recommend including following aspects in the modalities and procedures:

- Validation and verification services for carbon capture and storage projects require a complex validation/verification team, covering all areas of CCS-specific knowledge, such as geological, modeling, risk assessment, and HSEIA expertise.

3 .6. Validation and verification services

All provisions of section F of the CDM modalities and procedures, contained in the annex to the decision 17/CP.7, should *mutatis mutandis* to carbon dioxide capture and storage in geological formations project activities under CDM. In addition we recommend the consideration of following aspects into the modalities and procedures:

- Project participants should be required to submit documentation on the procedure and selection of the geological formation as carbon storage site to the Designated Operational Entity (DOE). The criteria should include "(1) adequate capacity and injectivity, (2) a satisfactory sealing caprock or confining unit, and (3) a sufficient stable geological environment to avoid compromising the integrity of the storage site[25]. Storage sites which consist of basins that (1) are thin (≤1000m), (2) have poor reservoir and seal relationships,

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[25] IPCC Special Report on Carbon dioxide Capture and Storage, 2006, chapter 5: underground geological storage, page 213ff.

(3) are highly faulted and fractured, (4) are within fold belts, (5) have strongly discordant sequences, (6) have undergone significant diagenesis or (7) have "overpressured reservoirs" (IPCC – Special report on carbon dioxide capture and storage) should be excluded. The project participant should follow state of the art selection procedures as per guidance set out by national or international standards or legislation.

- The crediting period should begin at the start of injection into the reservoir. We propose would propose the use of a renewable crediting period of 10 years, which might be renewed. The EB should come to a decision, with support from the CCS Working Group, on a maximum number of years for crediting.

3 .7. Project Design Document for carbon capture and storage in geological formations

Similar to the Project Design Document (PDD) under CDM, a CCS project participant should have to describe section A – E. In addition, we recommend the following points to be addressed by the project participant:

- A description of the site selection procedure;
- A description of risk assessment and modeling conducted, including a risk mitigation plan;
- The exclusion of trans-boundary issues;
- A description of how national and/or sectoral policies and circumstances have been taken into account, and especially how liability for short term, medium term and long term is addressed;
- Calculations, including a description of how uncertainties have been addressed:
    - using modeling as a support;
    - based on pre-monitoring details;
    - including likelihood of seepage.
- Socio-environmental impacts of the project;
- Risk and safety assessment and a plan for risk mitigation.

During the validation the Designated Operational Entity shall ensure that following documents are provided:

- Evaluation Permit
- Storage permit
- Operation Permit
- Emergency Response Plan
- Risk Assessment and Mitigation Plan
- Agreement on liability with the national authority
- Monitoring Plan

References:

[1] International Energy Agency: World Energy Outlook 2010.

[2] International Energy Agency: Energy Poverty Report.

[3] The Future of Coal – an interdisciplinary MIT study / Options for a constrained World, Massachusetts Institute of Technology, 2007.

[4] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide.

[5] IPCC Special Report on Carbon Dioxide Capture and Storage.

[6] IPCC Guidelines for National Greenhouse Gas Inventories 2006.

[7] Srivastava, R. D. (coordinating lead author) (2009). Best Practices for Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geological Formations. U.S. Department of Energy, National Energy Technology Laboratory. www.netl.doe.gov/technologies/carbon_seq/refshelf/MVA_Document.pdf.

[8] Implications of the Inclusion of Geological Carbon Dioxide Capture and Storage as CDM Project Activities, http://cdm.unfccc.int/EB/050/eb50annagan1.pdf.

[9] CO2QUALSTORE – Guideline for Selection and Qualification of Sites and Projects for Geological Storage of CO_2, DNV, 2010; http://www.dnv.com/binaries/CO2QUALSTORE_guideline_tcm4-412142.pdf

[10] CO2PIPETRANS - Recommended Practice for Design and Operation of CO_2 pipelines – JIP CO2PIPETRANS Phase 1 (2008-2009), DNV.

Annex 1: Monitoring in combination with modeling as performed by ADNOC

The procedure linking observations and models will be an ensemble data assimilation algorithm that will use the models to generate a set of possible system descriptions, all consistent with observations. This makes it possible to provide a cost-benefit analysis of the importance of different data types, as well as to design robust operating and monitoring strategies that can work well over a range of conditions.

