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Carbon Capture and Storage under the Clean Development Mechanism

Impact on the Long-term Climate Goal, Energy Supply Planning, and Development Paths

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Abstract

The inclusion of carbon capture and storage (CCS) projects under the CDM has become a very controversial topic. The international negotiations have so far focused on technical and methodological aspects of the inclusion of CCS under the CDM. However, the issue also has significant impacts on fundamental issues, i.e. how to achieve a long-term stabilization of the atmospheric concentration of greenhouse gases (GHGs), energy supply plans, and ultimately development paths. Despite its significance, these aspects have so far not been directly discucssed in the negotiations.

This paper attempts to present all aspects concerning CCS under the CDM, not only technical, methodological aspects but also long-term political aspects. To do so, the paper firstly explains the long-term requirements for mitigating climate change and the role of CCS in achieving this goal based on existing literature. It then overviews technical issues and analyzes methodological issues. Then the paper reviews stakeholders`positions on CCS and the inclusion of CCS under the CDM and identified factors to determine their positions. In the conclusions, we present all issues concerning the inclusion of CCS under the CDM to be addressed for agreeing on a decision on this issue at the MOP4.

Including CCS under the CDM raises a huge number of methodological issues related to drawing the project boundaries, potential leakages and the permanence of storage. The inclusion of CCS under the CDM firstly requires clarifying all the identified technical and methodological issues. It is also necessary to discuss whether CCS technology has a role in achieving the long-term climate goal while ensuring energy supply, and if so what is the best way to promote the technolgy. The CDM is one of the options, however, it is recommendable to discuss the issue in a broader framework, including technology transfer under the international climate regime and other initiatives, such as the Carbon Sequestration Leadership Forum.

Contents

1 Introduction

International climate negotiations are complex. Technical and methodological issues sometimes define more fundamental issues which should instead provide a basis for the former. As negotiations continue for several sessions, Parties normally recognize the implications for fundamental issues that are behind the technical and methodological issues, examine the implications, and form their positions on technical and methodological issues in line with ensuring their positions on the fundamental issues. By doing so, negotiations are sometimes accelerated but sometimes become very protracted.

Carbon capture and storage (CCS) under the CDM is one of these cases.

CCS consists of the capture, transportation and storage of carbon dioxide (CO_2) produced in the burning of fossil fuels. Using CCS technology, CO_2 is captured in concentrated form and, rather than it being released into the atmosphere, is then transported for long-term storage in geological formations.

CCS has been gaining attention since the IPCC published its Special Report on Carbon Capture and Storage (SRCCS) in 2005. Against this background, CCS was for the first time officially on the agenda at the Conference of the Parties (COP) 11 in Montreal under the agenda item "Cooperation with other conventions, scientific organisations and United Nations bodies". CCS was also put on the CDM agenda in the same year as three proposals for methodologies for baseline setting and monitoring for CDM projects were submitted to the CDM Executive Board (EB) in September 2005. Since this project type raises a number of fundamental issues, the EB referred the question of whether to approve CCS projects under the CDM or not to the COP/MOP.

COP/MOP 1 in Montreal subsequently decided to organize in-session workshops on CCS and on CCS under the CDM during the 24th Session of the Subsidiary Bodies to the UNFCCC (SB24) in 2006 and invited submissions from Parties (FCCC/KP/CMP/2005/L.7). A number of methodological and legal questions were raised in the submissions and at the workshop. At COP/MOP 2 in Nairobi, the EU, Canada, China, India, Japan, South Africa and especially the countries from the Organization of Petroleum Exporting Countries (OPEC) in general supported the inclusion of CCS under the CDM, while other countries such as the Least Developed Countries (LDCs), the Alliance of Small Island States (AOSIS) and Brazil voiced serious concerns about the maturity and appropriateness of CCS (Sterk/Ott/Watanabe/Wittneben 2007: 145, Watanabe/Sterk 2007:2). Parties compromised on a two-year process of further negotiations under the Subsidiary Body for Scientific and Technological Advice (SBSTA) with a view to taking a final decision at COP/MOP 4 (FCCC/KP/CMP/2006/L.8).

The international negotiations have so far focused on technical, methodological and legal aspects of the inclusion of CCS under the CDM. However, the issue also has significant impacts on fundamental issues, i.e. how to achieve a long-term stabilization of the atmospheric concentration of greenhouse gases (GHGs), energy supply plans, and ultimately development paths. Despite its significance, these aspects have so far not been directly discussed in the negotiations.

Considering that the Parties are supposed to come to a conclusion on the inclusion of CCS under the CDM by COP/MOP 4, this paper attempts to present all aspects concerning CCS under the CDM, not only technical and methodological aspects but also long-term political aspects.

To do so, the paper first explains the long-term requirements for mitigating climate change and the potential role of CCS in achieving this goal in section 2, overviews technical issues concerning CCS in section 3, and analyzes methodological, legal and long-term political issues concerning the inclusion of CCS under the CDM in section 4. Section 5 reviews stakeholders' positions on CCS and the inclusion of CCS under the CDM. In the conclusions (Section 6), the authors categorize and present all issues concerning the inclusion of CCS under the CDM to be addressed for agreeing on a decision on this issue at COP/MOP 4.

While technical and methodological issues have been identified in the existing literature, Parties' submissions and the results of the in-session workshop on CCS and CCS in the CDM (FCCC/KP/CMP/2006/3, FCCC/KP/CMP/2006/MISC.2), position papers and press releases, there is almost no literature touching upon the long-term political aspects. In order to identify stakeholders' views on these aspects and overcome the lack of literature, the authors organized a side-event at SB 26 in Bonn on 15 May 2007 and invited a wide range of experts. Prior to the side event, detailed questions were sent to the experts in order to bring their views into relief. A list of the experts and the questions are attached in the Annex of this paper. All experts responded to our questions in their personal capacity.

2 Political Aspects: Long-Term Climate Change Mitigation Goals and the Role of CCS

2.1 Long-Term Climate Change Mitigation Goals

Article 2 of the UNFCCC stipulates its ultimate objective, which is "to stabilize GHG concentrations in the atmosphere at a level that will prevent dangerous anthropogenic interference with the climate system" (UNFCCC Article 2). Although Article 2 of the UNFCCC does not explicitly define the required stabilization level, the accumulated scientific evidence on the impacts of climate change indicates that the increase of global average temperatures should not exceed more than 2°C compared to pre-industrial levels in order to avoid dangerous climate change (see e.g. IPCC 2001, Hare 2003, Morlot et.al 2005).

Limiting the temperature increase to 2°C would most probably require atmospheric greenhouse gas concentrations to be stabilized at less than 550 parts per million (ppm) CO_2 equivalent.[1] This requires deep GHGs emission cuts by 2050. According to den Elzen and Meinshausen (2005: 8), global emissions will need to be reduced by 30-60% compared to 1990 levels by 2050 to stabilize concentrations at 450/400 ppm; Stern (2006: 201) gives a reduction of 25% to achieve 550 ppm and 70% for 450 ppm, WBGU (2004: 23) gives

[1] Recent findings suggest that GHG concentrations need to be stabilised at a lower than 550 CO_2 equivalent in order to achieve the 2°C target with levels of certanity of more than 50% (den Elzen and Meinshausen 2005: 8, Hare and Meinshausen 2004: 38).

