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Proposed Task:

Geological Carbon Storage Technologies

(Submitted by the Co-Chairmen of Working Group III,
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The Panel may recall that it had authorized the Working Groups and the Task Force to prepare scoping papers, including work plans and financial implications, for Technical Papers, Special Reports and methodological work requested by the Seventh Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP-7).

COP-7 has requested a "technical paper" on Geological Carbon Storage Technologies. There was some discussion at the Twenty-fourth Session of the Bureau (Geneva, 17-18 December 2001) on whether the request is best served by a Technical Paper or a Special Report (vide B-25/Doc.2, circulated to the Panel for information).

The attached document is submitted for discussion and decision.

Discussion Note on DRAFT COP/MOP Request for IPCC Technical Paper on Geological Carbon Storage

Background

The Conference of Parties at its seventh meeting in Marrakech has agreed on a draft decision by COP/MOP1, including an invitation to the IPCC: "in co-operation with other relevant organisations, to prepare a technical paper on geological carbon storage technologies, covering current information, and report on it for the consideration of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol at its second session;" (FCCC/CP/2001/13/Add.1: Draft decision -/CMP.1, art.7). This invitation only becomes a formal request when COP/MOP1 confirms this decision (after entry into force of the Kyoto Protocol).

Capturing CO_2 from large point sources – e.g. chemical plants, power plants based on fossil fuels – and transporting and storing CO_2 in a way that it does not get back into the atmosphere is one of the possible options to mitigate climate change. Although the draft invitation from SBSTA emphasizes the storage of CO_2, it appears to be important that in a potential IPCC report at least as much attention is given to the capture of CO_2 since capture is an important factor in the economics of the overall option. CO_2 can be stored in deep water bearing formations (acquifers) and can also be stored in depleted oil or gas reservoirs or in coal seams, the latter denoted as 'CO_2 enhanced coal-bed methane production'. This is usually called geological CO_2 storage. Alternatively, carbon dioxide may be stored in the deep ocean. There is practical experience with storage in acquifers and depleted oil and gas reservoirs, only limited experimental experience with CO_2 storage in coal beds, and virtually no experience with deep ocean injection.

CO_2 capture and storage may have the potential to act as a bridge to a future era in which hydrogen as a key energy carrier can be based on "clean" fossil fuels. In this regard, the option can be viewed as particularly attractive for fossil fuel exporting countries, countries with large fossil fuel reserves, and countries with relatively easy access to CO_2 storage reservoirs. The technology may also be seen as an option to buy time for a transition to a non-fossil fuel future. Enhanced carbon sequestration ("sinks") on land (e.g. through ARD activities) or in the oceans (e.g. through iron fertilisation) are not discussed in this note.

Scope of this paper

The objective of this paper is to discuss the options for responding to the UNFCCC request. In this context we discuss in this note the question whether it should be an IPCC Technical Paper, an IPCC Special Report, or an IPCC Workshop, what the timing of the activities could be and which subjects need to be covered.

Technical Paper or Special Report?

In the invitation to the IPCC, COP/MOP1 will formally request to the IPCC a technical paper on geological carbon storage to be considered at the second session of the COP/MOP.

Assuming that the Kyoto Protocol will enter into force this year, the first COP/MOP will be at COP9 in November of 2003. The second COP/MOP may then be late 2004 at the earliest. By that time we foresee that the relevance of an IPCC Technical Paper on this issue is very limited, given the fact that a TP only can cover materials from existing IPCC Reports. The material currently available in IPCC reports is quite limited and - given the expected further advances of scientific understanding of carbon storage - will be outdated by 2004. Hence, it makes more sense to capture the important subject in a Special Report, which would enable the authors to utilise the latest scientific and technical information available on this issue. As suggested by the draft COP/MOP invitation, the report could be developed in co-operation with other organisations, such as the IEA Greenhouse Gas R&D programme. As done previously when preparing IPCC assessments, input from the private sector can be invited (workshops, review/expert meetings, regular IPCC reviews).