Data Assimilation and Monitoring Design

Mathematical modeling of the subsurface environment provides a useful way to assess candidate sites for carbon storage and to design effective carbon sequestration strategies. In particular, different sites and operating alternatives can be analyzed by varying the model inputs that characterize the target reservoir, as well as control variables, such as injection well locations, depths, and injection rates. This is a classical application of modeling technology that relies strongly on having access to a physically realistic model. Here we consider two other important modeling applications that are particularly relevant to the UAE CCS project: (a) using models to merge and interpret data (a process often called “data assimilation”), and (b) using models and data together to design cost-effective real-time monitoring strategies. To understand how models relate to data assimilation and monitoring it is necessary to briefly consider why we should integrate modeling and data collection activities in a CCUS monitoring program.

In the absence of a predictive model, monitoring is the only way to assess the performance of a carbon sequestration project. The disadvantage of a monitoring-only approach to performance assessment is that we are using the real world as a laboratory. If a sequestration strategy works well this is fine but, if it does not, the consequences could be undesirable and difficult to correct. That is why we use models (and small-scale lab and field experiments) to predict performance in advance. By trying out different alternatives in a controlled modeling experiment we can find designs that are likely to meet project specifications.

The subsurface models we use to identify promising sequestration strategies, however, do not have complete information on geological structure, flow properties, and other relevant environmental variables. If we had a fully predictive model, there would be no need to monitor performance because we would know the outcome with certainty. The real-world needs of the UAE CCUS project require a balance between the extremes of relying only on monitoring and relying only on modeling. We can construct models that give us useful information about the likely performance of a candidate reservoir but we also need to monitor since the model predictions are not certain. The most realistic and scientifically defensible approach to performance assessment of CO_2 sequestration is to integrate modeling and monitoring.

We will follow such an integrated approach here. First, we will develop data assimilation procedures (or work flows) that use models to combine measurements for performance assessment. Then we will expand these procedures to include a real-time monitoring design capability. Real-time design enables the CO_2 monitoring program to evolve as new measurements become available, using models that are continually updated. In both cases we will use models developed in other project tasks so that assumptions and results are consistent across the project.

This integrated approach to monitoring and operations has a long and successful history in meteorology, where complex mathematical models are routinely used to merge (or assimilate) diverse measurements for forecasting and also to design “adaptive observation” programs.

Here, we will build on our experience with data assimilation and monitoring methods in meteorology, hydrology, and, most important, petroleum engineering [Moore and McLaughlin, 1978; Graham and McLaughlin, 1989; McLaughlin et al., 1993; McLaughlin, 2002; 2007; Zhou et al., 2006]. Over the past several years we have contributed to the growing field of real-time petroleum reservoir management by developing modeling, estimation, and control strategies to make best use of observations collected before and during secondary recovery operations [Jafarpour and McLaughlin, 2008, 2009, 2009a]. This work provides an excellent basis and starting point for a focused design of the monitoring program.

Of particular interest for this project are the following types of measurements:

a) Fluid pressures, fluxes, and composition in injection and a limited number of monitoring wells;

b) Active seismic measurements ranging from cross-well to VSP to 4-D surface seismics;

c) Passive seismic measurements, including measurements that rely on induced seismicity;

d) Geodetic measurements, including data from (existing or newly deployed) GPS stations and InSAR surveys;

e) Time-lapse microgravity and/or gradiometry measurements;

f) Electrical resistance tomography;

g) Geochemical and surface monitoring of atmospheric CO_2 concentrations.

These measurements represent a suite of possible sensing technologies that we intend to investigate for this particular application. Some of these may prove to be technically inappropriate or too expensive for the conditions at the UAE. An assessment of the most promising sensing technologies will be an ongoing task of our project, carried out as performance and cost data become available.