45-60% of energy-related CO_2 emissions, accompanied by substantial reductions of other greenhouse gases for 400 ppm of CO_2 concentration (aprox. 450 ppm for all GHGs).

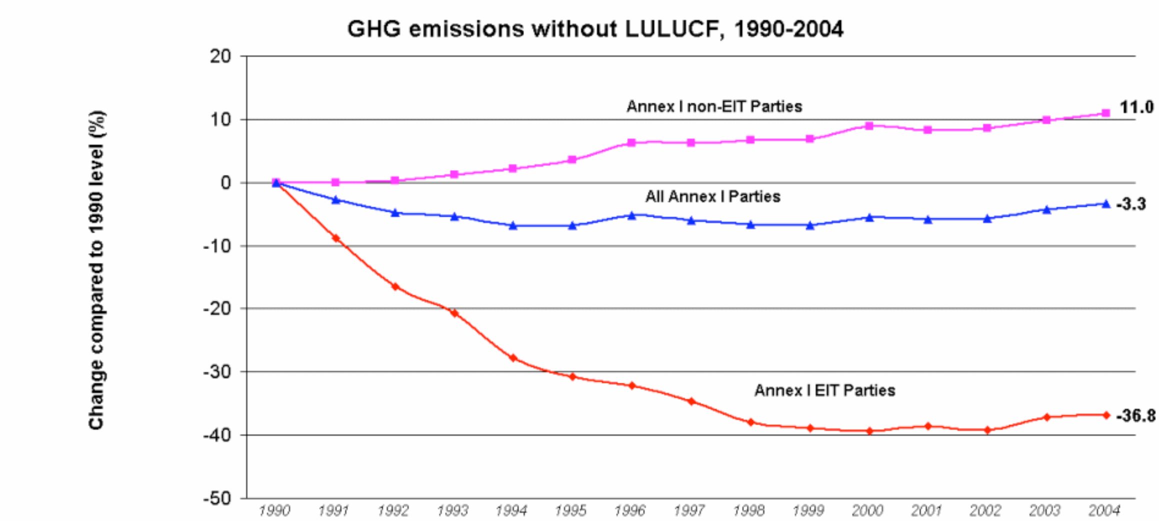
Moreover, the evidence shows that the rate of emission cuts required to meet a given stabilization goal is very sensitive to both the timing of the peak in global emissions, and its height. To limit the temperature increase to below 2°C, global GHG emissions would have to peak in less than 10 years (IPCC 2001: 153, Stern 2006: 199). Any delay would mean that emissions would need to be reduced much more drastically in a shorter timeframe, which would increase costs significantly.

Recognizing the above, the EU and some of its member states including the United Kingdom, France, Sweden, Germany, the Czech Republic, Denmark, and the Netherlands, have already set mid- and/or long-term emission reduction goals. These are generally in the order of 60-80% emission reductions by 2050 (Brouns and Ott 2005: 10-14).

Nevertheless, despite the accumulated scientific evidence and the declarations of some Parties, global society evidently faces significant difficulties in setting the path towards achieving these goals.

First of all, the above targets require more stringent reductions from Annex I Parties than the 5.2% reduction that they committeed to in the Kyoto Protocol. However, the latest UNFCCC data on Annex I GHG emissions shows that Annex I Parties have difficulty to even achieve the moderate Kyoto target: GHG emissions from Annex I Parties with economies in transition (EIT Paries) have decreased by 36.8% without taking removals from land-use, land-use change and forestry (LULUCF) into account. Meanwhile GHG emissions from the non-EIT Annex I Parties (without LULUCF) have increased by 11.0% compared to 1990 levels. Total aggregate GHG emissions from Annex I Parties without LULUCF have so far only decreased by 3.3 % between 1990 and 2004. Moreover, the emissions trend has been upwards since 2002 (FCCC/SBI/2006/26).

Figure 1: GHG Emissions without LULUCF, 1990 – 2004



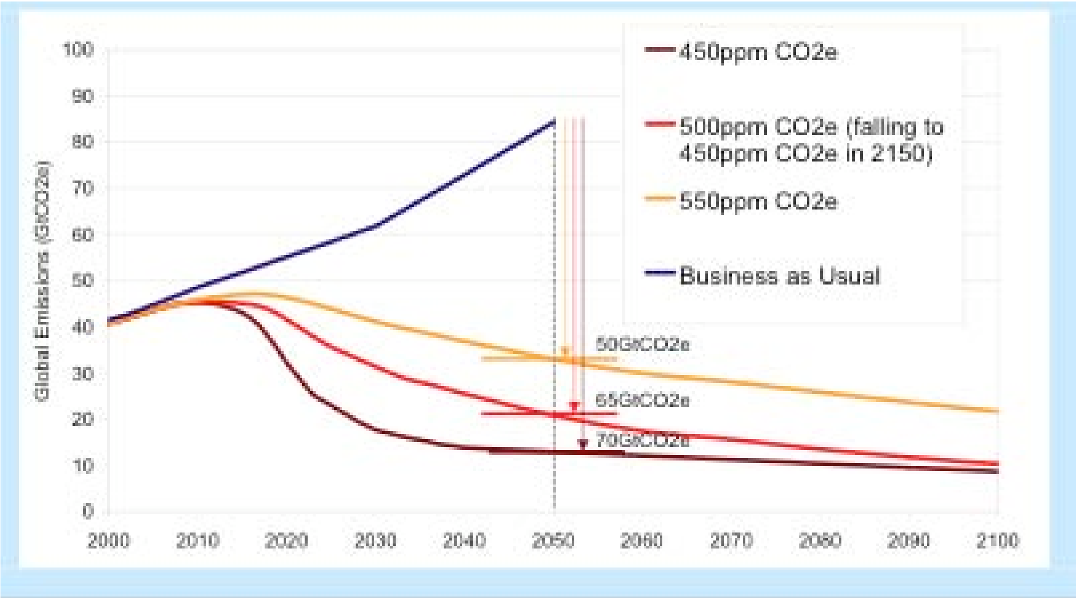
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Annex I EIT Parties	0.0	-8.9	-16.4	-20.8	-27.8	-30.7	-32.2	-34.6	-37.9	-38.9	-39.3	-38.6	-39.1	-37.2	-36.8
Annex I non-EIT Parties	0.0	0.0	0.2	1.2	2.2	3.6	6.3	6.2	6.7	6.9	8.8	8.2	8.6	9.8	11.0
All Annex I Paries	0.0	-2.7	-4.8	-5.4	-6.8	-6.7	-5.2	-6.0	-6.7	-6.8	-5.6	-5.8	-5.7	-4.2	-3.3

Note: The Parties that are allowed to use a base year other than 1990 have also provided data for their respective base years as per COP decisions 9/CP.2 and 11/CP.4. These Parties and their base years are Bulgaria (1988), Hungary (average of 1985-1987), Poland (1988), Romania (1989), Slovenia (1986).

