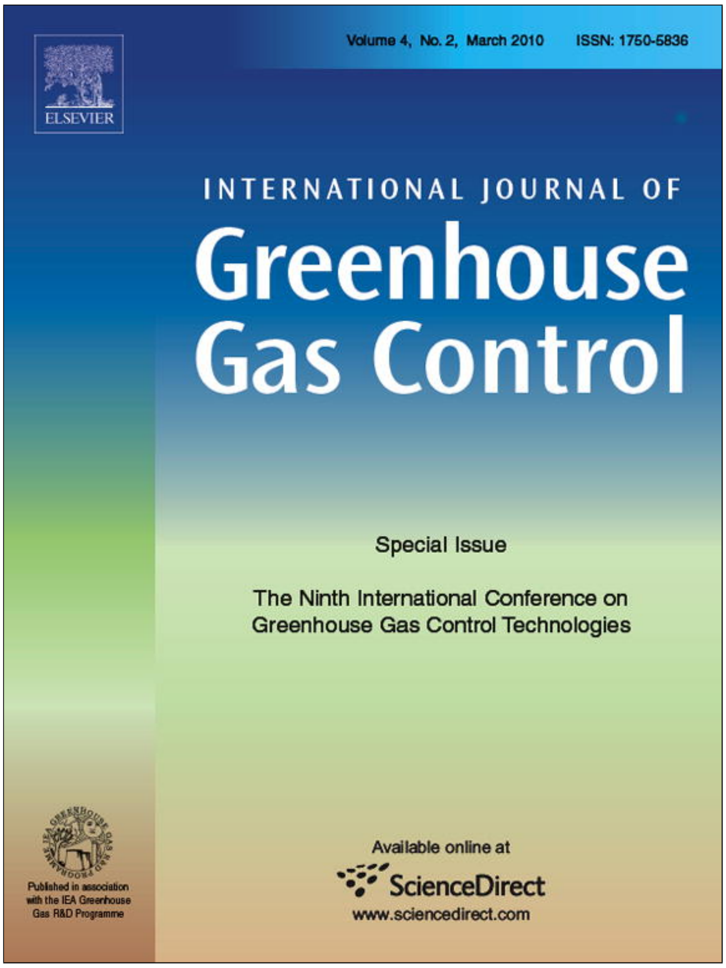
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Progress on including CCS projects in the CDM: Insights on increased awareness, market potential and baseline methodologies

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ABSTRACT

The inclusion of CO_2 capture and storage (CCS) in the Kyoto Protocol's Clean Development Mechanism (CDM) is still subject to controversy and discussion. A myriad of barriers prevents CCS in the CDM. Apart from political barriers, economic, social and procedural barriers play a role. This paper discusses relevant new results on the human capacity, procedural feasibility and economic potential of CCS in the CDM. The conclusions of a capacity building effort in Africa show that awareness and knowledge are low but that capacity building efforts are well received. A reality check on methodologies for hypothetical CCS projects shows that most of the issues can be resolved, and the CDM institutional arrangements can accommodate CCS. A bottom-up estimate of the potential of natural gas processing CCS in the CDM, based on a previously proprietary database from the oil and gas industry, suggests that there is an annual potential of about 174 $MtCO_2$ in 2020 in that sector. Most of that potential can be realized at CER prices between \$20 and \$30/tCO_2 but there is no sign of flooding the CDM market with cheap credits from CCS projects. Despite these results and more open information, the CCS and CDM debate, progress in the negotiations on CCS in the CDM is slow and there is no clear view on a solution.

1. Introduction

Climate change is one of the most pressing issues on the international policy agenda. Both industrialized and developing countries have expressed their concern over rapidly rising greenhouse gas emissions. Increasingly, the emerging economies in the developing world are contributors to the climate change problem (IPCC, 2007). Although their historical responsibility for the climate problem and their per capita emissions remain relatively small, their current and future emissions contribute increasingly to global emissions. Carbon dioxide capture and storage (CCS) is already recognized by industrialized countries as an important option to reduce carbon dioxide emissions. Increasingly, however, there is an insight that CCS needs to be deployed in rapidly developing coal-rich economies too if dangerous climate change is to be prevented (G8, 2009; Chen et al., 2009).