Fluid Flow Modeling

The fundamental objective of CO_2 sequestration operation is to maximize the overall amount of injected CO_2, while minimizing the risk of leakage. Safe, long-term sequestration of supercritical CO_2 in such large-scale aquifers is expected to be achieved through the objective of mechanisms of capillary, solubility, and mineral trapping. These mechanisms occur over a wide range of time scales, ranging from years to millennia. Capillary, solubility, and mineral trapping represent increasingly higher levels of CO_2 storage security. Because of the relatively long time scales required to trap, or immobilize, the CO_2, an impermeable caprock is needed to prevent the undissolved super-critical CO_2, which is buoyant and highly mobile with respect the resident brine, from leaking to shallower formations (e.g., fresh water aquifers), or to the atmosphere.

The total amount of CO_2 that can be sequestered in an aquifer is primarily a function of the rate at which CO_2 is immobilized by the different trapping mechanisms, as well as, the geologic `quality' of the aquifer based on its overall size, permeability characteristics, the relative impermeability of the caprock, and the absence of major geologic faults and fractures. The longer that the injected CO_2 remains in contact with the caprock (due to its buoyant supercritical state with respect to the resident fluid), the greater the risk of CO_2 leakage. Vertical and up-dip migration of large-scale CO_2 plumes over long periods of time also adds to the risk of leakage. Moreover, changes in the pressure field due to injection of large amounts of CO_2 may lead to the activation, or creation, of fractures and faults that provide CO_2 leakage pathways beyond the target formation.

In order to plan, execute, and monitor field-scale CO_2 sequestration operations, accurate modeling of the physical and chemical processes that govern solubility, capillary, and mineral trapping in subsurface geologic formations is necessary. For that purpose, the complex dynamics associated with the various trapping mechanisms and their interactions must be analyzed in detail and modeled accurately. That is, the governing equations must be formulated rigorously, and the length and time scales that govern the physical and chemical processes associated with subsurface CO_2 sequestration must be resolved adequately. Then, using a detailed characterization model for the specific storage target, high-resolution numerical simulation can be used to make quantitative predictions of the complex dynamics associated with field-scale CO_2 sequestration operations. The simulation capability must be able to cover the (relatively short) injection and the (much longer) post-injection periods.

The dynamics of multiphase flow and transport in large-scale heterogeneous geologic formations, which describe the complex solubility and capillary trapping processes rigorously, must be modeled accurately in order to obtain reliable predictions of the fate of the injected CO_2. The computed spatial and temporal distributions of the flow (pressure, velocity) and transport (saturations and concentrations) provide predictions of the overall effective storage capacity (related to volumetric `sweep' efficiency), migration distances of mobile CO_2 plumes, and assessment of capillary (residual) and solubility trapping. Such a simulation based approach is necessary to plan, execute, and monitor field-scale CO_2 sequestration projects.

Geomechanical Processes and Caprock Integrity

The interaction between the pore fluids and the rock is an essential component in the assessment of CO_2 storage in geologic formations. Thus, geomechanical studies provide critical input data for reservoir design and management. Injecting large volumes of carbon dioxide will create a pore-fluid that, at least initially, will disturb both the local mechanical and chemical equilibrium of pore fluid and the surrounding reservoir and cap rocks. The pressurization of the formation upon injection of supercritical CO_2 will reduce the effective stress in the rock. This process can have several effects that need to be evaluated, including the displacement of brine, the activation of dormant faults that can then serve as leakage pathways, and the creation of fractures that may compromise the integrity of the caprock. In addition to understanding these mechanical effects, both the short- and long-term reliability and stability of the repository demands detailed knowledge of chemical effects associated with the disturbance in chemical equilibrium. The kinetics of the interactions between the fluid and minerals [Emberley et al., 2004], and the effects of the fluid/rock interactions on the mechanical and transport properties of the reservoir and cap rock [Shukla et al., 2010] must be determined. A combination of theoretical, computational, and laboratory work to evaluate chemo/geomechanical processes and seal integrity in the target deep aquifers are needed. The knowledge of the regional state of stress, which is largely uncertain but can be inferred from oriented cores, minifrac tests, etc. are essential for model calibration.