Source. FCCC/SBI/2006/26. Figure 3. Changes in GHG emissions from Annex I Parties, 1990-2004

Secondly, achieving stabilization in the range of 450-550 ppm CO_2e requires substantial action not only from developed but also from developing countries. According to the Stern Review, even if Annex I Parties reduced their emissions to zero in 2050, the rest of the world would still need to reduce emissions by 40% from business as usual to stabilise concentrations at 550 ppm CO_2e and by almost 80% for 450 ppm (Stern 2006: 205-206). Considering the reluctance of developing countries to negotiate any kind of commitments for the future commitment periods of the Kyoto Protocol (Sterk/Ott/Watanabe/Wittneben 2007: 139-140, 146-147), stabilization requires a drastic position change of developing countries, too.

Figure 2: BAU Emissions and Stabilisation Trajectories for 450-550 ppm CO2e



Source: Stern (2006) Chapter 8. 14

2.2 The Potential Role of CCS and Energy Supply Planning

Nobody would argue the necessity of ambitious long term climate mitigation goals. However, there are essentially two diverging views about how to resolve the dilemma that international society encounters, i.e. ensuring a drastic emission reduction on the one hand while at the same time maintaining a stable energy supply as a precondition for economic well-being on the other. One view admits the role played by fossil fuels and is mainly represented by industries (Dirschauer 2007) and several scientists (e.g. Pacala and Socolow 2004: 969). CCS plays a significant role in this view. The IPCC also estimates that the average share of CCS in total emission reductions will amount to 15% for 750 ppm scenarios and 54% for 450 ppm scenarios[2], and that it will in any case be necessary to use CCS in order to achieve a 450 ppm target (IPCC 2005: 354). The other view puts the priority on renewable energy and energy efficiency measures and is represented mostly by NGOs (von Goerne 2007) and several experts (Miguez 2007, Schneider 2007). Proponents

[2] The full range across all scenarios for 450 ppm is 20 to 95% and 0 to 68% for 750 ppm scenarios respectively .

of this view fear that CCS may hamper the promotion of renewable energy and energy efficiency measures by diverting attention and essential resources.

The different views are underpinned by different energy scenarios, most notably represented by the IEA World Energy Outlook 2006 and the "energy [r]evolution" scenario published by Greenpeace and the European Renewable Energy Council (EREC) (Greenpeace and EREC 2007a, IEA 2006).

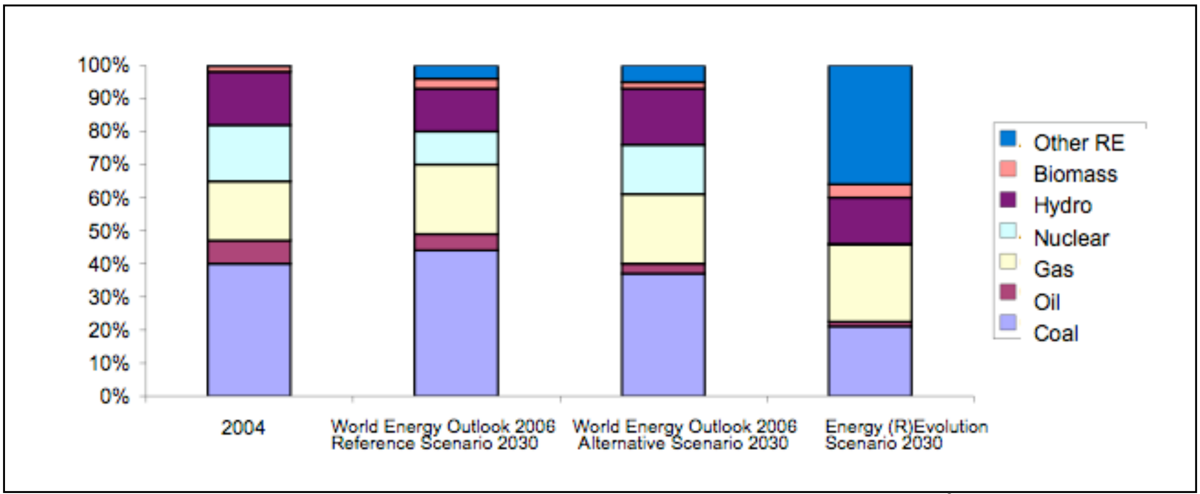
The IEA World Energy Outlook 2006 predicts that fossil fuels, especially coal, will continue to play a significant role in the foreseeable future (IEA 2006: 66). On the other hand, the energy [r]evolution scenario predicts that the world energy system could become independent from nuclear power by 2030 and that 70% of electricity generation could come from renewable energy sources by 2050 (Greenpeace and EREC 2007a:41).

According to the World Energy Outlook 2006, world primary energy demand was 11,204 Mtoe in 2004 and will by 2030 increase to 17,095 Mtoe in the "reference scenario" and to 15,405 in the "alternative scenario" (IEA 2006:66, 173). The share of fossil fuels edges up from 80% in 2004 to 81% in the reference scenario and is still at 77% in the alternative scenario (IEA 2006:66, 174). Coal will play a more dominant role in electricity generation, which is closely connected to development. Global electricity demand is projected to double from 14,376 TWh in 2004 to 28,093 TWh in 2030 (IEA 2006: 138). The percentage of electricity output provided from coal-fired power plants was around 40% (6,917 TWh) in 2004 and is projected to amount to around 43% (14,703 TWh) in the reference scenario and 37% even in the alternative scenario (IEA 2006: 138, 215).

According to the energy [r]evolution scenario, world energy demand in 2050 will amount to 13,132.76 Mtoe (550000PJ/a) in the reference scenario and 8,359.606 Mtoe (350000PJ/a) in the revolution scenario (Greenpeace and EREC 2007a: 39). Renewable energy will grow dynamically, which will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation (Greenpeace and EREC 2007a: 41). By 2050, 70% of electricity will be generated from renewable energy sources, with 42% coming from new renewables, mainly wind, solar thermal energy and PV (Greenpeace and EREC 2007a: 41).

The Factor 4 scenario developed by the Wuppertal Institute shows a similar picture. It projects that world primary energy demand can be stabilized by 2050 by energy efficiency in end use and supply and 50% of the remaining demand can be provided by renewables, thereby reducing world CO_2 emissions by 50% compared to the current level (Wuppertal Institute and GTZ 2004: 13).