Currently, the only official instrument providing an incentive for CO_2 reductions in developing countries is the Clean Development Mechanism (CDM), a mechanism under the 1997 Kyoto Protocol that allows industrialized countries with an emission reduction target (Annex-B countries) to achieve part of their emission reductions in the developing world (non-Annex-B countries) through trade of project-based certified emission reductions. Prices of CO_2 emissions under the CDM are currently in a range that would help early opportunities in the CDM become economically viable, although they are probably too low to provide an incentive to CCS in the power sector (Deutsche Bank, 2008).

The bigger problem, however, is that the early submissions of CCS projects to the CDM Executive Board, the governing body of the CDM, have led to severe controversies and, up to now, no admittance of CCS projects in the CDM (Shackley et al., 2009). The barriers to allowing CCS in the CDM are partly technical, such as how to account for the emission reductions, how to estimate risks of future leakage, and how to establish the project boundary (UNFCCC, 2008a). Below the surface of the negotiations, however, other considerations play a major role. Coninck (2008), among other issues, names the relative immaturity of CCS and hence its perceived unsuitability for deployment under the CDM and perceptions with respect to the potential for CCS projects to crowd out other project types from the CDM market. Barriers also relate to human capacity, such as the level of awareness on CCS among negotiators from developing countries and the engineering capacity in potential host countries for CCS–CDM activities, and procedural feasibility, notably whether the CDM procedures can accommodate CCS projects.

This paper aims to provide insights into progress on the barriers to CCS in the CDM since the discussion first started (UNFCCC, 2006), notably the human capacity, the economic potential of CCS

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in the CDM, and the procedural feasibility of CCS in the CDM. Firstly, we report on two workshops held in Africa in September 2007, the experiences there, and their relevance for CCS in the CDM. Secondly, we report early results of the quantitative impact of CCS in the natural gas processing sector, a mature technology which would likely constitute the early potential of CCS in the CDM. Thirdly, we report on the outcomes of three hypothetical baseline methodologies. To accommodate technological diversity and address as many methodological issues as possible, we included on the capture side a new-build coal-fired power plant, a retrofit coal-fired power plant and a natural gas processing facility. On the storage side, we included a depleted natural gas field, a deep saline formation and an Enhanced Coal Bed Methane (ECBM) operation. Based on the results, we discuss a potential institutional framework for CCS in the CDM, making use of the strengths of the CDM procedures and adding to them where CCS demands extra checks and balances.

2. Awareness of CCS in developing countries

The United Nations Framework Convention on Climate Change (UNFCCC) is a consensus-based organization. Decisions on the CDM, a Kyoto Protocol mechanism, are made by consensus in the Conference of the Parties serving as the Meeting of the Parties to the UNFCCC's Kyoto Protocol (COP/MOP). Although official surveys are not available, the discussion around CCS in the CDM has in the past shown a low level of awareness of CCS among most developing countries, particularly least-developed countries such as those in sub-Saharan Africa. Clearly, any agreement on including CCS in the CDM (whether positive or negative) needs to be made by informed decision-makers. The low level of awareness is therefore a barrier to ending the uncertainty around CCS in the CDM.

To address this barrier, in September 2007, two regional workshops on CCS and CDM were held in Dakar, Senegal and in Gaborone, Botswana (ECN, 2007).[1] The workshops were attended by in total 130 stakeholders from around 30 Sub-Saharan African countries. A dual focus of providing unbiased information on CCS combined with practical capacity building on CDM was chosen to appeal and reach a broader audience. The participants included government representatives, environmental organizations, industry representatives and researchers. The level of knowledge on both CCS and the CDM was low in both workshops, although on both fronts better in the Gaborone workshop. This was partly because of the South African participants in the Gaborone workshop, where many researchers and government representatives are quite familiar with CCS and industry is actively working on processes to capture and store CO_2 (Surridge and Cloete, 2009; SANERI, 2009)