Coupling Geomechanical and Fluid Flow Modeling

The interactions between the flow dynamics and geomechanical deformation must also be quantified in order to make predictions of large-scale subsurface CO_2 sequestration operations. Given that very large amounts of CO_2 must be injected into the host geologic formation (i.e., deep saline aquifer), we have to understand the complex interactions between the flow dynamics (e.g., pressure field and plume migration) and the stress and strain fields in and around the storage formation. Such interactions have been shown to affect the flow properties of the reservoir, including the porosity and permeability. More importantly, for large-scale sequestration operations, there is a major concern of activating, or even inducing, fractures that may provide pathways for the CO_2 to leak into shallower formations, or possibly all the way to the surface. Thus, reliable and computationally efficient methods the can describe the complex coupling between the flow dynamics and geomechanical deformation are needed.

To reiterate, quantification of the state of deformation and stress of the reservoir is essential for the correct prediction of a number of processes critical to geologic CO_2 storage, including pressure evolution, surface subsidence, seal integrity, hydro fracturing, and induced seismicity; therefore, a central aspect is the development of computational models for the simulation of coupled flow and geomechanics, which allows studying the state of stress at depth, caprock integrity and faulting activation upon CO_2 injection, with application to individual selected formations. The theoretical developments based on chemo-mechanics laboratory experiments that will test the interplay between CO_2 dissolution, rock strength, flow properties, and compaction for actual carbonate reservoir rock and caprock. The experiments will inform the computational models and will lead to an integrated assessment of caprock integrity, which will identify not only the potential for leakage risk, but also which leakage pathway is most likely (e.g., well leakage, sandy caprock, fractured caprock, or active faults).

I. The key to the successful implementation of above modeling approach is the use of an integrated multi-disciplinary team which can leverage the vast experience gained in ADNOC of dealing with subsurface uncertainty. The whole approach is transparent and allows the reviewers to appreciate and challenge the assumptions/inputs.

Annex 2: Examples for CO_2 seepage monitoring

I. Isotopic Characterization of CO_2 for Monitoring

CO_2 is a ubiquitous compound that is in the atmosphere, water and soil. CO_2 concentrations change both spatially and temporally. The causes of changes could be natural and/or due to human activity (e.g. increased vehicular traffic). An important aspect of monitoring is to determine whether any change in surface concentration is due to possible leakage from the sequestered CO_2. This determination requires "foolproof" tracers that would work in a CO_2 rich environment.

The recommended geochemical tracers are cluster isotopes - long chains made of different isotopes of carbon and oxygen. These compounds are formed during the combustion process. They contain the "DNA" signatures of every batch of CO_2 produced. The concentrations of a subset of these isotopes in the atmosphere are extremely low. Because of the low background they are extremely sensitive to small changes.

For monitoring with isotopic tracers, the isotopic signature of the CO_2 being injected is determined. Then, periodically or whenever an escape is suspected, air and soil samples are tested to determine whether they contain any CO_2 bearing the isotopic signatures of the injected CO_2.

II. Diode Laser Absorption Sensors for Continuous CO_2 Surface Monitoring

In addition to the proposed wide spectrum of subsurface CO_2 monitoring, another approach would be to develop a new approach for continuous CO_2 detection at the surface. The monitored surface of the storage reservoir can be 10's to 100's of square kilometers and the use of fixed and/or mobile gas analysis detectors to continuously monitor the CO_2 concentration is far from practical. In contrast, laser beams that can travel several kilometers without losing their coherence and can therefore scan large surface areas. By choosing an appropriate wavelength, detection scheme, and inversion technique, the concentration and location of a chemical species can be determined. The work proposed in this task aims at developing diode laser absorption techniques for continuous CO_2 surface leak detection.

Laser based methods (such as laser-Raman scattering radar) for the remote detection of atmospheric pollutants have been studied and used since the early seventies [Hildal and Byer, 1971; Inaba and Kobayasi, 1972]. Although these early techniques are still in use today for vertical distribution of gases in the troposphere and stratosphere, they have not been adopted for ground surface scanning and detection. In addition, these systems are bulky and very expensive. Infra red (IR) Diode laser based techniques—developed in the 80's and 90's and found broad use in industrial and environmental applications—are smaller and less expensive [Allen, 1998; Webber et al., 2000; Martin, 2002]. The use of IR laser absorption spectroscopy was initially restricted to laboratory experiments on chemical kinetics, especially in the field of combustion and plasma processes [Sassi, 1999]. But since the late nineties there has been a rapid expansion towards its use in more applied areas such as atmospheric and pollution monitoring as well as process monitoring and control. These advances have largely benefited from improvements in laser technology and associated electro-optics deriving from applications in the telecommunications and consumer electronics industries. In addition, there has been an increased interest in direct species and parameter measurements in the atmosphere and in the environment in general.