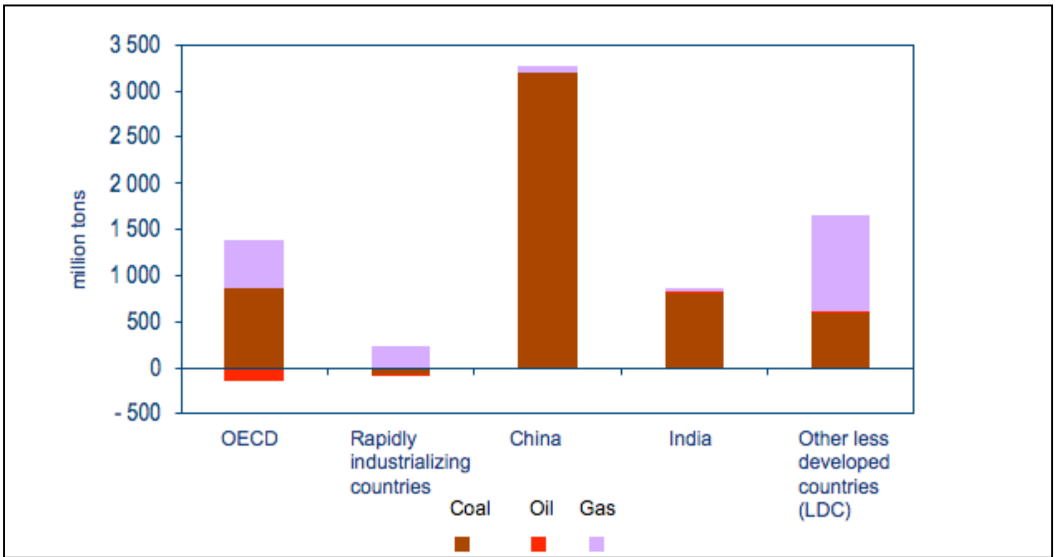
Figure 3: Coal use for today and tomorrow



Source: Valentin, D. (2007) "Coal use for today and tomorrow" presentation in Wuppertal[3]

The IEA predicts that coal will play a dominant role in electricity generation especially in China and India in order to meet increasing demand for electricity with the most abundant domestic resources (IEA 2006: 140), which would cause a huge increase of CO_2 emissions from these countries without appropriate measures (IEA 2006: 144). For example, China`s enery-related CO_2 emissions are projected to more than double between 2004 and 2030 (IEA 2006: 81). By contrast, the energy [r]evolution scenario projects that about 33% of primary energy demand could be covered by renewable energy in China.[4] As a result, CO_2 emissions in China would remain stable at around the 2003 level of 3300 Mt CO_2e (Greenpeace and EREC 2007b:8).

Figure 4: Increase in Power-Sector CO2 Emissions by Fuel in the Reference Scenario 2004-2030



Source. IEA 2006. 144 Figure 6

[3] Translated into English by the authors. The original title was "Kohlenutzung heute und morgen".
[4] Revolutionary scenario is not available for India. India is included in the South Asia region.

With this background, CCS has been advocated by those who believe that fossil fuels will play a significant role in the future. Considering that energy demand will grow in developing countries, particularly in China and India where coal may keep playing a significant role, the inclusion of CCS under the CDM is gaining more attention in the international negotiations.

3 The Potential of CCS

Despite an increasing interest towards CCS, there is still significant scientific uncertainty about its potential.

3.1 Storage Potential

Geological storage of CO_2 is widely accepted, whereas ocean storage (injection of CO_2 in the deep sea) has in principle been ruled out for the moment due to the question of permanence and unknown impacts on marine ecosystems.

Estimates of the global storage capacity in geological formations range from 1,678 – 11,100 Gt CO_2, whereas the technical potential and actual usability is estimated at 2,000 Gt CO_2, equalling around 75 times global CO_2 emission in the year 2005 (27.3 Gt CO_2) according to the IPCC (2005: 11). The estimation provided by Hendriks, Graus and van Bergen (2004: IV) is in the same order of magnitude, giving a total potential of 1,700 Gt CO_2 as “best”.

Table 1 presents the CO_2 potential by type of reservoir. Regionally, the largest storage potential is located in the former Soviet Union (21%) and the Middle East (20%), followed by Eastern Asia (16%), the USA (6%) and South East Asia (4%).

Table 1: CO2 storage per type of underground reservoirs

Reservoir type	CO_2 storage
Oil fields onshore	9%
Natural Gas fields onshore	37%
Coal beds	16%
Oil fields offshore	6%
Natural Gas fields offshore	18%
Aquifers	14%

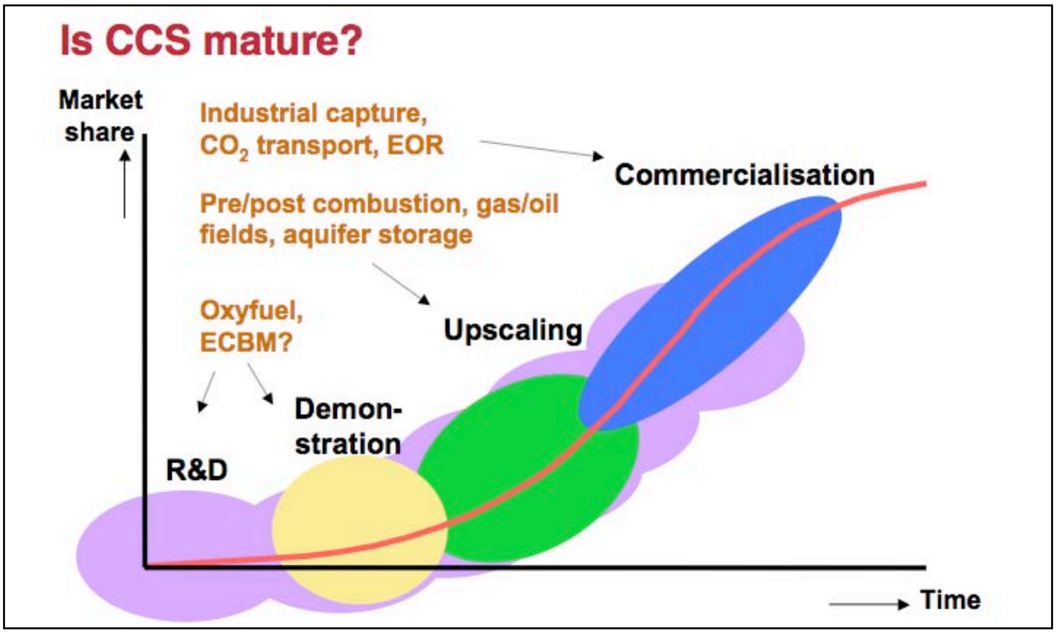
Source: Hendriks, Graus, van Bergen 2004: IV

There is, however, still great uncertainty regarding the potential storage capacity due to the varying types of storage reservoirs and lack of data. Projecting the possible total amount of CO_2 storage potential requires site-specific surveys and testing of the individual storage capacity.

3.2 Technical Potential

It is generally considered that CCS will not be available for the power sector on a large scale before 2020 since it is still in the research and development phase, focusing on pilot and demonstration projects (Fischedick 2007: 24, IPCC 2005: 8). Figure 5 shows the possible stages of development of the CCS technology in relation to time and market availability.

Figure 5: Maturity of CCS technology in relation to time and market share



Source: de Coninck 2007

CCS will become mature for different groups of CO_2 point sources at different times. Early opportunities will already exist during the first commitment period from 2008 to 2012 for gas processing, refineries, hydrogen and ammonia. The power and the cement industry will probably join as from 2012 to 2020, as technical potential rises after 2012 (de Coninck 2007), followed by the iron, steel and biomass industries as of 2020 to 2030.