Timing

Preparing an IPCC Special Report would require considerable more time than preparing an IPCC Technical Paper (2 years at minimum). The option of a Special Report on CO_2 capture and geological storage would therefore introduce a problem with the foreseen timing in the request of the Parties.

One solution (A) would be to start earlier than COP/MOP1. This course of action, however, would put funds at risk, should the Kyoto Protocol not enter into force and the invitation never formalized. This option would allow a Special Report to be ready for COP/MOP2, but would require a decision to be made about the issue at the 2002 IPCC Plenary. For this option, the information in this note could serve as the broad Terms of Reference for the Special Report (see "subjects to be covered by the Report"). This would imply that the IPCC Plenary would delegate the approval of a more detailed scoping paper, including a report outline and a proposal for a writing team to the new IPCC Bureau, taking into account nominations for authors to be requested after the 2002 Plenary. We assume that such a Bureaumeeting would be held in late 2002. In this case, an expert meeting could be held at relatively short notice – e.g. in the August-September 2002 period - to allow for a broad input into such a scoping paper.

Alternative solution (B) is delaying the report and wait until after entry into force of the Protocol. This implies that the report would not be ready until perhaps 2005, which will probably be after COP/MOP2 and closer to the Fourth Assessment Report. The disadvantage of this option is that the timing implied by the draft COP/MOP decision would be infeasible. The advantages however would be that there would be no risk that

IPCC would embark upon an unrequested report, and that there would be more time for a more careful preparation. Also in this case, an expert meeting, or possibly an IPCC workshop, could be held which would provide input into a detailed scoping paper, which would be submitted for approval at the 2003 IPCC Plenary. This expert meeting or workshop could be held a little bit later than in option A, allowing for more preparatory time, e.g. in the December 2002 -February 2003 period. This second option may lead to a prompt start of the preparations of a Special Report after the 2003 Plenary, if the 2002 Plenary would decide to allow an author nomination process, anticipating but not prejudging the approval process. In this case, the scoping paper submitted for a decision to the IPCC 2003 Plenary could include a proposal for a writing team. We note that waiting with further decisions until the formalization of the COP/MOP invitation would only enable a start of the project in 2004 after a decision by the 2004 IPCC Plenary. This option (C) would lead to a parallel development of the proposed Special Report and the Fourth Assessment Report, which would be inefficient. In this case, the subject may be covered in a special section or appendix of the FAR.. . .

Subjects to be covered by the Report

As a first indication, important subjects to be covered would include (see Annex A for a further preliminary discussion):

- Sources of CO_2 and technologies for CO_2 capturing;
- Transport of CO_2 from capture to storage;
- CO_2 storage options, including:
  - Deep saline water-bearing formations called saline aquifers;
  - Depleted oil and gas reservoirs;
  - Oil reservoirs that may be used for CO_2 enhanced oil recovery (EOR);
  - Deep coal seams containing methane (Enhanced Coal Bed Methane Recovery (ECBM);
  - Deep ocean (even if this may not be formally part of the invitation, we consider this to be one of the storage options in addition to geological formations).
- Costs and energy efficiency of CO_2 capturing and storing in comparison with the costs of other large-scale options, especially in the area of electricity generation and usage;
- Other technological and economic implications of large-scale introduction of geological carbon storage technologies;
- Environmental impacts;
- Monitoring of the CO_2-capture and storage
- Impediments and barriers to the implementation of geological carbon storage.

The assessment will take previous assessments into account, such as those by IPCC and the World Energy Assessment, but also explore new developments since the publication of those assessments. Estimation of the currently available literature on the subjects:

Subject	Literature availability
Sources of CO_2	Advanced
Technologies for capturing CO_2	Advanced
Saline aquifers	Sparse
Depleted oil and gas reservoirs	Sparse
Enhanced oil recovery (EOR)	Advanced
Enhanced Coal Bed Methane Recovery (ECBM)	Sparse
Deep ocean storage	Sparse
Costs	Advanced
Environmental impacts	Sparse
Impediments	Sparse

Several R&D projects are in progress and the amount of available literature in theses areas is expected to increases considerably in the coming years.