In laser absorption measurement the narrow band laser beam is wavelength tuned across a much broader molecular absorption line and the change in the detected-transmitted laser power is measured (Figure 4). At known temperature and pressure, among other experimental parameters, this power change is proportional to the absorbing species concentration along the path length of the laser beam. Spatially resolved absolute concentrations can be obtained using tomographic inversion methods. The technique can be used to simultaneously monitor several species with high spatial and temporal resolutions. In addition to their widespread use and low cost, IR diode lasers can be used with fiber optic technology and inexpensive spectrometry components to build large emitter/sensor networks that can scan very large areas. Recently, this technique has been used for in situ sensing of atmospheric CO_2 with laser diodes emitting near 2.05 micrometers in laboratory experiments. A compact version of this technology has been adopted for the European campaign of atmospheric measurements [Zeninari et al., 2004]. Recently, it has become possible to measure field-scale isotopic CO_2 with tunable diode laser absorption spectroscopy for stable isotope studies of ecosystem-atmosphere CO_2 exchange [Bowling et al., 2003].

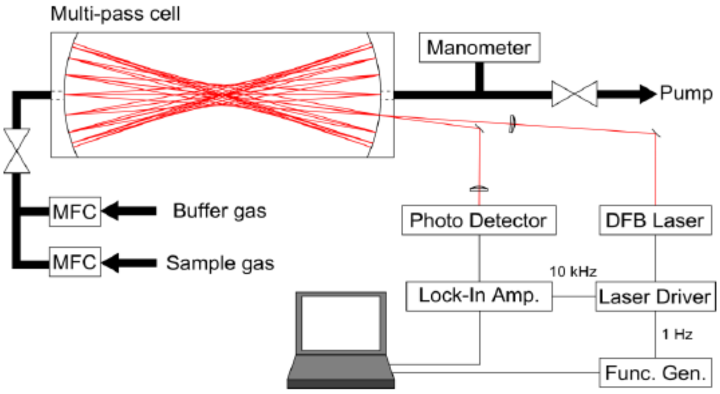

Figure 4: Laboratory diode laser absorption apparatus for species detection [Asakawa et al., 2010].

MIT work on laser diagnostics techniques [Sassi, 1999], and the commercial availability of IR diode lasers in addition to all the emission and detection optical components, might provide confidence that an effective network of diode laser absorption sensors for continuous CO_2 leak detection can be deployed over large areas.

Paper no. 10: United States of America

February 2011

SUBMISSION BY THE UNITED STATES OF AMERICA

Introduction

The United States, as an observer Party to the Kyoto Protocol, welcomes the opportunity to share its views on addressing issues in the modalities and procedures for the inclusion of carbon dioxide capture and storage (CCS) in geological formations as project activities under the clean development mechanism. Although CCS is occurring now on a relatively small scale, CCS technologies have the potential to enable large emitters of CO_2 to significantly reduce greenhouse gas (GHG) emissions. These technologies allow CO_2 to be captured at stationary sources and injected underground for long-term storage in a process called geologic sequestration (GS). Our comments will highlight our experience in developing regulations to ensure the protection of underground sources of drinking water (USDWs) and for GHG monitoring and reporting. The requirements that we describe are focused on protection of USDWs and GHG reporting for facilities that choose to inject CO_2 underground for geologic sequestration, rather than requirements for facilities to undertake CCS activities or control GHGs. However, we hope this submission will provide useful information that will enhance discussions under the CDM related to the safety and effectiveness of CCS.

