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# $CO_2$ capture and storage

## State-of-the-art in the climate negotiations

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## Abstract

$CO_2$ capture and storage (CCS) is increasingly seen as a potentially effective means of mitigating climate change. The technology is different from mitigation options such as renewable energy or nuclear energy as it does produce the $CO_2$ but prevents its emission to the atmosphere and therewith the contribution of carbon dioxide to climate change. Being a new technology in the climate change mitigation portfolio, CCS has not yet established itself in the climate change negotiations. No examples of the technology have for instance been implemented in the CDM (Clean Development Mechanism) and the EU ETS (European Union Emission Trading Scheme) also excludes its use until a methodology is provided, although the Norwegian government reports CCS emission reductions in its National Communication. By means of an interim evaluation, this paper examines the climate policy developments in the field of CCS, both internationally and on a national level.

Based on recent developments in the scientific literature, the IPCC, the UNFCCC, national policies, and non-UN international initiatives, it is concluded that the policy prospects of CCS are promising, although there are a number of barriers that need to be overcome before CCS is fully established in the climate change regime. Those barriers include the development of a common methodology for greenhouse inventories and accounting of CCS, notably the challenges of potential impermanence (notably through potential leakage of the reservoirs) monitoring, and - in the case of CDM - the contribution to sustainable development.

[1] More details at: www.seq.nl.

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# 1. Introduction

$CO_2$ capture and storage (CCS) is increasingly seen as a potentially effective means of mitigating climate change. The technology is different from mitigation options such as renewable energy or nuclear energy as it does produce the $CO_2$ but prevents its emission to the atmosphere and therewith the contribution of the emission of carbon dioxide to climate change. Being a relatively new technology, CCS has not yet established itself in the climate change negotiations. For the confidence of governments and the private sector in the technology, it is important that CCS is fully acknowledged and has workable accounting methodologies in the Kyoto regime. At this point, no conclusion has been reached on this. By means of an interim evaluation, this paper examines the climate policy developments in the field of CCS, both internationally and on a national level, to end with some findings on the indication the present policy state gives.

$CO_2$ capture can be applied to large $CO_2$ point sources. It essentially comprises the capture and separation of $CO_2$ from the flue gases and the subsequent transport and storage thereof. Capture can be done in three ways: by capturing and separating the $CO_2$ after combustion (post-combustion decarbonisation), by extracting the $CO_2$ and combusting or using the resulting hydrogen (pre-combustion decarbonisation), or by combusting the fossil fuel with pure oxygen, resulting in high $CO_2$ concentrations after combustion and easier separation (oxyfuel combustion). Depending on the geographical characteristics and the economics, transport can be done by pipelines or ship. The storage of $CO_2$ can be done in saline aquifers, coal beds, or in oil or gas fields. It can be done in depleted ('empty') oil and gas fields, but also in fields still in production, where the $CO_2$ may mobilise the fossil fuels, resulting in higher fossil fuel recovery. This is called Enhanced Oil or Gas Recovery (EOR or EGR) and can actually make the usually expensive CCS-options economically feasible.

The (additional) costs of applying CCS in the electricity sector are in the range of 25-40 €/t$CO_2$ avoided (IPCC, 2005). There is currently no policy in place that gives an incentive large enough to allow large-scale implementation in the power sector. The EU Emissions Trading Scheme currently boasts prices of around 20 €/t$CO_2$, but it is uncertain whether prices will stay that high and whether the current lack of liquidity of the EU $CO_2$ market is driving the price to an unrealistically high level. In addition to uncertainties on price volatility, the perspectives for a post-2012 regime similar to the Kyoto Protocol, with targets, timetables and emissions trading, are highly uncertain. Other possibilities of a climate change regime are in the field of relative emission targets or in technology agreements.

Whether CCS is accepted under the climate change regime, is essential to the success of its short and/or long-term implementation. In Chapter 2, the publications and developments in the UN-based bodies: the Intergovernmental Panel on Climate Change, and the United Nations Framework Convention on Climate Change, are discussed. Chapter 3 focuses on national programmes: the European Emission Trading Scheme, and national taxes or policies. Chapter 4 will look into non-UN international processes. Some conclusions are listed in Chapter 5.

# 2. United Nations

## 2.1 Introduction

The main purpose of applying CCS is to reduce the emission of $CO_2$, the most important greenhouse gas held responsible for the recent warming of the atmosphere. Politically, greenhouse gas emission reduction, or climate change mitigation, are addressed in the United Nations Framework Convention on Climate Change (UNFCCC, 1992), which stipulates that the dangerous anthropogenic interference with the climate system should be prevented. It also includes a commitment of Parties to make a 'National Communication', which (among other things) contains an inventory of emissions.

