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A Review of CCSand CDM and there management

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Abstract

The clean development machanism (CDM)of the kyoto protocol is a financial incentive intended to make economically marginal greenhouse gas(GHG) prevention projects more feasible.carbon dioxide capture and sequestration (CCS) is a possible GHG mitigating strategy.The Intergovernmental panel on climate change(IPCC) defines a CCS project as a process consisting of three phases: the separtion of carbon dioxide from industrial and energy related sources: trasportation of the carbon dioxide to a storage location ; and longterm isolation of the carbon dioxide from the atmosphere.This paper focuses on prospects of CCSasCDM projects in general and in context of southern Africa.Currently there is no evidence of longe term proven track record of integrated CCS system ;only three industrial scale CCS projects exist globally.Nevertheless, new concepts have been proposed for CCS CDM projects such as longterm liability and certified emission reduction (CER) cancellation . However, these concepts are not in the current CDM framework at present . It is thus difficult to prove CCS as an eligible CDM project without first addressing possible expansion and shortfalls of the current CDM structure. More research is also required to quantify the trade offs presented between mitigation carbon dioxide from the atmosphere at the possible detriment of the areas of storage in the Southern Africa context. Only then may CCS projects be deemed more viable in the CDM context.

India is the party to the United Nations Framework convention on climate change(UNFCCC)and the objective of the concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climat system. India accepted to the Kyoto protocol in august 2002 and on the objectives of acceding the development of CDM,to beat the target of 5.2% below 1990 levels.

Keywords: clean development mechanism, capture, sequestration, carbon dioxide capture and sequestration, carbon dioxide capture and sequestration, south Africa, india.

1.Introduction

In 1997, the Kyoto protocol was adopted at the third session of the conference of the parties(COP) to the United nations framework convention to climate change(UNFCCC).Thereby, Annex-I countries, or industrialized countries, accepted legally binding commitments to reduce green house gas(GHG) emissions. The Annex-I signatory countries agreed to reduce their anthropogenic emissions of GHGs, on average ,by 5.2% below 1990 levels in the commitment period 2008 to 2012. The targeted GHGs are CO2,CH4,N2O,HFCs, PFCs, and SF6(UNFCCC,2007).Various GHG reduction incentives exist. The UNFCCC drives one such incentive, the clean development mechanism(CDM)UNFCCC,2007.

Whereby industrialized countries, through the companies within them, could earn GHG emission reduction credits. The incentives for developing countries to participate in the CDM are acquiring technology acquiring foreign capital and accelerated growth. The CDM aims to mitigate GHG emissions by offering a trading plateform for proven emission reductions in developing countries through technological interventions by developed countries. Emission reductions are quantified in so called certified emission reduction (CER) units that are tradable. A CER is simply the prevention of one tone of carbon dioxide gas equivalent emitted in developing country. The other targeted GHGs are all related via a GHG potential rating back to equivalent carbon dioxide. For example, methane(CH4) has a 21 fold GHG potential than carbon dioxide(CO2) over a period of 100 years. This implies that one tone of CH4 emissions prevented (UNFCCC,2007).CERs are traded on the open market at a price driven by supply and demand pertaining to specific projects, the trends in carbon market are reported by the World Bnak(capoor and Ambrosi, 2007) . The CDM is governed by the executive board(EB)of the UNFCCC(2007),whilst the trading of the CERs is facilitated by the carbon finance unit of the world bank(2007).

1.1 Carbon dioxide capture and sequestration

One technology that aims to mitigate GHGs is carbon dioxide capture and storage(CCS). It is important to distinguish between CCS and other GHG mitigation strategies such as increased energy efficiency (winkler and van Es, 2007), switching to less carbon intensive fuels, renewable energy sources, enhancement of biological sinks and even nuclear power. The Intergovernmental panel on climate change(IPCCC,2005) of the United Nations defines CCS as a process consisting of three technological components:

- The separation of CO2 from industrial and energy related sources;
- The transport of the CO2 to an appropriate storage location; and
- The longe term isolation of the CO2 from the atmosphere.

The conventional understanding of the CCS process is that CO2 would be compressed and transported for storage in geological formations ,for pumping into the ocean, for land storage in biomass or as mineral carbonates , or for usage in industrial processes(Stephens and van der swaan,2005). It is currently believed that the industrial use of CO2 will be limited and the other storage approaches are the most promising. For CCS to be viable large point sources of CO2 originate from the energy sector, as is summarized in table 1(IPCC,2005).

The table highlights that the world's power sector has the largest amount of point sources and contributes an order of magnitude more to CO2 emission than any other industry. The worldwide power or electricity sector is thus deemed to hold the most potential for CCS projects. It is then an obvious assumption that many CCS projects in the energy sector would claim CERs(IEA,2007). This is not the case; currently not a single CCS project is registered as a CDM project(UNFCCC,2007).