Protection of Drinking Water

In December 2010, the U.S. Environmental Protection Agency (U.S. EPA) finalized a rule, under authority of the Safe Drinking Water Act, that establishes new federal requirements for the underground injection of CO_2 for the purpose of long-term underground storage, or geologic sequestration, and a new well class – Class VI – to ensure the protection of USDWs from injection related activities. The elements of the rule build upon the existing Underground Injection Control (UIC) Program regulatory framework, with modifications to address the unique nature of CO_2 injection for GS, including:

- Geologic site characterization requirements to ensure that GS wells are appropriately sited.

- Requirements for the construction and operation of the wells that include construction with injectate-compatible materials and automatic shutoff systems to prevent fluid movement into unintended zones.

- Requirements for the development, implementation, and periodic update of a series of project-specific plans to guide the management of GS projects.

- Periodic re-evaluation of the area of review around the injection well to incorporate monitoring and operational data and verify that the CO_2 is moving as predicted within the subsurface.

- Rigorous testing and monitoring of each GS project that includes testing of the mechanical integrity of the injection well, ground water monitoring, and tracking of the location of the injected CO_2 using direct and indirect methods.

- Extended post-injection monitoring and site care to track the location of the injected CO_2 and monitor subsurface pressures until it can be demonstrated that USDWs are no longer endangered.

- Clarified and expanded financial responsibility requirements to ensure that funds will be available for corrective action, well plugging, post-injection site care, closure, and emergency and remedial response.

- A process to address injection depth on a site-specific basis and accommodate injection into various formation types while ensuring that USDWs at all depths are protected.

- Considerations for permitting wells that are transitioning from Class II enhanced recovery to Class VI that clarify the point at which the primary purpose of CO_2 injection transitions from enhanced recovery (i.e., a Class II well) to long-term storage (i.e., Class VI).

The Class VI requirements are designed to promote transparency and national consistency in permitting of GS projects while also allowing flexibility, where appropriate. Many components of the rule provide flexibility by allowing the permitting authority discretion to set certain permit criteria that are appropriate to local geologic settings.

Greenhouse Gas Reporting

The GHG Reporting Program was established under authority of the Clean Air Act and requires reporting of GHG emissions and other relevant information from certain source categories in the United States. The Program provides a comprehensive and transparent approach to reporting, and information obtained through subpart PP and subpart RR will enable tracking of the amount of CO_2 that is captured and sequestered in the United States.

Reporting of CO_2 Supply

On October 30, 2009, U.S. EPA issued a final rule under subpart PP of the GHG Reporting Program that requires the reporting of CO_2 supplied to the U.S. economy. In addition to other types of CO_2 suppliers, Subpart PP applies to all facilities with production process units that capture and supply CO_2 for commercial applications or that capture and maintain custody of a CO_2 stream to sequester or otherwise inject it underground. These facilities are required to report the amount of CO_2 in a stream captured, and provide information on the downstream CO_2 end use.

Reporting of Geologic Sequestration

On December 1, 2010, U.S. EPA issued a final rule under subpart RR of the GHG Reporting Program that requires facilities that inject CO_2 underground for GS to report GHG data to U.S. EPA annually. Subpart RR covers any well or group of wells that inject a CO_2 stream for long-term containment in subsurface geologic formations, including all wells permitted as Class VI under U.S. EPA's UIC Program. Facilities that conduct enhanced oil and gas recovery are not required to report geologic sequestration under subpart RR unless the owner or operator chooses to opt-in to subpart RR or the facility holds a UIC Class VI permit for the well or group of wells used to enhance oil and gas recovery.

Subpart RR requires facilities that conduct GS to report basic information on CO_2 received for injection, to develop and implement a U.S. EPA-approved site-specific monitoring, reporting and verification (MRV) plan that is best suited for each facility, and to report the amount of CO_2 sequestered using a mass balance approach and annual monitoring activities. This rule is complementary to and builds on U.S. EPA's UIC permit requirements, including recently finalized requirements for Class VI injection wells.