The aforementioned "capture-ready sources" (gas processing, refineries, hydrogen and amonia) would incur only compression costs. Enhanced Oil Recovery (EOR), i.e. injection of CO_2 into oil wells to increase the yield, as well as Enhanced Coal Bed Methane (ECBM) are also considered a cost-effective option, provided that more information of the underground mechanics of these two options becomes available to answer questions related to expenses and technical feasibility in more detail. However, referring to Hendriks, Graus and van Bergen (2004: 22), the cost reductions for EOR and ECBM very much depend on oil and natural gas prices.

Turning to rapidly industrializing countries, the growth rates of CO_2 point sources at which CCS could be applied will be very different from country to country as the following tables (Table 2 and Table 3) show for selected industry sectors. Especially for China, a massive growth of CO_2 point sources is expected (de Coninck 2007).

Table 2: Technical potential of CCS, 2008-2012

Country ($Mt\ CO_2/yr$) Industry/Sector	Brazil	China	India	Mexico	Saudi Arabia	South Africa	Total
Refineries	18	40	30	15	17	6	**125**
Ammonia	0,2	56	2,2	2,3	0	0,5	**61**
Hydrogen	0	0	0,4	0	0,5	0	**1**
Gas processing	Not available, possibly 100-200 Sleipners worldwide?						

Source: de Coninck 2007 (based on IEA GHG CO2 point sources database, version 2006)

Table 3: Technical potential of CCS, 2012-2020

Country ($Mt\ CO_2/yr$) Industry/Sector	Brazil	China	India	Mexico	Saudi Arabia	South Africa	Total
Power[1]	56	4159	663	113	82	270	**5344**
Cement[1]	38	30	80	38	17	11	**213**

Source: de Coninck 2007 (based on IEA GHG CO_2 point sources database, version 2006)

In summary, early capture opportunities already exist, especially for refineries in Brazil, China and India. Especially for the power and cement industries in India and China, the technical potential for CCS will theoretically rise significantly after 2012.

However, the barriers to promote CCS on a large-scale need to be overcome first, such as long lead times of projects and uncertainties on the actual storage potential, and data on the application of the various stages of CCS, i.e. capture, transport and storage, on large-scale industries.

Since the CCS technology will become more mature in the future, the application potential is expected to rise after 2012, especially for the power sector in developing countries. There will only be a low market impact during the first Kyoto commitment period. As it would be most cost-effective to apply CCS to new power plants due to high reconstruction costs and lower efficiency rates of older power plants, de Coninck (2007) highlights the need to implement CCS before 2012, if the growing carbon dioxide from coal-fired power plants is to be reduced through the CDM. But since CCS might become viable in the power industry only between 2012 and 2020, this option may not be available in any case.

[1] Projected emissions in 2012, assuming growth rates between 50% (China) and 10% (Brazil) relative to 2006.

3.3 Economic Potential

CCS projects consist of capture, compression, transport, and storage of CO_2. Capture costs are the dominating factor within the CCS process cycle and depend on the characteristics of the plant and the capture technology (pre-, post- or oxygen combustion) applied. Bode and Jung estimate the costs for capture as ranging from 24 EUR to 52 EUR / t CO_2 avoided (Bode and Jung 2006: 176), while Fischedick et al. estimate 54 EUR / t CO2, accounting for more than 60% of total costs (Fischedick 2007: 21).

Transportation costs, which arise mainly from transport by pipeline, are in general the smallest factor in the CCS process cycle, although depending on transportation distance, amount transported, pressure of CO_2, landscape characteristics, pipeline diameter and country regulations. Cost estimates range from 1 to 6 EUR / t CO_2 per 100km pipeline (Bode and Jung 2007: 177) to 1 to 8 US$ / t CO2 per 250km pipeline or shipping (IPCC 2005: 42).

Storage costs mainly depend on the technical investment that is necessary for drilling of wells and operational costs, etc. Depending on the depth, the permeability and the type of storage reservoir, costs range from 1 to 11 EUR / t CO_2 (Bode and Jung 2006: 177). IPCC projections (IPCC 2005: 42) estimate costs for geological storage at 0.5 to 8 US$ / t CO2 and an additional 0.1 to 0.3 US$ / t CO2 injected for monitoring and verification.

Estimates of total costs for the whole CCS project cycle vary by source and due to the variability of reservoir-specific factors, from minus 3 to plus 106 EUR / t CO_2 avoided (Bode and Jung 2006: 177). The IPCC's SRCCS (IPCC 2005: 41, 43) estimates overall cost for three different power systems. For pulverized coal power plants with geological storage but no EOR, costs for CCS are estimated at 0.02 to 0.05 US$ / kWh, whereas costs for natural gas combined cycle power plants (NGCC) are estimated at 0.01 to 0.03 US$ / kWh. The CCS costs estimated for an integrated coal gasification combined cycle power plant (IGCC) range from 0.01 to 0.03 US$ / kWh.

Since coal-based power plants offer the largest potential for capturing CO_2, cost reductions are expected to be most substantial in this field. In general, the application of EOR with CO_2 storage is expected to substantially reduce the costs for all electricity systems by 0.01 to 0.02 US$ / kWh, since the costs for CCS can partially be compensated by EOR gains (IPCC 2005: 41).

The IPCC (IPCC 2005: 11) predicts that the costs of capture could decrease by 20-30% within the next decade, and the full cost reduction potential should be even higher since the technologies are still in the research and demonstration phase and will become more mature. Transport and storage costs will decrease at a much slower rate in the future, due to further development of the technology and increase in sales.

Estimates regarding the costs of avoiding dangerous climate change and limiting temperature increase below 2°C by applying CCS differ widely due to different technologies applied and existing uncertainties (capture process, transport capacity, storage capacity, etc.). For example, some EOR projects show a possible net yield of 40 EUR / t CO_2, others indicate net costs of 100 EUR / t CO_2, in cases where constellations are disadvantageous (smaller non-EOR projects with large transport distances) (Fischedick et. al 2007: 21).

4 Methodological Issues of Including CCS under the CDM

Methodological issues of including CCS under the CDM and possible solutions have been identified in the existing literature and through the UNFCCC process, i.e. the in-session workshop and Parties' submissions. Still, the current knowledge of the methodological issues was too immature to come to a decision. Parties therefore agreed to invite further submissions from international organizations and non-governmental organization (FCCC/SBSTA/2006/MISC.2).

This section explains the methodological issues following the categories defined by the UNFCCC, i.e. project boundaries, leakage, and permanence, based on the existing literature, the SB24 in-session workshop report (FCCC/KP/CMP/2006/3), and Parties' submissions (FCCC/KP/CMP/2006/ MISC.2).

4.1 Project boundaries

The project boundary of a CDM project needs to 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 (FCCC/KP/CMP/2006/3: 10).

Two issues were discussed; the definition of the project boundary for CCS projects and the definition of the project boundary when the storage reservoir spans international boundaries.

Regarding the definition of projects, stakeholders shared the view that the full activity chain of the CCS technology should be included within a CDM project boundary, i.e. the whole process of capture, transport, injection and storage of CO_2 (FCCC/KP/CMP/2006/3: 5).