The Kyoto Protocol (UNFCCC, 1997) lists commitments for actual reductions in greenhouse gases for industrialised (Annex B) countries between 2008 and 2012. Within the Kyoto Protocol, it is possible to trade emission reductions. This emissions trading can be based either on the allowances of the Annex B countries, in which case it is called 'international emissions trading', or based on separate projects that reduce emissions, in which cases it is called 'Joint Implementation' (JI) or 'Clean Development Mechanism' (CDM), depending on whether the host country is an Annex B or a non-Annex B country. For JI and CDM to be implemented, greenhouse gas accounting methodologies should be established, which is addressed in Paragraph 2.4. The Kyoto Protocol ends in 2012, and the negotiations on a post-Kyoto or a post-2012 regime are starting now.

The Intergovernmental Panel on Climate Change (IPCC) is also a UN organisation, but is the scientific branch of climate change in the UN. It has no direct links to the UNFCCC, but provides information to the UNFCCC. It should be noted that the IPCC does not provide any recommendations to the UNFCCC and therefore has no policy influence; the organisation is fully policy-neutral. However, its reports can have an impact on policymaking as the parties of the UNFCCC will draw conclusions from the IPCC results, and take those into account in their policy decisions. The one occasion where IPCC does provide guidance to the UNFCCC is in the case of the inventory methods for greenhouse gas emissions. Those inventory methods are published in the 'IPCC Guidelines for National Greenhouse Gas Inventories'. The latest is from 1996, and the IPCC is working on an update (Revised Guidelines) to be published in 2006.

This chapter will first address the way CCS is discussed in the IPCC, and will proceed with National Communications where it occurs, with the Kyoto Protocol and JI/CDM, and with the role of CCS at the Conferences of Parties (COP) and in the post-2012 negotiations.

## 2.2 CCS in the Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change is an UN-based scientific organisation. It is generally regarded as the most authorative organisation in the field of climate change. It produces reports that give policy-relevant information, but it is not in IPCC's mandate to advise governments on policy. The IPCC also produces Guidelines for greenhouse gas inventories, which distinguish themselves from the regular IPCC Assessment Reports.

In the IPCC Third Assessment Report (2001), CCS was briefly discussed. It was noted that the potential for greenhouse gas reduction was large, but that significant barriers still needed to be overcome. The rapid rise of CCS on the political agenda, however, caused the IPCC to produce an intermediate, detailed assessment of the option. The two new products of IPCC are both important for the acknowledgment of CCS as a climate change mitigation action.

### 2.2.1 The IPCC Special Report on Carbon dioxide Capture and Storage

Responding to a draft decision of the UNFCCC's Conference of Parties, the IPCC started work on a 'Special Report on Carbon dioxide Capture and Storage' in February 2003. The report (IPCC, 2005) was finalised in September 2005. Its publication contributes greatly to acknowledgement of $CO_2$ capture and storage as a climate change mitigation option. The report looked at technical, economic, safety and regulatory aspects of capture, transport and storage options, including geological storage, but also ocean storage and mineral carbonation. The results of the Special Report argue that:

- CCS should be seen as a mitigation option in a portfolio of mitigation options. It will not solve the climate problem by itself; implementation of energy demand reduction and carbon-free energy supply also need to be enhanced.
- Several components of CCS are mature technologies or technically available. Large-scale demonstration projects in the electricity sector, however, still remain to be implemented.
- CCS has certain risks. Leakage from a geological reservoir can lead to local risks because of impacts of elevated $CO_2$ concentrations in the air or in groundwater. Geological storage in reservoirs that are subject to an appropriate selection, are generally regarded to have local risks comparable to similar operations, such as natural gas storage or Enhanced Oil Recovery-projects already taking place.
- CCS could also lead to 'global risks' because (large-scale) re-emission of $CO_2$ from a leaking reservoir could make CCS potentially ineffective as a mitigation option. Estimates of the fractions of $CO_2$ retained in storage are estimated to be sufficient to still make CCS worthwhile from the climate change perspective.
- CCS comes with a cost. Additional costs of CCS are on the order of a few US$ct/kWh produced electricity, or equivalent to several tens of US$/t$CO_2$ avoided.
- With current costs estimates, large-scale application of CCS could reduce overall mitigation costs by 30% or more. The contribution of CCS to mitigation of climate change, according to the modelling done, would range from 15 to 55% under their assumptions. This translates into the economic potential, or demand for $CO_2$ storage, which amounts to 220 to 2,200 Gt$CO_2$, cumulatively over the course of this century.
- The technical storage potential of geological storage of $CO_2$ is estimated to be at least 2,000 Gt$CO_2$, which would be sufficient to store the likely demand for $CO_2$ storage (the economic potential).
- CCS still faces legal and regulatory barriers. Legally, not all countries have a legal framework for CCS. Especially long-term liabilities are a challenging question. International law, for sub-seabed storage of $CO_2$, is unclear about the permissibility of CCS.
- On the regulatory side, the report notes that Guidelines for greenhouse gas inventories have not been agreed with respect to CCS although it notes that the IPCC Revised Guidelines are being written (due to be published in 2006, see the next chapter).