In developing these reporting requirements, U.S. EPA took into account the 2006 IPCC guidelines for national GHG inventories, which directly address accounting for GS and include methodologies for estimating emissions from capture, transport, injection and geologic sequestration of CO_2.[26] For geologic sequestration specifically, the U.S. EPA requirements are consistent with the IPCC guidelines' Tier 3 methodology[27] for estimating and reporting emissions based on site-specific evaluations of each GS site. For example, the U.S EPA requires a comprehensive surface emissions monitoring plan (the MRV plan, described in the next section) based on the likelihood, timing, and magnitude of potential surface leakage of injected CO_2 (determined through site characterization and modeling). The reporter's selection of monitoring technologies must be based on the specific geology and conditions at the GS site. In addition, the monitoring plan is expected to evolve as site knowledge increases, as models are validated or updated, and to keep up to date with new monitoring methodologies.

Monitoring, Reporting, and Verification (MRV) Plans

Each facility that conducts GS (must develop and implement a U.S. EPA-approved site-specific MRV plan. We considered it important for all facilities conducting GS to demonstrate that they have met MRV standards. An adequate MRV plan would be tailored to site-specific conditions and

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[26] 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 2—Energy. Chapter 5 Carbon Dioxide Transport, Injection, and Geological Storage, available at: http://www.ipccnggip.iges.or.jp/public/2006gl/index.htm.

[27] Tier 3 methods include either detailed emission models or measurements and data at individual plant level where appropriate.

be designed for each stage of the GS project. In addition, the MRV plan would allow for modification or adaptation of the plan based on monitoring results.

This site-specific flexible approach was taken for three reasons. First, each facility will have a unique set of geologic, environmental, and operational conditions that are best addressed with site-specific solutions to satisfy each MRV requirement. Second, as projects mature, reporters will collect new information and may choose to improve their conceptual site models and modify their monitoring, modeling, and evaluation techniques. Third, we recognize that the uncertainties and inherent variability in the natural systems will necessitate modifications to the selected methods and approaches over time and in response to unexpected events.

Many of the injection and monitoring technologies that may be applicable for GS are commercially available today and will be more widely demonstrated over the next few years.[28] While technologies for quantifying CO_2 surface leakage from GS sites are continuously being refined, it is generally recognized that, when properly planned and implemented, monitoring methods will be effective at detecting surface leakages. A wide range of techniques for monitoring GS have been used at GS sites as well as for a number of years in other applications, including oil and gas production, enhanced oil and gas recovery, and plant and soil science. These techniques may be used at a GS site to monitor the injected CO_2, the surrounding rocks and fluids, wells and equipment, and the surface conditions.

The major components of the MRV plan[29] include the delineation of the areas to be monitored for surface leakage of CO_2, the identification of potential surface leakage pathways for CO_2 in the monitoring area and the likelihood, magnitude, and timing, of CO_2 leakage through these pathways, and a strategy for establishing expected baselines, detecting and quantifying any surface leakage of CO_2.

The monitoring strategy should be designed so that potential leakage pathways are monitored in a comprehensive manner that allows for timely and accurate identification of leaks, including establishing expected baselines so that the reporter can discern whether or not the results of monitoring are attributable to surface leakage of injected CO_2. The strategy for detecting CO_2 leakage to the surface could include taking measurements on a continuous basis, such as pressure

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[28] For more information on injection and monitoring technologies, see, e.g., Environmental Protection Agency, General Technical Support Document for Injection and Geologic Sequestration of Carbon Dioxide: Subparts RR and UU, Greenhouse Gas Reporting Program (Nov. 2010), available at http://www.epa.gov/climatechange/emissions/subpart/rr.html; J.J. Dooley, C.L. Davidson & R.T. Dahowski, “An Assessment of the Commercial Availability of Carbon Dioxide Capture and Storage Technologies as of June 2009,” Joint Global Change Research Institute, Pacific Northwest National Laboratory, PNNL-18520 (2009), available at http://www.pnl.gov/main/publications/external/technical_reports/PNNL-18520.pdf.