Recommendations

First, we recommend – if it would be decided to move ahead on the issue of CO_2 storage – not to prepare a Technical Paper, but a Special Report to take into account new developments since the TAR.

Second, we recommend such a Special Report not to be limited to geological carbon storage, as included in the draft COP/MOP invitation, but to include the capture of CO_2 in the assessment being an inherent component of this CO_2 emissions mitigation option.

Third, as a way forward we propose three options to be decided upon by the 2002 IPCC Plenary.

- Option A (start in 2002) involves a start of the preparations for a Special Report on CO_2 capture and storage immediately, on the basis of the information contained in this note. This option could allow to meet the deadline mentioned in the draft COP/MOP1 decision. A discussion on a more detailed scoping paper with outline and proposed writing team would be delegated to the Bureau. In this case, it is recommended that the 2002 IPCC Plenary decides to send out a request for nominations for lead authors as soon as possible.
- Option B (start in 2003) involves a slightly more cautious approach, waiting with a final decision until the entry into Force of the Kyoto Protocol (but not until the formalization of the draft request by COP/MOP1). In this case, the IPCC Plenary could decide to send out a request for nominations for Lead Authors after the 2002 Plenary in order to enable a decision on both contents and writing team during the 2003 Plenary.
- Option C (start in 2004) involves a much more cautious approach, waiting with the start of the work on a Special Report until the formalization of the COP/MOP invitation, mostly likely not before late 2003. In this case, we recommend the

inclusion of the subject as a special issue to be covered in the Fourth Assessment Report rather than in a Special Report.

- For all options, we recommend that IPCC Working Group III organize an expert meeting or workshop on carbon capture and storage, possibly together with other institutions active in this field of research, such as the IEA Greenhouse Gas R&D Programme. This meeting would allow to gain a clear understanding of the current state of the art and the expectations for further technological developments in this area. For option A, this meeting could be an expert meeting at relatively short notice (e.g. early autumn 2002), providing input into a scoping paper which would be submitted to a late 2002 Bureau meeting. For option B, this meeting could be an IPCC workshop, e.g. in winter 2002/2003, providing input into a scoping paper to be submitted to the 2003 IPCC Plenary meeting. For option C, this meeting could be an IPCC Workshop to be held after COP/MOP1, e.g. in early 2004, providing input for the Fourth Assessment Report.

Co-Chairs of IPCC Working Group III,

Ogunlade Davidson
Bert Metz

Annex A
Overview of relevant geological carbon capture and storage aspects

Sources of CO_2

An important issue is the availability of CO_2 from large industrial sources of CO_2:

- Natural gas processing plants, rejecting significant amounts of CO_2 into the atmosphere.
- Chemical plants – hydrogen plants, fertiliser plants (ammonia production) – with their inherent production of pure CO_2 as a by-product. (generally rejected into the atmosphere).
- Refineries, most of which nowadays rely on dedicated hydrogen plants for upgrading of heavy fuel oil, gasoline, etc. ('whitening of the barrel').
- Power plants based on fossil fuels (coal, natural gas) that are operated in base load.

According to the IPCC WG3 TAR, substantial reduction of CO_2 from fossil fuel combustion can be achieved by capturing and storing CO_2 at costs which would be competitive with many of the other deep reduction options. The option can be considered next to the other two main options in the energy system: efficiency improvements and fuel shifts. Strategies for achieving deep reduction in CO_2 emissions would be most robust if they would involve all three options. The prospects of CO_2 capture and storage depend *inter alia* on the economic structure and the power generation mix. CO_2 capture is governed by economies of scale. This is why larger plants operating continuously are preferred. Also, the CO_2 content of a gas or flue gas may be important. For some gas fields with high CO_2 –content, the CO_2 needs to be separated out anyway. In case of hydrogen plants – for ammonia production or refinery complexes – and gas processing plants, CO_2 separation is needed. The CO_2 only needs to be purified, compressed, and dried. Therefore, such plants are promising CO_2 sources. Within a few decades, hydrogen production combined with CO_2 storage may become more and more important due to the development of fuel cell technology based on hydrogen. Such fuel cells may be applied in many areas, including transportation.