The definition of the project boundary in cases where the reservoir spans international boundaries is contentious. Two options have so far been proposed. One is excluding project activities whose reservoirs extend to more than one country for the time being, the other is that cross-border reservoirs should not be a barrier and approval should be left to the countries whose jurisdiction the reservoir is located in (FCCC/KP/CMP/2006/3: 6). Especially Canada expressed the view that it should be possible to find a solution based on experience regarding mining, oil and gas operations, pollution control, waste disposal, subsurface property rights, etc. (FCCC/KP/CMP/2006/MISC.2: 16).

4.2 Leakage[5]

Under the CDM, the term "leakage" is defined as the net change of anthropogenic emissions by sources of greenhouse gases as a result of the project but outside the project boundary during the crediting period (FCCC/KP/CMP/2005/8/Add.1, p.17 para 51). Two issues, i.e. the accounting of leakage due to upstream and downstream emissions and that of emissions resulting from the use of additional hydrocarbons recovered in enhanced oil recovery (EOR) were identified in this category.

Regarding the accounting of leakage due to upstream and downstream emissions, it was discussed whether the increased use of fossil fuel resulting from the loss in conversion efficiency of the power plant should be accounted for as leakage. The additional energy requirements for CCS result in a significant overall loss in conversion efficiency of the power plant. The loss in conversion efficiency implies a greater use of fossil fuel by the power plant to supply the same output, which in turn leads to increased emissions (upstream emissions) from producing, processing and transporting fossil fuel (FCCC/KP/CMP/2006/3: 6-7).

Regarding the accounting for emissions resulting from EOR, two different views have been expressed. Oil-producing countries stressed that emissions from EOR should not be accounted for since there was lack of evidence that EOR will result in a significant increase of oil production. They also highlighted possible double accounting issues, i.e. accounting for emissions from the oil produced through EOR at the consumption stage and in the CDM project (FCCC/KP/CMP/2006/3: 6). Others expressed their concerns that EOR could lead to increased oil extraction and that such emissions should be treated as leakage and accounted for (ibid). The issue of economic additionality regarding EOR was also raised as EOR enhances oil extraction and thus provides economic benefits to the project participants. The EU proposed that additionality should be demonstrated on a case-by-case basis, rather than rejecting EOR in principle (e.g. EU in FCCC/KP/CMP/2006/MISC. 2:11).

4.3 Permanence

The term permanence relates to potential seepage, i.e. the likely escape of injected CO_2 from a storage reservoir after the crediting period of the project.

Non-permanence was recognized as one of the most severe methodological issues as it is still difficult to predict long-term seepage rates for a full-scale project (OECD/IEA 2004: 94-97). Therefore, CCS projects under the CDM would encounter a number of methodological issues in relation to permanence, including criteria for suitable storage site selection, suitable methods for storage, monitoring, and liability for seepage during and after the crediting period(s).

Since the seepage rate in well-selected geological reservoirs is considered to be very low (DTI 2004), strict criteria for site selection could reduce the non-permanence issue (Haefeli et al. 2004). At the climate negotiations, a number of Parties also stressed the importance of careful selection and proper management of the

5 The difference between permanence and leakage is that permanence refers to seepage of injected CO_2 within the project boundary beyond the crediting period while leakage refers to increased emissions outside the project boundary during the crediting period. Seepage from a reservoir during the crediting period is accounted for either as project emissions (from the part of a reservoir that is within the project boundary) or as leakage (from the part of a reservoir that is outside the project boundary). Seepage beyond the crediting period would not be accounted for under the present modalities and procedures of the CDM.

reservoir to prevent seepage (e.g. FCCC/KP/CMP/2006/MISC.2: 18, 23, 29, Canada, Japan and Norway). For the careful selection and proper management, detailed ex-ante risk assessment (FCCC/KP/CMP/2006/MISC.2: ibid: 18, Canada) and the development of guidelines for the assessment of potential storage sites by the EB (ibid: 29, Norway) were proposed.

Proper monitoring is essential to account for seepage. However, there is so far no agreement what duration the monitoring period should have (during the injection and crediting period of the project activity or beyond) and how the cost for monitoring beyond the crediting period should be financed.

Liability for seepage was identified as another important issue. The necessity of clear and transparent licensing and regulatory arrangements, which should include proper site closure procedures, are almost agreed. The necessity of liability beyond the crediting period was also agreed. However, there is no agreement on which entity should take the liability, the host country or the project participants (ibid:12, FCCC/KP/CMP/2006/3).

Apart from the above, the issue of accounting for seepage was also raised. The necessity for an appropriate, transparent, and simple accounting system beyond the crediting period was almost agreed. Several options on accounting for seepage were presented; discounting, cancellation or replacement of certified emission reductions (CERs) should seepage occur, issuance of temporary CERs, insurance, and the creation of a remediation fund for any seepage (FCCC/KP/CMP/2006/3: 8).

5 Current stakeholders' positions

Sections 2 to 4 explained the implications of CCS for the long-term climate mitigation goal, CCS potential, and methodological and legal issues for including CCS under the CDM. This section summarizes stakeholders' positions on CCS and CCS under the CDM based on Parties' submissions, the reports of the in-session workshops during SB24, and the SB 26 side event.

5.1 Positions on CCS

Parties and stakeholders in principle admitted that CCS would be one of a range of mitigation options but also highlighted that it was necessary to clarify technical and methodological issues for a wide and a full-scale application of CCS (FCCC/KP/CMP/2006/, FCCC/KP/CMP/2006/MISC.2, Coninck 2007, Schneider 2007).

Australia, Saudi Arabia, Norway, and Canada were among the most positive about CCS as such. For example, Australia and Saudi Arabia stated that CCS would play "a vital part in mitigating the impact of climate change" (FCCC/KP/CMP/2006/MISC.2: 3), or was "the most promising and effective win-win means to combat CO_2 emissions" (ibid: 33). Canada also viewed that CCS could serve as a critical bridge towards a low-carbon world, given the forecast global growth in fossil fuel use (ibid: 15).

The EU's position was more moderate compared to the above statements, stating that CCS involving geological storage was "an acceptable mitigation option" in the portfolio of actions for stabilizing GHG concentrations in the atmosphere, provided it complied with national regulations, international obligations including relevant multilateral maritime agreements and IPCC guidance (ibid:10).[6]

Brazil was the most negative. It expressed that CCS "may" be an option in the portfolio of mitigation options for stabilization of atmospheric greenhouse gas concentrations, especially for the Annex I Parties (ibid:14)[7]. It noted the reservation, however, that the widespread application of CCS would depend on technical maturity, costs, diffusion and transfer of the technology to developing countries and assessment of environmental issues. Therefore it supports the acceleration of research, development, deployment and diffusion of CCS technologies (ibid:14).[8]

Industry stakeholders in general support CCS, putting a great hope on the CCS technologies for further development of successful large-scale applications, through which "the future utilisation of the domestic coal reserves (in Germany) and the long-term security of supply can both be guaranteed" (Vattenfall 2006: 7) or considering that CCS could be an important bridge for solving the climate change issue if certain conditions are fulfilled (Shell 2007).