CCS comes at the expense of additional CO2 production due to the capturing technology, proposed compressing and the transport energy

Table 1: Worldwide large stationary CO_2 sources emitting more than 0.1 Mt CO_2 per year Source: IPCC (2005)

Process	Number of sources	Emissions (Mt CO_2 per year)
Fossil fuels		}
Power	4 942	10 539
Cement production	1 175	932
Refineries	638	798
Iron and steel industry	269	646
Petrochemical industry	470	379
Oil and gas processing	Not available	50
Other sources	90	33
Biomass		
bioethanol and bioenergy	303	91
Total	7 887	13 466

Required. This must be accounted for to ascertain the net reduction in atmospheric CO2 reduction .Accounting for emissions associated with a CDM project activity is a standard process. However, certain challenges with the non-permanence of CCS have been noted (Bode and Jung,2005). The paper subsequently reviews:

- The maturity of CCS technologies and current CCS projects;
- The applicability of CCS as a GHG reducing technology;
- The eligibility of CCS projects for the CDM;
- The current activity and development of CDM methodologies for CCS accreditation; and
- The potential of CCS in south Africa.

The overall aim of this paper is to determine whether the CDM might benefit the implementation of CCS projects in southern Africa.

2. The maturity of CCS technologies and current CCS projects

2.1 CCS technologies

The IPCC(2005) identified various methods for CO2 capture systems. These systems can broadly be subdivided into the following strategies(Stephens and van der Swaan, 2005):

- Post –combustion;
- Pre-combustion; and
- Oxyfuel combustion systems

Figure 1 illustrates the various categories of CO2 capturing systems. The IPCC(2005) argues that post –combustion capture of CO2 in power flue gas can be scrubbed to retrieve the CO2. For pre combustion the technology required for capture is widely applied in fertilizer manufacturing and in hydrogen production(IPCC,2005). Oxyfuel combustion uses higher oxygen containing streams to produce purer ~~CO2 waste streams. Easier separation of CO2 is thus~~ achieved.

Gronkvist et al further researched the

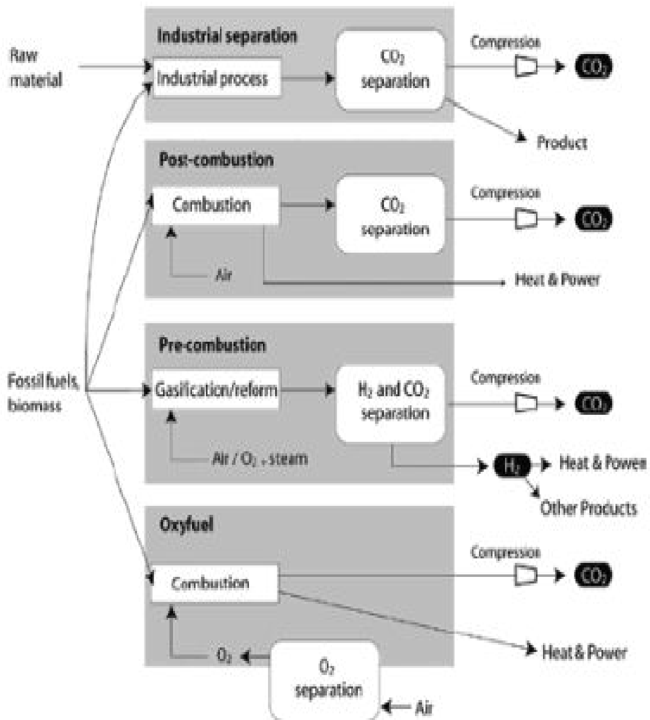

Figure 1

Advantages of using an increased oxygen supply in processes producing CO2. However using an oxygen enriched stream in industrial processes will come at increased energy expenditure; the cost and energy expenditure of producing the oxygen stream must be accounted for various transportation methods can be used for transporting the captured CO2 to the place of storage. The methods include:

- Pipelines for transporting of large amounts of up to approximately 1000 km,e.g. in the USA,over 2500 km of pipelines transport more than 40 Mt CO2 per year(IPCC,2005).
- Small amounts of CO2 can also be carried by rail and road tankers, but it is unlikely that these could be attractive options for large scale CO2 transportation.
  The long term isolation options are as follows;
- The storage of CO2 in deep ,onshore or offshore geological formations currently uses the same technologies developed by the oil and gas industry. According to the IPCC(2005) Enhanced coal bed methane recovery(ECBM) could lead to additional revenues from the oil or gas recovery.
- Two potential methods for oceanic storage are currently focused on (IPCC,2005); injecting and dissolving CO2 into the water column(typically below 1000 meters) via a fixed pipeline or a moving ship, or by depositing it via a fixed pipeline or an offshore plateform onto the sea floor at depths below 3000m , where CO2 is denser than water and is expected to form a lake that would delay dissolution of CO2 into the surrounding environment.
- Limited applications currently exist for using CO2 as an industrial feedstock. Finding new and innovative uses for CO2 in a production environment will be of great value and is expanded on later in this paper.