The IPCC Special Report on Carbon dioxide Capture and Storage has generally been well-received, in the press as well as in the scientific and policymaking communities. Although it is outside of the mandate of the IPCC to make recommendations to the policymaking community, the Subsidiary Body on Science and Technology Assessment (SBSTA) has included the report in the agenda of its meeting at COP11, in November 2005.

### 2.2.2 The IPCC Guidelines on greenhouse gas inventories

The IPCC has a Task Force, which focuses on its 'National Greenhouse Gas Inventory Programme'. The UNFCCC uses the inventory guidelines as developed by the IPCC. The last version of these Guidelines stem from 1996. The Task Force is now working on Revised Guidelines, due for publication in the first half of 2006.

$CO_2$ capture and storage was not mentioned in the 1996 Guidelines for Inventories as it was not yet regarded as being a mitigating option. Given the results in the 'IPCC Special Report on CCS', the Revised Guidelines will contain a chapter on capture and geological storage of $CO_2$. The question often asked (Bode and Jung, 2004) is whether CCS should be treated as an option that reduces $CO_2$ emissions *by source*, or *as a $CO_2$ sink*. This choice has consequences for the treatment of CCS under the flexible mechanisms of the Kyoto Protocol, as the category in the inventories is usually also applied to the accounting rules for greenhouse gas reduction. The main question is how to account for the potential impermanence of the $CO_2$ in the storage reservoir.

In the case of CCS being treated as a reduction *by source*, the emissions resulting from leakage of $CO_2$ from a geological reservoir could be included under the 'fugitive emissions' category. If CCS is treated *as a sink* of $CO_2$, the modalities for sequestration of $CO_2$ by forests or land use could be used, which include provisions for impermanence. Problematic, however, is that the timescales and the characteristics of $CO_2$ release for CCS are very different compared to those for biological sinks. This leads to the conclusion that for inventories, the method of including CCS as a 'reduction of $CO_2$ by source' is the most appropriate. The Revised Guidelines in their draft versions indeed chose this approach.

## 2.3 CCS in National Communications

All parties to the UNFCCC are obliged to submit National Communications to the UNFCCC, indicating their greenhouse gas emissions, their projections, vulnerability to and impacts of climate change, and policies and measures taken for mitigating and adapting to climate change. How CCS is reported in these National Communications is therefore a model for the reporting of the emission reductions under the Kyoto Protocol.

There are currently three major CCS projects: in Algeria, in Norway, and in the United States and Canada. Algeria's National Communication dates from 2001, when the injection in the 'In Salah'-field had not yet started. Canada injects $CO_2$ in the Weyburn field for EOR since 2000, but as the emissions are reduced or effectuated in the United States (capture is done at the Beulah gasification plant in North Dakota, USA), the Canadian government has no emissions to report. The United States inventory dates from 2002 and also does not include the emission reductions at the Beulah plant, possibly because the capture had not yet started when the most recent inventory was done. The only National Communication that reports greenhouse gas emission reductions from CCS is the 3rd National Communication of Norway (Miljøverndepartementet, 2002).

Norway established a tax on $CO_2$ emissions from the offshore industry in 1991. The tax was high enough for Statoil, the national oil and gas company, to decide for the application of $CO_2$ capture and storage at one of its offshore gas recovery operations, in the Sleipner field off the Norwegian coast. In the case of Sleipner, the natural gas contained a large fraction of $CO_2$, which needed to be separated in order for the gas to meet the international standards. Normally, the $CO_2$ would be vented to the atmosphere. In the case of Sleipner, an extra, horizontal well was drilled into a saline formation above the gas field, and instead of being vented, since 1996, the $CO_2$ is injected into that formation. Extensive monitoring takes place around the project, which was the first large-scale (around 1 $MtCO_2$/yr) CCS-project in the world. In the meantime, the Weyburn and the In Salah projects have followed.

Norway has reported the Sleipner case in its National Communication as a greenhouse gas reduction measure (Miljøverndepartementet, 2002). It is the main effect of the environmental tax regime that Norway imposed, and, according to the document, reduces around 2% of the Norwegian greenhouse gas emissions. The document also stipulates that the new gas field to be exploited by Statoil, the Snøhvit field, would lead to emissions of 0.9 $MtCO_2$/yr. It therefore ar-

gues that “the government will ensure that the companies responsible for developing the Snøhvit petroleum field draw up a plan (..) for testing $CO_2$ reduction technologies.”

It should be noted that in the Norwegian National Communication, the Sleipner project is treated as a reduction of $CO_2$ emissions by source, and not as a sink. Although the report has no concrete status under the (national) Kyoto reduction target (as the Kyoto commitment period starts in 2008), the inventory has been approved by an in-depth review.