The following conclusions could be drawn with respect to CCS in sub-Saharan African countries (ECN, 2007):

- In general the priority for Africa is economic development. In the field of climate change, Africa's priority is adaptation, while mitigation is seen as less important. However, for both economic development and adaptation to climate change, increase in energy consumption is necessary. As far as CCS can help this technology could be useful, but climate change mitigation is not a priority for the continent.
- If insufficient incentives are given, CCS may increase the cost of electricity to consumers. This is a cause of concern among participants. There is a need to get more certainty of the cost of the different CCS options, also those outside of the electricity sector.
- In case CCS would be eligible under CDM, there should be proper accounting for any seepage that might occur at some point in the future, e.g. by discounting the Certified Emission Reductions (CERs).
- Several issues regarding liability for monitoring and accounting of greenhouse gas (GHG) reductions over long time scales were discussed. In Norway (host of the Sleipner and Snøhvit CCS projects) the Petroleum Act gives guidance for these issues, but after productivity of the gas fields has ceased the government takes over responsibility. The question is whether such a model could be replicated in African countries.
- The CDM is the only mechanism currently that has the potential to incentivise CCS in Africa. In that light inclusion of CCS should be considered by UNFCCC parties.
- More capacity building on CCS is necessary. Also developing a detailed atlas of suitable storage sites in Africa would be useful.
- Early demonstration projects in the African region could help build more confidence in the technology; funds could be set up to support this if the CDM incentive is insufficient.

For many participants, including negotiators in the UNFCCC, the workshop was the first time they had heard about CCS. This low level of awareness on the part of key stakeholders in relevant countries could be a significant barrier to any informed consensus decision on CCS in the CDM. Capacity building with many more government representatives needs to take place, and it is recommended that this is taken up by industrialized countries and internationally operating companies. We observed that during COP/MOP 3 meeting in Bali in December 2007 many African representatives dropped their resistance to CCS in the CDM, although it could not be confirmed that the workshops were the main driver for this.

3. CDM market impacts of natural gas processing CCS

Various estimates have been made on the market impacts of CCS in the CDM (IEA, 2007; Zakkour et al., 2008). The main questions addressed in such analyses are: how much CCS would be implemented under the CDM, would it crowd out other options to a significant degree, and would the inclusion of CCS lead to a drop in the CER price? The CDM is a market mechanism looking for the lowest-cost mitigation options and avoiding technological and financial risks to meet the CER demand. Therefore we look at the current supply potential of CERs and the potential of CCS under the CDM, including the technological and economic barriers.

Cost estimates for CCS in the power sector are generally above $40/t$CO_2$ (Deutsche Bank, 2008). For other sectors such as ammonia, cement, ethanol and hydrogen production, Zakkour et al. (2008) estimate the cost to be higher than $60/t$CO_2$. This is far below CER prices in 2009, reported to be below $20 (Point Carbon, 2009a). The only sector in which CCS could be deployed below $20/t$CO_2$ is natural gas processing operations (Zakkour et al., 2008). In addition to the more favourable economics, it should also be mentioned that the natural gas processing sector also dominates the currently implemented CCS projects with the Sleipner and Snøhvit projects (both off the coast of Norway) as well as the In-Salah project (onshore in Algeria), implying lower technological barriers compared to other sectors. Therefore it is likely that this sector is the most important for CCS in the CDM, at least up to 2020.

Until recently, data on the potential for CCS in this sector were hard to get by as it could have commercially sensitive information. Estimates in existing literature have their limitations as they are based a top-down approach and rough approximations, such as IPCC (2005) which arrives at some 50 MtCO_2/year in 2002. IEA (2007) did a similar analysis and arrived at 334 MtCO_2/year in 2020 that sector. Recently, however, other data became available. Zakkour et al. (2008) used bottom-up data to arrive at a technical

[1] Presentations and participant lists can be found on www.ccs-africa.org.

potential in non-Annex I countries of 219 $MtCO_2$ in 2012 and 313 $MtCO_2$ in 2020 at CER prices of $30/$tCO_2$. These estimates do not take into account potentially slow legislation and licensing processes. For comparison, Point Carbon (2009b) estimated that around 1.6 $GtCO_2$-eq was traded in 2008 in the CDM.