[29] For more information, see Environmental Protection Agency, Mandatory Reporting of Greenhouse Gases: Injection and Geologic Sequestration of Carbon Dioxide, Final Rule, 75 Fed. Reg. 75060 (Dec. 1, 2010), available at http://www.epa.gov/climatechange/emissions/subpart/rr.html; Environmental Protection Agency, General Technical Support Document for Injection and Geologic Sequestration of Carbon Dioxide: Subparts RR and UU, Greenhouse Gas Reporting Program (Nov. 2010), available at http://www.epa.gov/climatechange/emissions/subpart/rr.html.

readings in injection and monitoring wells, or continuously reading eddy covariance monitoring. The leakage detection strategy could also include regularly scheduled periodic monitoring events and surveys designed to evaluate conditions at a snapshot in time. Regularly scheduled monitoring events could include periodic sampling of water chemistry, mechanical integrity testing of injection and monitoring wells, or whole-area airborne surveys conducted at regular intervals. Given the uncertainty concerning the nature and characteristics of leaks that will be encountered, U.S. EPA expects that the CO_2 leakage quantification strategy in the MRV plan will provide a list of possible quantification methods and a discussion of when and how those methods might be employed for each surface leakage pathway identified during site characterization.

GHG Reporting Data Elements for Geologic Sequestration

Facilities that conduct GS must report annually the mass of CO_2 received for injection for the first time into a well at the facility, as well as the source of the CO_2 received. In addition, these facilities must submit an MRV plan to U.S. EPA, implement the U.S. EPA-approved plan, and report annually the following:

- The mass of CO_2 injected into the subsurface.
- The mass of CO_2 produced from oil or gas production wells or from other fluid wells.
- The mass of CO_2 emitted from surface leakage.
- The mass of CO_2 equipment leaks and vented CO_2 emissions from sources between the injection flow meter and the injection wellhead and between the production flow meter and the production wellhead.
- The mass of CO_2 sequestered in subsurface geologic formations, by subtracting total CO_2 emissions from CO_2 injected in the reporting year.
- The cumulative mass of CO_2 reported as sequestered in subsurface geologic formations in all years since the facility became subject to subpart RR.

The reporter would be required to report the annual amount of CO_2 sequestered at a facility using a mass balance equation, in which the sum of CO_2 emissions would be subtracted from the amount of CO_2 injected to equal the amount of CO_2 sequestered. Although not included in this submission, mass balance equations are provided in the Subpart RR regulatory text at 40 CFR 98.443.

Annual Monitoring Reports for Geologic Sequestration

Facilities with a U.S. EPA-approved MRV plan must also submit an annual monitoring report to U.S. EPA which contains the following information:

- A narrative history of the monitoring efforts conducted over the previous calendar year, including a listing of all monitoring equipment that was operated, its period of operation, and any relevant tests or surveys that were conducted.

- A description of any changes to the monitoring program that the reporter concluded were not material changes warranting submission of a revised MRV plan.
- A narrative history of any monitoring anomalies that were detected in the previous calendar year and how they were investigated and resolved.
- A description of any surface leakages of CO_2, including a discussion of all methodologies and technologies involved in detecting and quantifying the surface leakages and any assumptions and uncertainties involved in calculating the amount of CO_2 emitted.

Suggested References

Environmental Protection Agency, Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells, Final Rule, 75 Fed. Reg. 77230 (Dec. 10, 2010), available at http://water.epa.gov/type/groundwater/uic/wells_sequestration.cfm.

Environmental Protection Agency, Mandatory Reporting of Greenhouse Gases: Injection and Geologic Sequestration of Carbon Dioxide, Final Rule, 75 Fed. Reg. 75060 (Dec. 1, 2010), available at http://www.epa.gov/climatechange/emissions/subpart/rr.html.

Environmental Protection Agency, General Technical Support Document for Injection and Geologic Sequestration of Carbon Dioxide: Subparts RR and UU, Greenhouse Gas Reporting Program (Nov. 2010), available at http://www.epa.gov/climatechange/emissions/subpart/rr.html.

Environmental Protection Agency, Mandatory Reporting of Greenhouse Gases, Final Rule, 74 Fed. Reg. 56260 (Oct. 30, 2009), available at http://www.epa.gov/climatechange/emissions/ghgrulemaking.html.

Report of the Interagency Task Force on Carbon Capture and Storage (2010), available at http://www.epa.gov/climatechange/policy/ccs_task_force.html.