## 2.4 Kyoto Protocol

Given the cost and - apart from enhanced resources production - the general lack of co-benefits, the only incentive for carbon dioxide storage is climate change mitigation. Structural policy incentives for carbon dioxide capture and storage in most countries are still absent (see Chapter 3). CCS will therefore not be deployed on a large scale unless a policy incentive is installed which makes CCS economically attractive. In the context of the Kyoto Protocol, this can be the project-based flexible mechanisms: Joint Implementation and the Clean Development Mechanism.

The Kyoto Protocol entered into force in 2005, which made the greenhouse gas emission reduction targets binding for those countries that have ratified the Protocol. Also, the flexible mechanisms have become legal instruments. Although the Kyoto Protocol acknowledges ‘carbon sequestration technologies’ as a mitigation measure (UNFCCC, 1997), it has not been discussed within the United Nations Framework Convention on Climate Change (UNFCCC) or in bodies governing the flexible mechanisms, such as the Executive Board of the CDM (CDM EB). A related question is whether $CO_2$ capture and storage will be possible as part of the EU Emission Trading System, which is discussed in Paragraph 3.2. Whether $CO_2$ capture and storage (CCS) would be eligible under JI and CDM is subject to debate. Recent studies include GCSI (2004), Haefili et al. (2004), ERM/DNV (2005) and Bode and Jung (2004, 2005), but they have not given an overview consistent with the technical characteristics of CCS or with the UNFCCC rules for mitigation options.

### 2.4.1 What are JI and CDM?

Joint Implementation (JI) and the Clean Development Mechanism (CDM) have been included as part of the Kyoto Protocol to allow trading of reductions in greenhouse gas emissions between countries. The term ‘project-based’ distinguishes JI and CDM from the other Kyoto mechanism, International Emission Trading (IET). IET is based on the allocated emissions of an Annex B country (an Annex B country is a country that has an emission target under the Kyoto Protocol). In project-based mechanisms, the carbon credits that can be traded are determined by the reduction of greenhouse gas emissions with regard to a baseline. The baseline should reflect the greenhouse gas emissions of a certain activity (e.g. the production of energy) if the JI or CDM project would not take place. Table 2.1 reflects some of the major characteristics of JI and CDM.

Table 2.1 *Characteristics of Joint Implementation and the Clean Development Mechanism*

| | Joint Implementation | Clean Development Mechanism |
|---|---|---|
| Buyer | Annex B (Western Europe, Canada, Japan) | Annex B (Western Europe, Canada, Japan) |
| Seller | Annex B (mostly Eastern Europe or Former Soviet Union) | Non-Annex B (mostly developing countries) |
| Aim | - Reduce greenhouse gas emissions (Kyoto aim)<br>- Decrease Kyoto compliance costs Annex B countries | - Reduce greenhouse gas emissions (Kyoto aim)<br>- Decrease Kyoto compliance costs Annex B countries<br>- Enhance sustainable development in non-Annex B countries |
| Unit | Emissions Reduction Units (ERUs) | Certified Emission Reductions (CERs) |
| Responsibilities | Additionality: JI Supervisory Committee (to be established) | Additionality: CDM Executive Board<br>Sustainable development: host country government |
| Accounting time | 2008-2012 | 10 years or 3 × 7 years (with baseline renewal) after project start (2000 or later) |
| Favoured countries | Romania, Poland, Baltic states | Brazil, India, China |
| Favoured energy technologies | Bio-energy, hydropower | Wind energy, hydropower |

As emission reductions are more cost-effective in Eastern Europe and in developing countries than domestic measures, JI and CDM for many Annex B countries will play a considerable role in achieving the emission reduction that is required as part of the Kyoto Protocol. Moreover, demand for CDM/JI credits will be enhanced by the EU Emission Trading System, which allows (up to a certain point) trading of JI or CDM credits.

Each JI or CDM project should make a difference with regard to what would have happened otherwise. This condition, which ensures the contribution of the mechanisms to the overarching aim of the Kyoto Protocol: reducing greenhouse gas emissions, is summarised in the word 'additionality'. For JI, additionality is less relevant than for CDM. The ERUs sold from the one country to the other are automatically subtracted from the Kyoto budget of the selling country. Therefore, there is always a zero-sum game for the total emission allowances under the Kyoto Protocol. The host countries for CDM, as opposed to JI, are non-Annex B countries with no Kyoto allowances for sale. The risk of free riders (a project that does not provide a net reduction in greenhouse gases but is selling CERs) in CDM resulted in a particularly vehement discussion on project additionality.

Another relevant characteristic of the CDM is the sustainable development criterion. A CDM host country can decide not to give approval for a CDM project based on the judgment that the project is not contributing to sustainable development in the country. This condition has been a major factor determining the success of CDM in some countries. The Government of India, e.g., has been favouring CDM projects through its 'loose' CDM criteria (Sethi, 2004), whereas the government of Thailand has proven to be much stricter before approving CDM projects (Krairapanond, 2003).