This paper presents a new bottom-up analysis based on a database that was made available by IHS, an oil and gas consultancy. The database contains detailed data of gas fields around the world, including over 500 gas fields (925 reservoirs) in 49 non-Annex I countries. For each gas field the IHS database covers the production status of field, total recoverable amount, remaining amount, and the production starting date. The CO_2 content in volume% is included on a more detailed level, i.e. for each reservoir.

With the help of the IHS database, we analyze the potential for CO_2 emission reduction by CCS in the natural gas processing in non-Annex I countries. The amount of CO_2 contained in each field was taken to be the average CO_2 content of the different reservoirs in a field, multiplied by the remaining quantity of natural gas in each field. This adds up to 7.7 $GtCO_2$ that could potentially be captured if the fields are all developed. Then all fields with a CO_2 content lower than 4% (the threshold used in IPCC (2005)) were excluded based on the assumption that CCS operations become less economical with lower CO_2 content. The total economically recoverable quantity of CO_2 is then 6.1 $GtCO_2$ (2.9 $GtCO_2$ and 3.2 $GtCO_2$ for existing and new fields, respectively).

In order to estimate an average annual potential for CCS the quantity of CO_2 in each field was divided by the remaining production time, as calculated by dividing the remaining gas by the average production rate, up to a maximum of 40 years. For new gas fields 40 years was taken as the default value. The obtained technical potential is 174 $MtCO_2$/year in 2020. Sensitivities were also computed on the potential geological storage capacity in these fields for the year 2020 assuming production last on average 50 years (146 $MtCO_2$) or as little as 30 years (222 $MtCO_2$). These figures are in the same range as those estimated by Zakkour et al. (2008) for the year 2012, but significantly lower than for 2020.

Fig. 1 shows the break-down for the countries with the highest potential for the central estimate of 174 $MtCO_2$/year.

In order to put this result in context of the overall CDM market that contains an array of other low-carbon technologies, we have included the data on natural gas processing in a marginal abatement cost (MAC) for the non-Annex I region. The MAC used was reported earlier elsewhere (Bakker et al., 2007). It is based on detailed bottom-up mitigation studies in non-Annex I countries, though some non-CO_2 reduction options had to be grouped as no detailed cost data could be retrieved, resulting in three 'plateaus' in the curve. The abatement cost per ton of CO_2 captured and stored on average for different types of fields was calculated using the

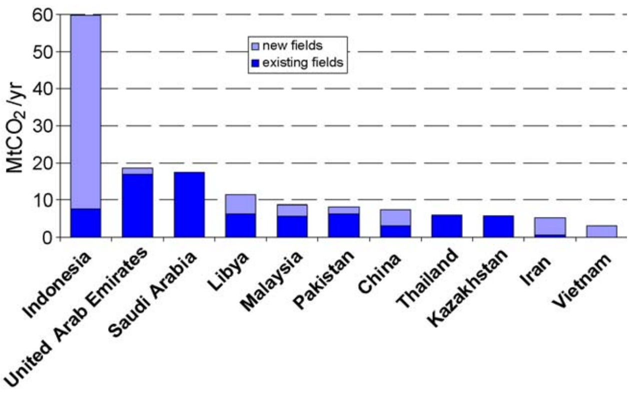

Fig. 1. Mitigation potential for CCS in natural gas processing in 2020.