On the other hand, some NGOs are inclined to refuse the utilisation of CCS in principle, referring to technical and methodological issues, but also the long-term issue (CAN 2006, von Goerne 2007). CAN expressed its concern about environmental risks but also about the continued and increased reliance on fossil fuels resulting from a widespread application of CCS, with a wide range of local environmental and social impacts associated with extraction, transportation and burning of fossil fuels (CAN 2006). WWF is more flexible, admitting that CCS may play an important role in reducing atmonspheric CO_2 concentrations in the future, but still stresses the necessity to "resolve key questions and concerns before giving the green light to the approach to utilise CCS" (WWF 2006).

The review shows that industries and NGOs expressed positions on technical and political aspects, while Parties expressed positions mainly regarding technical aspects.

5.2 CCS under the CDM

Regarding CCS under the CDM, stakeholders' views were more diverse compared to the views on CCS as such. Qatar and Saudi Arabia were among the most positive about the inclusion of CCS under the CDM without mentioning technical issues (FCCC/KP/CMP/2006/MISC.2: 31, 33), while the Least Developed

6 International obligations including relevant multilateral maritime agreements mainly refer to the Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter of 1972 (London Protocol) and the Ospar Convention. Regarding the London Protocol, the issue was resolved when the First meeting of the Contracting Parties to the Protocol on November 2, 2006 decided to amend the Protocol. With this amendment, storage of carbon dioxide under the seabed will be allowed from 10 February 2007. The amendments regulate the sequestration of CO_2 streams from CO_2 capture processes in sub-seabed geological formations for permanent isolation. Guidelines on how to store CO_2 in sub-seabed geological formations will be developed for adoption by the Parties to the London Protocol when they meet for their second session in November 2007.

7 Jose Miguez of Brazilian Ministry of Science and Technology stressed at the SB 26 side-event in his personal capacity that reduced emissions from CCS should be additional to the targets that Annex I Parites committed themselves to under the Kyoto Protocol (Miguez 2007).

8 Brazil is expected to continue to rely on hydropower to meet most of its power-generation needs and the share of hydropower in total electricity generation will increase slightly to 79% in 2030 (IEA 2006: 481). As a result, Brazil does not have so much potential on CCS compared to China as mentioned in the section 3. It is regarded that the mentioned facts underpin Brazil's position.

Countries (LDCs), the Alliance of Small Island States (AOSIS) and Brazil explicitly opposed the inclusion of CCS under the CDM (Sterk/Ott/Watanabe/Wittneben 2007: 145, Watanabe and Sterk 2007: 2).

Other Parties viewed that project activities involving CCS could be considered under the CDM given that all technical, methodological and legal issues were resolved. The EU raised a number of outstanding methodological aspects (FCCC/KP/CMP/2006/MISC.2:10). Bangladesh had the same position as the EU (ibid: 13), while Australia, Canada, Japan, and Norway were more positive, but still highlighted that the inclusion of CCS under the CDM depended on the resolution of the technical issues. Canada was the most positive among them, stating that all methodological issues could be addressed through appropriate methodologies under the CDM (ibid: 16). Parties made little reference to political aspects in the negotiations and submissions.

Industries have focused on CCS as such and not expressed positions on the inclusion of CCS under the CDM. However, they are considered to be a driver for the inclusion of CCS under the CDM (Miguez 2007, Schneider 2007), mainly for political reasons. For example, Dirschauer of Vattenfall Europe stressed that "it is difficult to think of a world which does not use coal even in developed countries, and the reality that CCS projects are under way needs to be taken into account when there is no silver bullet to solve the challenge of climate change." (Dirschauer 2007)

Some NGOs and experts who prioritize renewable energy opposed the inclusion of CCS under the CDM for methodological but also political reasons, stressing the timing issue, technology lock-in effects, and incompatibility of CCS with the original objective of the CDM. As for timing, global GHG emissions have to peak in less than 10 years while CCS will not be available on a large scale until 2020. With regards to technology lock-in effects, statements criticized that CCS was used as a vehicle to build new coal power plants now that would continue to emit large amounts of CO_2 and would prevent development of renewable energy (von Goerne 2007, Miguez 2007). In terms of compatibility of CCS with the original objective of the CDM, i.e. to contribute to the ultimate objective of the Convention and to promote sustainable development, statements criticized that CCS created a positive incentive for further fossil fuel production, especially through EOR, and would thus lead to overexploitation of natural resources and be harmful to the environment (von Goerne 2007, Miguez 2007).

The review shows that Parties focused their considerations on methodological aspects and did not directly consider political aspects so far, while industries, NGOs, and experts paid more attention to political aspects.

6 Conclusions

The examination conducted in this paper highlighted that the inclusion of CCS under the CDM encounters not only technical, methodological, and legal problems but also political issues.

The technical and methodological issues that have been identified are summarized in Table 4, Table 5 and Table 6.

Table 4: Scientific Consensus and Future Research Aspects on Technical Potential of CCS

	General / Scientific Consensus	**Future Research Aspects**
Storage Potential	Large capacities in geological storage formations assumed but much uncertainty on details	Potential needs to clarified by site-specific surveys
		Geographical relationship between CO_2 point sources and storage sites needs to be considered
Technical Potential	CCS still in the pilot and demonstration phase	Market impact of CCS for different sectors over different time scales for Annex I and Non-Annex I countries
	Mature technology-application potential of CCS rises with time	Overall potential of CCS to contribute to GHG mitigation
Economic Potential	Decrease in costs with maturing of technology (20-30% within next decade)	Further detailed cost analysis for CCS full-cycle system

Source: Created by authors

Table 5: Methodological Issues Concerning CCS and CDM

Issues			**Description of issues**	**Current status of negotiation**
Methodological issues	**Project boundary**	Definition of project activities	Full activity chain of the CCS technology to be put within the CDM project boundary, i.e. the process of capture, transport, injection and storage of CO2	Almost agreed
		Cross-boundary projects	Difficulty to apply conditions of methodologies for a project boundary which involves more that one host country of the CCS process	• Exclude cross-boundary projects, or • Not exclude but let the Parties involved decide
	Leakage	Accounting of leakage due to upstream and downstream emissions	Whether upstream emissions from the increased use of fossil fuel resulting from the loss in conversion efficiency of the power plant should be accounted for as leakage	Under discussion
		Emissions from EOR	Accounting for increased oil yield	Should be accounted for as leakage or not?
			Economic additionality regarding EOR	Case-by-case demonstration of additionality has been proposed
		Basis for reporting and accounting		Are the IPCC new reporting guidelines sufficient or not ?