In order for JI and CDM to be effective in reducing greenhouse gas emissions, complicated procedures are required. Among other things, the process includes a baseline study (usually done in-kind or by an external consultant) and a validation (done by a certification company). The associated transaction costs are a barrier for JI and CDM, especially given the fact that the current prices of ERUs and CERs are low; around 7 US$/t$CO_2$. The combination of high upfront transaction costs and relatively low revenues is a disincentive for JI and CDM. It is expected that transaction costs will decrease as baseline methodologies become more standardised, addi-

tionality requirements are clarified, and increased experience of consultants and validators with JI and CDM projects. However, for the first JI/CDM projects of a new technology, the transaction costs will inevitably be high. This would also apply to CCS.

### 2.4.2 Suitability of CCS for JI and CDM

The eligibility of CCS as a technology for project-based Kyoto mechanisms depends mainly on the feasibility for the following aspects of JI or CDM: 1) an accounting and baseline methodology should be developed; 2) long-term storage should be ensured; 3) additionality should be demonstrated; and 4) for the case of CDM, contribution to sustainable development must be demonstrated. The other aspects named in Table 2.1 are not expected to limit the suitability of CCS as JI or CDM projects.

1) *Baseline methodology*: A baseline methodology in correspondence with the options offered in the Marrakech Accords should be followed (see Article 48 of these Accords). The baseline methodology should take into account that even the baseline type of technology for a planned power plant could differ when the decision is taken to include CCS, as e.g. a gas turbine combined cycle could be most attractive in the base case, but when CCS is applied, an IGCC could be more appropriate (IPCC, 2005). It is important that emissions that resulting from $CO_2$ capture, transport, and injection be taken into account in the baseline.
2) *Storage permanence*: It cannot be guaranteed that all $CO_2$ stored in geological reservoirs is stored permanently. Part of it may be irreversibly mineralised underground, which would mean permanent storage. Release of $CO_2$ from a reservoir means, from the point of view of a $CO_2$ market, that the $CO_2$ credit loses its value, because the value in $CO_2$ credits exists solely in the fact that it is keeping the $CO_2$ from the atmosphere. Similar permanence problems exit in the field of JI/CDM forestry projects. These problems have been addressed by creating the possibility of renewing $CO_2$ credits after the Kyoto commitment period. The permanence problems for CCS arise on a longer term than the 50 years commonly mentioned for forestry. A definition for storage effectiveness and an acceptable way for dealing with this problem would need to be designed in order to make it feasible under JI/CDM.
3) *Additionality*: The Kyoto Protocol requires from JI/CDM projects that the reductions they provide are additional to any that would occur in the absence of the certified project activity. Apart from some notable exceptions (such as an already present $CO_2$ taxation (Norway) or revenues are expected from $CO_2$ injection (e.g. in Enhanced Oil Recovery, EOR)), CCS is performed with the sole purpose of $CO_2$ emission reduction and is therefore additional. The recent discussions in the CDM EB on additionality resulted in rejection of most of the baseline methodologies submitted. This has led to the conviction that proof of additionality will be the main barrier for CDM registration for most technologies. Renewable energy and energy efficiency technologies could also be applied for other reasons than climate change mitigation: they can be cost-effective in many cases, part of a security of energy supply programme, or be applied for reduction of emissions of other pollutants such as $SO_2$ and $NO_x$. The unlikelihood that CCS would be deployed without an incentive in the field of $CO_2$ reduction appears to provide advantages in terms of additionality.
4) *Sustainable development*: Whether CCS would apply as 'achieving sustainable development' (UNFCCC, 1997) in non-Annex I countries is difficult to tell, and this may constitute a large barrier to compatibility of CCS and CDM. The contribution of CCS to climate change mitigation is obvious, but whether it contributes to broader sustainable development purposes, given the environmental risks CCS may induce, is doubtful. India, e.g., formulated interim sustainable development criteria in the field of social, economic, environmental and technological well-being. A project could comply with these criteria by additional employment generation, transfer of environmentally sound technologies, and pollution reduction (Sethi, 2004). It is unclear how many CDM host countries would consider CCS as an acceptable technology for a CDM project. On the other hand, many non-$CO_2$ projects (e.g. $N_2O$ destruction in industrial processes) in the current portfolio also do not appear to contribute to sustainable development, even though they have been approved by the host countries.

The issues listed above are all essential for CCS deployment in countries without incentives to apply the technology, such as non-Annex B countries or Annex B countries easily complying with their Kyoto commitments. In order to transfer CCS technology to these countries, the flexible mechanisms of the Kyoto Protocol are currently the only structural vehicle. However in a post-2012 climate policy other incentives for deployment in non-Annex I countries may be created.