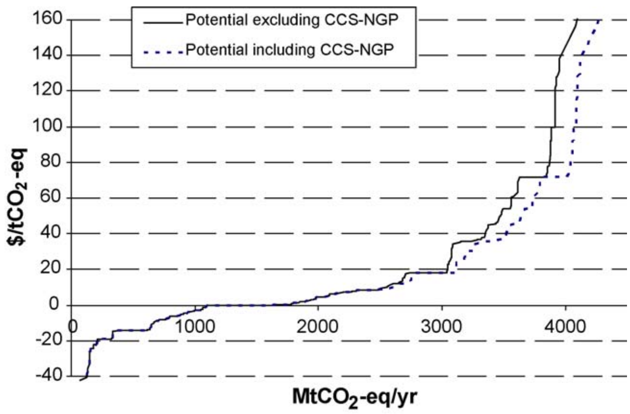

Fig. 2. Marginal GHG abatement cost curve for CDM eligible technologies in all non-Annex I countries in 2020. The figure suggested adjusted CDM project activity cycle for a proposed CCS operation under the CDM. There are three changes in the normal cycle: The DOE needs to be especially accredited, the host country competent authority will have to license the project before the DNA does, and the CCS panel provides advice to the Executive Board on the approval of the project, and on the issuance of the credits. (PP = Project Participants; EB is CDM Executive Board) (Groenenberg et al., 2008).

approach of Zakkour et al. (2008): $8.8/$tCO_2$ for new on-shore fields, $12.3/$tCO_2$ for existing on-shore fields, $23.4/$tCO_2$ for new off-shore fields and $31/$tCO_2$ for existing offshore fields. The overall MAC curve (solid line in Fig. 2) includes the major sectors, greenhouse gases and technologies that are currently eligible under the CDM, as well as CCS outside the natural gas processing sector. It does not include the abatement potential through avoided deforestation. The dotted line in Fig. 2 shows the same MAC curve but with inclusion of CCS for natural gas processing. It should be noted that both curves show marginal cost of GHG reduction options and, in accordance with common practice, do not consider external impacts of these technologies. Including external impacts such as those on the natural environment may change the cost-benefit ratio of distinct technologies represented in the curve. Risks of damage due to CO_2 seepage due to CCS operations however are assessed to be low (Heinrich et al., 2004), and not significant in comparison to the direct cost of the technology. For this assessment therefore the consideration of externalities is not essential.

The total annual economic potential for supply of CERs in all non-Annex I countries up to $30/$tCO_2$ is more than 3 $GtCO_2$-eq/year. A significant part of the potential has negative cost (the so-called no-regret options), indicating there are other barriers than just economic barriers for the uptake of these technologies. These are mostly for energy efficiency options and a common feature of bottom-up cost curves (Bakker et al., 2007). Demand for CERs in 2020 is very uncertain, with projections in the range of 500–1700 $MtCO_2$-eq/year (UNFCCC, 2008b), i.e. below the potential up to $30/$tCO_2$. Analysis of the August 2009 CDM project portfolio (UNEP/Risoe, 2009) shows that the energy efficiency options provide only a relatively small part of the CER supply (16%), suggesting that non-economical barriers are important. Renewables (mainly hydro and biomass) and non-CO_2 reduction options, which have positive abatement costs (Bakker et al., 2007), supply more than 80% of the CERs up to 2012 (UNEP/Risoe, 2009). Therefore it is likely that the CER demand in 2020 will be met by abatement options from different parts of the cost curve, not just those with the lowest abatement cost.

From Fig. 2 it can be observed that there is a small economic potential for CCS natural gas processing operations at costs below $20/$tCO_2$, but that the larger potential is at costs between $20 and $30/$tCO_2$. Assuming abatement options with a cost up to $30/$tCO_2$

Table 1
Overview of results of hypothetical baseline methodologies (Groenenberg et al., 2008).