Base-load coal- or gas-fired power plants hold promise due to their economies of scale. However, CO_2 capture tends to be more expensive for a power plant (diluted CO_2) than in case of chemical plants. A power plant fuelled by coal or natural gas with CO_2 capture is not state-of-the-art today. Commercially available CO_2 capture processes are generally not optimised for flue gases of coal- or gas-fired power plants. Therefore, this option requires more RD&D.

Options for geological CO_2 storage

There are several options for geological storage of CO_2, viz.:

- Deep saline water-bearing formations called saline aquifers.
- Depleted oil and gas reservoirs (or possibly reservoirs in the production stage).

- Oil reservoirs that may be used for CO_2 enhanced oil recovery (EOR). In this case some of the CO_2 might come up with the produced oil and gas. This could be monitored by established methodology.
- Deep coal seams containing methane, offering potential for CO_2 enhanced coal-bed methane production.

Each option has advantages and disadvantages. Experience with oil and gas production may favour CO_2 storage projects in depleted oil and gas reservoirs. Geological maps of the deep underground may be combined with geographical data of CO_2 sources, in order to select prospective CO_2 storage projects. Until this date, there is limited experience with CO_2 storage in deep saline aquifers or with CO_2 storage for enhanced oil recovery.

An option in the early RD&D stage is CO_2 storage in deep coal seams: 'CO_2 enhanced coal-bed methane production' (ECBM). Several pilot projects are in preparation. Whether ECBM is economically feasible depends *inter alia* on the thickness and depth of coal seams.

Costs of CO_2 capturing and storing

The costs related to the different elements of CO2 capture and storage options should be assessed, taking into account costs of additional energy use.

Steam reformers for chemical plants and oil refineries are, at the same time, both large providers of hydrogen and large point sources of CO_2. Finding economical outlays for the by-product CO_2 in geological formations instead of the atmosphere could be a relatively short-term option. It has been noted before that the development of fuel cell technology based on hydrogen could enlarge the potential of hydrogen production combined with CO_2 storage.

Commercial power plants with CO_2 capture are in the RD&D stage. Industry, power generators, and the society at large will have to bear the cost of capture, transport, and storage of CO_2. In case of CO_2 enhanced oil recovery and CO_2 enhanced coal-bed methane production, there are also revenues from oil and gas respectively.

Environmental impacts

The integrity of CO_2 storage is important to prevent not only the adverse climate impacts of CO_2 leaking too rapidly into the atmosphere, but also catastrophic releases, both from reservoirs and pipelines. In case of CO_2 enhanced oil recovery as practised today, most of the CO_2 stays below ground, although retention times are not well understood.

Aquifers deeper than 800 meters may be suitable for CO_2 storage. At this depth CO_2 will stay in a dense liquid phase. Information is needed of the capacities of such aquifers to store CO_2 and their leakage rates. Usually, deep saline aquifers are hydraulically separated from shallower 'sweet water' aquifers and surface water used by people. However, leakage of CO_2 from aquifers could entail contamination of sweet-water aquifers. Also, it needs to be assured that leaks do not result in the build-up of lethal pockets of CO_2 in valleys or in individual basements. Critical issues relate to caprock integrity and solution rate. The risk of leakage and its relationship to total amounts of CO_2 captured, verification and monitoring methodologies, the risk of adverse health effects, and accident risk need to be addressed.

Impediments and barriers to the implementation of geological carbon storage

The viability of CO_2 storage may depend on finding public acceptance and political consensus. CO_2 may be hazardous in case of rapid release. The risks associated with transport of CO_2 by pipeline and injection of CO_2 may be important for acceptance of geological storage. Monitoring of CO_2 at the site of storage may be essential to preclude accidents, but also to convince regulatory authorities and parties with a commercial interest that CO_2 storage is real and permanent or to verify the rate of leakage.