Towards the end of 2005, a methodology for a power sector CCS project was submitted to the CDM Executive Board, which considered it in its 22nd meeting, from 23 - 25 November, 2005. It concluded that it had too little guidance to consider the methodology at this point and reported in its meeting report (Item 23):

> *"In the context of a methodology submitted to the Board which proposes using carbon capture storage as a CDM project activity, the Board considered the general issue of carbon capture and storage as CDM project activities but could not come to an agreement. The Board agreed to request guidance from the COP/MOP on whether carbon capture and storage projects can be considered as CDM project activities taking into account issues relating to project boundary, leakage and permanence."*

When this report went to press, the issue was not discussed at the COP/MOP.

## 2.5 CCS at the 11th Conference of Parties

The Conference of Parties to the UNFCCC (COP), which meets every year to discuss and negotiate climate policy in its different bodies, will meet in 2005 Montreal, Canada, for the 11th time since the entry into force of the UNFCCC.

A COP meeting takes about two weeks and is built around the climate negotiations of the UNFCCC. In addition to these negotiations, in the so-called 'high-level segment' in the last three days, the meeting consists of several parallel processes. Attendance is on the order of thousands of government delegates and observer organisations. In addition to the COP negotiations, plenary meetings of the Subsidiary Bodies take place (the SBSTA and SBI meetings). In parallel to the official UNFCCC-related meetings, side-events are organised by observer organisations and governments. Because of these meetings, the COPs are also podia for research and policy discussions related to climate change. In addition to the side-events, observer organisations present themselves at an exhibit.

COP11 is particularly important as it will be also be the first Meeting of the Parties to the Kyoto Protocol (MOP1). The Kyoto Protocol entered into force on February 16th, 2005.

Up to COP10, CCS received little attention in both the international negotiations or during the side-events, although there was one book presentation by the International Energy Agency on 'Prospects of $CO_2$ capture and storage' (IEA, 2004). The focus has mainly been on renewable energy, flexible mechanisms of the Kyoto Protocol and on national policies, and also increasingly on adaptation and development issues.

COP11 will see a change to this relative silence on CCS. The 'IPCC Special Report on CCS' was published during COP11. The Subsidiary Body on Science and Technology Assessments (SBSTA) had an agenda item on the publication of the IPCC Special Report, but this agenda item was removed on initiative of the United States. This focussed attention on the subject in the corridors. The report was eventually still considered but under the reports to the SBSTA of scientific organisations. A presentation of the Special Report was given followed by declarations of delegations on the report and on CCS in general. All delegations supported the conclusions of

the Special Report, and the European Union (represented by the United Kingdom and supported by Norway) proposed to follow up on the report and the Revised Guidelines (to be published end of April 2006) in a workshop. The United States, Canada, Australia and the G77 and China declared their support of the report, but did not name any consequences. Saudi Arabia was particularly positive on the report, calling it 'the best mitigation option'. A contact group was established, but results of that were not clear when this report went to press.

In terms of side-events, the following side-events on CCS are planned:

- The presentation of the 'IPCC Special Report on Carbon dioxide Capture and Storage' (November 30th).
- An side-event on CCS by the International Petroleum Industry Environmental Conservation Association (December 1st).
- A Feature Day of the Canadian Government on (December 2nd).
- An International Emissions Trading Association (IETA) and World Business Council on Sustainable Development side-event on CCS and the Clean Development Mechanism (December 2nd).

The number of side-events concentrating on CCS has therefore increased greatly, which shows that CCS is gaining a place in the climate change community.

## 2.6 Post-2012 negotiations

The 1st commitment period of the Kyoto Protocol ends in 2012, and deliberations in the COP on the future of the climate policy regime are starting in both the scientific and policy community. At COP10, several parties have tried to initiate discussions on post-2012 commitments, which resulted in the organisation of an informal 'Seminar of Government Experts' (SOGE) on the issue, which took place in May 2005 in Bonn (back to back with a SBSTA meeting). This meeting took two days and took place in a good atmosphere. It is expected that the statements during the SOGE will have significance to the real post-2012 negotiations, which are expected to start during COP11. It is uncertain at this point what will be the outcome, as the different delegations disagree on what a post-2012 treaty should look like.

Officially, technology was not on the agenda during SOGE, but nevertheless much attention was devoted to it, and notably to CCS. Many countries, especially those countries heavily relying on fossil fuels and specifically coal, alluded to the role of CCS as a post-2012 climate mitigation action. Although no definite conclusions can be drawn from this informal seminar, it seems that CCS can form one of the few common grounds that are so needed to reach *some* agreement on commitments beyond 2012 to prevent climate change.

# 3. National policies

In this chapter, national policies are reviewed in two parts: the EU ETS and national carbon taxes in Norway and New Zealand. In several countries, notably the United States, research plays a major role in CCS policy. The scope of this report is to assess structural incentives to CCS technology and therefore an extensive assessment of the research expenditures in different countries would go beyond the scope of this report. It is apparent, however, that research budgets for CCS, both from governments and the private sector, are increasing.