		Retrofit + ECBM	New build + gas/oil/ saline formation	Natural gas processing + gas/oil/ saline formation
Project specifics project	CO_2 source	Existing pulverized coal-fired power plant	New pulverized coal-fired power plant	Natural gas processing plant
	Capture process	Retrofit post-combustion	Post-combustion	Not specified
	Transport	Pipeline	Pipeline	Pipeline (short)
	Storage	ECBM operation	Depleted gas or oil reservoir, or saline formation	
Dilemmas	Project boundary	CO_2 source and capture, transport and injection infrastructure, and full storage complex	CO_2 source and capture, transport and injection infrastructure, and full storage complex	CO_2 compression, transport and injection infrastructure and storage complex
	Energy penalty accounting	Assuming electricity from the grid	Assuming most conservative of (a) baseline; (b) grid build margin; c) grid operating margin	Emission from fossil fuel combustion supplying power for compression, transport and injection
	Additionality demonstration	Combined tool for demonstration of additionality and baseline methodology	Tool for demonstration of additionality	Combined tool for demonstration of additionality and baseline methodology
	Accounting of hydrocarbon recovery	Conservatively neglected as gas recovered in ECBM likely cleaner than the baseline	Not applicable	Not applicable
	Monitored gases	Capture: CO_2 Storage: CO_2, CH_4	Capture: CO_2 Storage: CO_2, CH_4	Capture: CO_2 Storage: CO_2, CH_4
	Leakage	Emissions resulting from extra coal mining	Emissions resulting from extra coal mining	No leakage
	Long-term liability	Provision in baseline methodology applicability conditions that host country should overtake liability after the storage site is proven safe		

could supply the CERs to meet the demand in 2020, we conclude that CCS in natural gas processing could provide about 5–10% of the supply. This is a small but not insignificant figure, and leads to the conclusion that some CCS in the natural gas processing sector is likely to appear in the CDM if it would be allowed, but it is not likely to have a large CDM market impact.

4. Methodological dilemmas of CCS in the CDM

A third issue related to CCS is whether the current CDM modalities and procedures can accommodate the specifics of CCS technologies. For any CDM project activity, the project developer has to demonstrate that the project reduces emissions compared to a baseline and that the project would not happen in absence of the CDM. For this, the project developer has to hand in a Project Design Document (PDD) and, if it does not yet exist for the project category, a baseline methodology. In those documents, the project boundary, baseline emissions and project emissions need to be laid out clearly, and the additionality of the project needs to be argued. For CCS specifically, this means that the energy penalty, seepage and long-term liability, and, in the case of EOR or ECBM, how potential emissions from enhanced hydrocarbon recovery need to be accounted for.

In order to explore how this can be done, we have developed illustrative baseline methodologies for three hypothetical CCS project activities under the CDM. To address as many methodological issues as possible, and to ensure variety in capture as well as storage methods, the following technologically diverse methodologies were elaborated:

- Capture of CO_2 from an existing coal-fired power plant and its use in a newly developed ECBM recovery operation.
- Capture of CO_2 from a new-build pulverized coal plant, excluding plants co-firing bio-mass, and its subsequent storage in depleted oil or gas fields or saline formations.
- Capture of CO_2 from a natural gas processing plant and storage in depleted oil or gas fields or saline formations.

The standard CDM baseline methodology document (available on http://cdm.unfccc.int) was completed for the three project types.[2] In the process of following CDM regulations, a number of methodological dilemmas were identified and addressed. The most crucial ones are summarized in Table 1.

The work done on the methodologies suggests that most issues can be resolved within the existing framework of a normal CDM baseline methodology format. An extra feature may include more space for detailed monitoring and geological data.

The development of the CCS baseline methodologies, however, did suggest that it would be helpful if some targeted institutional settings could be added to the current CDM institutional infrastructure. These would particularly be needed to ensure compliance with requirements on site characterization and selection, monitoring and liability. We suggest the following institutional structure for guaranteeing that CCS is implemented safely and permanently under the CDM:

- The applicability conditions in the CDM baseline methodology require that the host country has legislation in place to permit CCS operations in a responsible manner and deal with site selection, monitoring, site development and long-term liability.
- The competent authority for CCS permitting in the host country drafts a decision on a storage permit for the CCS operation, in which site integrity and storage permanence are duly dealt with.
- The Designated National Authority (DNA) in the host country includes the draft decision of the competent authority in its Letter of Approval on the CCS project as a CDM activity.
- A dedicated CCS accreditation would be required for Designated Operational Entities (DOEs) for performing Third Party validation

[2] Available on http://www.ecn.nl/publications/default.aspx?nr=ECN-E–08-070.

and verification of CCS operations. The DOE should have demonstrable experience with CCS. It would validate and verify according to the normal procedures for CDM projects.