Table 5: continued

Issues			Description of issues	Current Status of negotiation
	Permanence	Site selection criteria	Necessity of careful selection and proper management of the reservoir to prevent seepage was almost agreed.	
			Way to maintain careful selection and proper management	Diligence and thorough ex-ante risk assessment? Development of guidelines for the assessment of potential storage sites by the EB, considering the 2005 SRCCS? Characterization, analysis and documentation of a site in the Project Design Document (PDD)?
		Liability in the case of seepage	Necessity for clear and transparent licensing and regulatory arrangements was almost agreed.	
			The entity to take the liability	One option: Project developer held liable until the closure of the site, host country will be held liable afterwards.
		Monitoring of seepage	Necessity of proper monitoring was almost agreed.	
			Financing of monitoring cost	Who will bear the cost?
			Duration	During the injection and crediting period of the project activity or beyond?
		Accounting	Necessity for appropriate, transparent, and simple accounting system beyond the crediting period was almost agreed.	
				Several options Discounting, cancellation or replacement of certified emission reductions (CERs) should seepage occur, issuance of temporary CERs, insurance, and the creation of a remediation fund for any seepage

Source: Created by authors

Table 6: Potential Benefits and Open Issues for CCS and CCS under the CDM

	Potential Benefits	**Issues**
General CCS	• Resolving the dilemma between achieving long-term climate goal and securing energy supply from fossil fuels • Enhancing broader particpation of fossil-fuel dependent Annex I Parties (=large emitters)	• Technology lock-in effects (Distract investment from renewables and energy efficiency) • Timing issue (CCS will not be operationalized on a full scale before 2020)
Specific for CCS under the CDM	• Resolving the dilemma between achieving long-term climate goal and securing energy supply from fossil fuels • Enhancing broader participation of fossil-fuel dependent non-Annex I Parties (=large emitters) • Enhancing more ambitious commitments from Annex I Parties	• Technology lock-in effects (Distract sufficient investment from renewables and energy efficiency) • Compatibility of CCS with the original objective (Contradiction with sustainable development, increased production and use of fossil fuels)

Source: Created by authors

This paper highlighted that the inclusion of CCS under the CDM also has implications for more fundamental issues apart from well-known technical and methodological issues. The review of Parties' positions identified, however, that Parties have expressed positions concerning CCS under the CDM mainly regarding methodological aspects so far, while industries and NGOs touched upon political aspects as well as technical and methodological aspects.

As described in the section 2, there are two contradictory views about how to achieve GHGs reductions to combat climate change. Proponents of the first approach hold that energy efficiency and renewable energy have sufficient potential to meet future energy demand and satisfy the development needs of developing countries. They therefore argue that these options should be promoted as much as possible and fear that promotion of CCS could divert too much attention and essential resources.

By contrast, proponents of the second approach maintain that coal will remain the mainstay of global energy supply and that CCS will therefore be necessary to reconcile energy needs with climate protection.

Regarding technological aspects, it is not yet clear whether CCS will be applicable on a large scale. In particular large-scale application before 2020 is doubtful. At the same time, climate science stresses that global GHG emissions need to peak during the next decade and then be sharply reduced in order to keep the increase of average global temperatures below 2°C. According to current scientific knowledge about its potential, CCS will not be able to make a major contribution towards this turnaround of global emission trends by 2020. On the other hand, some cost-effective early options have been identified. In order to realize this potential, it would be sensible to launch the projects as soon as possible. Yet, many technical barriers still have to be overcome.

Nevertheless, the current stage of development of CCS leads to the conclusion that CCS cannot be promoted *in lieu* of aggressively promoting energy efficiency and renewable energy. Given that global emissions need to peak within the next decade and that large-scale viability of CCS is not yet proven, focussing on CCS to the detriment of other options entails the severe risk of finding in the end that the technology is not viable or is not politically feasible while climate change has already spiraled out of control.

Section 4 has highlighted that a huge number of methodological issues have to be overcome in order to include CCS projects under the CDM. Considering that CDM projects yield Certified Emissions Reductions (CERs), which will allow for increased emissions in industrialized countries, all accounting, monitoring, and liability issues must first be clarified.

Moreover, CCS is a very expensive technology at current costs. Excluding cost effective options such as EOR, which might in any case not be counted as “additional” under the CDM, the lowest estimates of CO_2 reduction cost start at about 30 EUR / t CO_2. Current CER prices range from 5-16 EUR depending on the project’s stage of implementation (GTZ 2007), i.e. significantly below the costs of CCS. Therefore, CCS would not attract CDM projects unless CER prices will significantly increase, which will probably come about only through severely tightening future emission reduction commitments post-2012.

In the end, this is a matter of political decision on future energy supply planning and the pathway towards it primarily at the national level. This includes the consideration of the geographical and geopolitical situation of each country, the availability of domestic resources, and acceptability of CCS.

The inclusion of CCS under the CDM firstly requires clarifying all the identified technical and methodological issues. It is also necessary to discuss whether CCS has a role in achieving the long-term climate goal while ensuring energy supply, and if so what is the best way to promote the technology. The CDM is one of the options, however, it is recommendable to discuss the issue in a broader framework, including technology transfer under the international climate regime and other initiatives, such as the Carbon Sequestration Leadership Forum.

The CDM has advantages because the framework has already been established while technology transfer under the international climate regime and other initiatives have not created any specific framework yet. On the other hand, the disadvantages of the CDM are that its accounting must be accurate because it yields CERs, which will be used to offset higher emissions in industrialized countries, the financial incentive is still low considering the current CER price and the cost of CCS, and CDM project have to undergo a lengthy approval process, which could be avoided under technology transfer under the international climate regime and other initatives. In other words, technology transfer under the international climate regime or other initatives must be designed and implemented to overcome the disadvantages of the CDM and to complement it, once it is decided to use CCS on a large scale.

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ANNEX

Annex 1: Questionnaire send to parties in advance to the SBSTA Side Event

General questions:

- What is your country (organization)'s position on CCS? (proponent, opponent)?
- What is your country (organization)'s position on CCS in the CDM?
- What is the status of development/investment of CCS technologies?
- What are the reasons for the above position?

To all:

- What kind of issues are you particularly concerned about as regards to CCS or CCS in the CDM?
- What kind of benefits, do you believe, CCS would provide?
- What kind of development path do you have in your mind? With or without CCS, with or without CCS in the CDM would affect your view? i.e. what is the way to mitigate CO2 emissions while ensuring energy supply and development?

To Parties (Vattenfall as well):

- What is your estimation of potential of CCS site in your country (ocean and geo)?
- What kind of energy policy plan (energy mixture) does your country(organization) have? With CCS or without CCS would affect it? With or without CCS in the CDM would affect it?
- With CCS or without CCS, what kind of climate mitigation targets do you prospect for your country?
- What about with or without CCS in the CDM?

Annex 2: List of Panelists

- Rie Watanabe, Wuppertal Institute for Climate, Environment and Energy
- Wolfgang Sterk, Wuppertal Institute for Climate, Environment and Energy
- Heleen de Coninck, Energy Research Centre of the Netherlands (ECN)
- Lambert Schneider, Öko-Institut, Institute for Applied Ecology
- José Miguez, Ministry of Science and Technology, Executive Secretary ob Brazilian Interministerial Commission on Global Climate Change
- Gabriela von Goerne, Greenpeace International
- Wolfgang Dirschauer, Vattenfall Europe

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The positions expressed in this policy paper are strictly those of the authors.

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