In the US, budgets for technology research on CCS include the Carbon Sequestration Regional Partnerships (US$ 145 million) and the FutureGen Initiative (demonstration of zero-emission coal-based power plant producing hydrogen, US$ 1 billion) (DOE, 2005), although the actual implementation of FutureGen is uncertain at this point. In The Netherlands, recently, an investment subsidy support programme of approx. 150 million Euro has been dedicated into the 2006 Budget for 'Clean Fossil Fuels'-projects.

## 3.1 EU Emissions Trading Scheme

The large potential of CCS for $CO_2$ reduction and the positive incentive the $CO_2$ price may give to CCS, raise the question of the inclusion of CCS in the European Union Emission Trading Scheme (EU ETS) (Cozijnsen, 2005). The European Commission (2004) makes the following mention of guidelines on CCS inventory methodologies:

> *"Such guidelines will take into account the methodologies developed by the UNFCCC. Member States interested in the development of such guidelines are invited to submit their research findings to the Commission in order to promote the timely adoption of such guidelines.*
>
> *Before such guidelines are adopted, Member States may submit to the Commission interim guidelines for the monitoring and reporting of the capture and storage of $CO_2$ where covered under the Directive. Subject to the approval of the Commission, in accordance with the procedures referred to in Article 23(2) of the Directive, the capture and storage of $CO_2$ may be subtracted from the calculated level of emissions from installations covered under the Directive in accordance with those interim guidelines."*

For CCS to be eligible in the ETS, it therefore depends on when the revised IPCC guidelines on GHG accounting are available (see Paragraph 2.2, it is expected that these will become available during the first half of 2006). By default, however, the notion that 'the capture and storage of $CO_2$ *may* be subtracted from the calculated level of emissions' appears to give a preference to the 'emission reduction *by source*' approach to accounting of $CO_2$ emission reductions through CCS (see discussion under Paragraph 2.2.2). Moreover, this sentence effectively allows for the application of CCS under the ETS (subject to EC approval), albeit that precise guidelines on monitoring and accounting still require further development from, or by, the Member States.

Therefore, the IPCC Guidelines will also have to give guidance on specific issues for CCS in relation to emission trading. These pertain mainly to the possibility of leakage, and reporting and monitoring, and include (ERM/DNV, 2005):

- how to account for leakage,
- liability of reporting and monitoring and choosing an appropriate timeline.

A report by Ecofys, Tüv, KPMG and WRI (2005), reporting on a stakeholder consultation on the Review of the EU ETS Monitoring and Reporting Guidelines, also indicates that possibility of leakage outside the boundaries of the installation covered by the ETS should be addressed.

Potential ways to address this question of impermanence are outlined in Zakkour and Haefili (2004). They name two approaches:

- A *discounting* approach: potential future emissions from a CCS project (leakage) are 'reconciled' to a present day value. Leakage can be both fugitive emissions during transportation of $CO_2$ as well as during storage.
- A *permitting* approach: this relies on the effectiveness of an appropriate storage site permitting regime, which should include elements on site operator due diligence in site selection, an emergency plan for leakage, monitoring, and time-limited licenses. In this case, a storage site operator should compensate for any leakage.

Although the permitting approach seems most practical for CCS projects, for the ETS (as also pointed out by Ecofys et al. (2005)) the site operator is usually not covered by the ETS. The circumstance could therefore occur that the leakage is not accountable under the ETS. It appears from the documentation that clarity should be given on this point before CCS can be incorporated in the ETS as a large application. It is expected that the European Commission will issue an official Communication in 2006 on how the technology and application of CCS can be promoted, including the integration into the ETS.[2]

## 3.2 Taxes and other incentives

An energy tax based on the carbon content of the energy source can be an effective policy instrument to reduce greenhouse gas emissions, as exemplified by the Norwegian case and 'Sleipner' (see Paragraph 2.3). In addition to Norway, New Zealand recently announced introduction of a carbon tax from 2007, amounting to approximately 8.5 €/t$CO_2$-eq. It is however not clear which activities the tax will cover.

A number of European countries, including the UK, The Netherlands, Denmark and Sweden, have introduced energy tax systems at least partly based on carbon content, i.e. fuels with higher $CO_2$ emissions per unit of energy are higher tax compared to those less carbon-intensive. In general, households face a higher tax than commercial and industrial users.

[2] See Working programme 2006, October 21, 2005, at: http://europa.eu.int/comm/atwork/programmes/docs/wp2006_en.pdf.

# 4. Other international developments

Outside of the official UN climate change organisations and national policies, other multilateral initiatives are undertaken. This chapter briefly reviews the IEA Greenhouse Gas R&D Programme and the Carbon Sequestration Leadership Forum.