- Installing a "CCS panel" under the CDM Executive Board (in functioning analogous to the existing AR or the SSC panels) consisting of geological, technical and legal experts, that would consider:
  - Whether the host country indeed has an effective legislative framework in place, and thus whether the requirements are met. This would need to happen only once before the project registration.
  - The validation report of the DOE on technical details. Guided by that advice, the CDM Executive Board approves or rejects the request for registration of the CCS–CDM project.
  - The verification report by another accredited DOE on the request for issuance of the CERs. The CCS Panel opinion on this will guide the CDM Executive Board in this decision, apart from the usual considerations on the credits generated by the CDM project.

The recommendations would rule out any CDM projects in candidate host countries that do not manage to regulate the risks of CCS operations on their territories in a timely fashion. It would avoid the need of an international regulatory regime for CCS. The institutional structure is schematically illustrated in the figure below.

One of the implications of such an institutional framework for responsible CCS inclusion in the CDM is that non-Annex I countries would need to develop a regulatory frameworks for CCS if they want to host CCS–CDM projects. In major industrialized regions, notably the European Union, the United States and Australia this has turned out to be time-consuming and to require substantial input from experts in research and industry. While some developing countries may have the resources to develop such a framework themselves, have mining laws that are applicable (such as in Algeria for In-Salah) or are willing to broadly adopt a framework developed in an industrialized country, many countries may prefer to prioritize other policy issues. We therefore also recommend that Annex-I countries make available funds to help interested developing countries develop the legal framework to implement CCS safely. In that respect, we arrive at the same conclusion as a tradition of technology transfer literature (Lall, 1992; IPCC, 2000) and other documents on CCS (IPCC, 2005; IEA, 2007).

The recommendation for an institutional framework is intended as a first proposal to enable safe deployment of CCS in developing countries and take away concerns around CCS compromising the environmental integrity of the CDM. Any institutional framework on CCS needs to strike a balance between a safe regime and one that is practically feasible. The requirement of a national CCS regulatory framework is likely to delay the implementation of CCS operations in non-Annex I countries, possibly by years, if such legal frameworks need to be developed. In addition to this, the licensing process itself takes time. In the initial phases, the development of the host country legal framework could combine learning on technology and learning on legislation, if the CDM Executive Board could give a provisional approval. Such a procedure would allow developing countries interested in CCS in the longer term to develop a legislative framework early on.

5. Conclusion

In recent years insights are increasingly provided that can help solve information barriers related to CCS in the CDM. We have reported on progress in three major barrier areas around CCS in the CDM: awareness in developing countries, CDM market impacts of CCS, and procedural feasibility of CCS in the CDM.

Firstly, awareness and knowledge of CCS is a prerequisite for an informed consensus on CCS as CDM activities among Kyoto Protocol parties. Workshops have been held in Africa that have helped negotiators understand CCS better, and have clarified Africa's stake in CCS. It became clear that there is a looming gap in awareness and knowledge in sub-Saharan Africa and that economic development, not CCS or climate change mitigation is Africa's first priority.

Secondly, current CO_2 prices in the CDM are too low for deployment of CCS in the power sector and other sectors. CCS in the natural gas processing sector however is cheaper and faces fewer technological barriers and is therefore likely to be the most important sector for CCS in the CDM. A bottom-up estimate of the potential of natural gas processing CCS in the CDM, based on a previously proprietary database from the oil and gas industry, suggests that there is an annual potential of about 174 $MtCO_2$ in 2020 in that sector. Most of that potential can be realized at CER prices between \$20 and \$30/tCO_2-eq. Although this potential is considerable, other mitigation options would still dominate the portfolio of CDM projects. Therefore CCS is unlikely to impact the CDM market significantly up to 2020.

Thirdly, we have demonstrated that baseline methodologies can be developed and most dilemmas related to CCS can be addressed within the CDM structure or with few adjustments. For dilemmas such as how to account for the energy penalty, different approaches were tested. We recommend, based on the various results, that more is invested in awareness raising and capacity building on CCS in least-developed countries, and that a limited institutional structure compatible with the current CDM modalities, procedures and institutions, is added onto the current CDM procedures.

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