## 4.1 IEA Greenhouse Gas R&D Programme

The IEA Greenhouse Gas R&D Programme was established in 1991 to perform research in the field of greenhouse gas reducing technologies. Over time, the focus has increasingly been on $CO_2$ capture and storage technologies. Numerous studies were performed, varying from technological studies to costs and policy analyses. The Programme is financed by its members, which include European and North American countries, but also Venezuela, India, and Korea. Industry members include almost all major oil companies, as well as several electricity firms.

An important aim of the IEA GHG R&D Programme is dissemination of results and data of its evaluation studies. It has played an important role in spreading knowledge on CCS to its members. Its two-yearly conferences (Greenhouse Gas Technology conference) attracted an increasing number of participants and papers over time, until the 7$^{th}$ conference in September 2004 in Vancouver, Canada, knew an attendance of over 700. The next conference will take place in June 2006 in Trondheim, Norway.

The IEA GHG R&D Programme does not play a role in international negotiations of climate change, although its studies fuel discussions on the options for climate change mitigation. The IPCC Special Report on Carbon dioxide Capture and Storage substantially based itself on direct and indirect results of projects developed by the IEA GHG R&D Programme.

## 4.2 The Carbon Sequestration Leadership Forum

The Carbon Sequestration Leadership Forum (CSLF) was established on the initiative of the United States in June 2003. The United States invited 12 other countries to join the CSLF, and its membership has grown steadily to 21, including countries of central importance in (post-2012) climate negotiations, such as Saudi Arabia, China and India.

The purpose of the CSLF as formulated in its charter of 2003 is:

- To facilitate the development of improved cost-effective technologies for the separation and capture of carbon dioxide for its transport and long-term safe storage.
- To make these technologies broadly available internationally.
- To identify and address wider issues relating to carbon capture and storage.

The charter also stipulates “this could include promoting the appropriate technical, political, and regulatory environments for the development of such technology”.

The CSLF kicked off with a number of studies on essential questions in CCS, such as public perception, safety, capture technologies, and storage capacity. As the CSLF has no budget of itself and only coordinates research efforts already done by others, its impact on the research agenda's of its Member States is unclear. It also has a procedure of approving existing CCS projects as ‘CSLF projects’, as a quality brand. Of the projects approved, the majority is in the European Union.

Although the CSLF establishes itself as a technical body not looking at policy decisions, it consists of both a Technical Group and a Policy Group. A proposal by South Africa to submit a CDM methodology to the Executive Board to test the viability of CCS under the CDM was rejected at the last meeting, indicating that the CSLF's purpose is not to interfere with the Kyoto process.

# 5. Discussion and conclusion

In general, we conclude that the political prospects of CCS are promising, although there are a number of barriers that need to be overcome before CCS is fully established in the climate change regime. We base this conclusion on the following notions and results:

- The scientific activity around CCS has exploded over the past two years. Research spending is increasing and in some countries is on the same level as spending on renewable energy. Conferences are attracting large participation and the number of papers in the scientific and popular media is growing.
- The 'IPCC Special Report' is generally positive on CCS as a mitigation option, but notes the current lack of methodologies for greenhouse gas accounting for CCS. Its Revised Guidelines, due to be published in the first half of 2006, will probably regard CCS as an emission reduction by *source*, which can be regarded as a signal that there is more confidence in the permanence of CCS than of (biological) *sinks of* $CO_2$. $CO_2$ injected into the Sleipner-project is reported in its Norwegian National Communications since 2001 as a $CO_2$ reduction by source. In this sense, Norway is the first country to make a decision on the 'reduction by source' or 'sink' discussion.
- Politically, the 'IPCC Special Report' has raised interest and will play a substantial role at the upcoming Conference of Parties to the UNFCCC in December 2005, COP11. The SBSTA, the Subsidiary Body on Science and Technology Assessment, has put the report on the agenda, which means that governments will make declarations on the issue. In post-2012 climate change discussions, CCS seems to be one of the few points all major players agree on.
- The flexible mechanisms of the Kyoto Protocol, and notably the CDM, are the vehicles for the transfer of CCS technology to developing countries. In principle, the CDM does not exclude technologies (except for nuclear). This means that *if* a methodology is approved for a CDM project, it can be a precedent for more. The barriers to this identified in this paper are different from the barriers in other projects; notably the contribution to sustainable development, how to address storage permanence and the financial attractiveness. Given this, and upon receiving a methodology on CCS submitted to the CDM Executive Board, the Board turned to the COP/MOP for more guidance.
- The European Commission, in its documentation on the EU ETS, acknowledges CCS but asks for a methodology to be able to account for it. There has not yet been a Member State that has tried such a methodology, also given the open questions on permanence and liability in the Scheme.

In order to bring CCS forward in climate policy, we conclude that the main challenge at this point is the establishment of a common methodology for accounting. The underlying problems are how to account for potential leakage of $CO_2$ and how to make a reliable monitoring plan.

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