Energy is required irrespective of what capture, transport and storage technology is used during CCS. The increase in energy expenditure when the CO2 was simply vented to atmosphere. The advantage of CCS is seen in that less CO2 emissions to atmosphere will occur. The IPCC (2005) modeled the increase of energy expenditure for power plants and the results are shown figure2.

The vast extent of research on all technological aspects of CCS make it impossible to summarise the fields of research in this paper. Also this paper specifically focuses on CCS from a CDM perspective only.

2.2 Current CCS projects

Ther are extensive commercial experiences with the use of each of the three technological components of CCS in other applications (Stephens and van der Zwaan, 2005). However, minimal experience has been obtained in terms of integrating capture, transport and storage into one system, few such integrated industrial sized CCS projects are developed and researched currently. The three largest industrial scale CCS projects are the Sleipner project, operated by Statoil in the North Sea 250 km off the coast of Norway (WEC, 2007); the In Salah gas project, a joint venture beween Sonatrach, BP and Statoil, which is situated in the central Saharan region of Algeria (BP, 2007); and the Weybum CO2enhanced oil recovery (CO2-EOR) project, which is located in the in the Willistin Basin, a geological structure extending from south-central Canada into north-central United States, and approximately 325 km south of Weybum, in Beluah, Norh Dakota (IEA,2002).

2.2.1 The Sleipner CCS project

The Sleipner project was the first commercial scale CCS project (BRU,1996). CCS is achieved by geologically storing the CO2 in a saline formation approximately 800 m above the seabed.

The CCS CO2 injection operation started that by early 2005 more than 7 Mt of CO2 would have been injected at a rate of approximately 2700 tonnes per day (IPCC , 2005) , Over the lifetime of the project it is estimated that a total of 20 Mt CO2 is to be stored.

2.2.2. The Salah CCS project in 2005 the IPCC classified the In Salah CCS project as the world's first large scale CO2 project in a gas reservoir (Riddiford et al, 2005). Liberated CO2 from natural gas is re-injected into a sandstone at a depth of 1800m. The IPCC (2005) initially estimated a storage potential of upto 1.2 Mt Co2 per year . Injection commenced in April 2004 and over the life of the project, it is estimated that 17 Mt CO2 will be geologically stored (IPCC, 2005)

2.2.3 The Weyburn CCS project

The source of the CO2 for the Weyburn project is the Dakota Gasification Company facility, coal is gasified to make synthetic gas (methane), with a relatively pure stream of CO2 as a by product (whittaker and Gilboy,2003). The CO2 stream is dehydrated, compressed and piped to Weybum in south-eastern Saskatchewan, Canada, for use in the field. The Weyburn CO2-EOR project is designed to take CO2 from the pipeline for about fifteen years , with delivered volumes dropping from 5000 t about 3000 tonnes per day over the life of the project. It is expected that some 20Mt CO2 will be stored in the field, under current economic conditions and oil recovery technology (IPCC, 2005). The oil field layout and operation is relatively conventional for oil field operations.

CO2 injection began in late 2000. Currently,some 1600 m^3 (10063 barrels) per day of oil is being produced from the field. According to the IPCC 92005) all the produced CO2 is captured and recompressed for reinjection into thr production zone. Currently, some 1000 tonnes of CO2 per day are reinjected . Even more CO2 per day will be captured and sequestrated as the project matures. To date, there has been no indication of CO2 leakage to the surface and near surface environment (White, 2005, Strutt et al., 2003). Leakage in this context refers to physical leakage of CO2 that will eventually reach the surface and then the atmosphere. In the CDM context leakage normally refers to emissions outside the project boundary that occurs as the result of the project activity.

3.Application of CCS

CDM in essence is an auditing system that provides an incentive for employing additional proven technologies to mitigate GHG emissions. Certain issues relating to the lack of maturity of CCS research, technologies and projects have been raised. Subsequently there is concern about the true GHG mitigation potential of CCS, and therefore the registration of CCS as eligible CDM projects. The concerns for the various non-biological CCS options are discussed below. To date the Kyoto Protocol has not considered CCS from biomass (biotic CCS) and it appears that it is not possible to receive emission credits for biotic CCS under the first commitment period of the Kyoto Protocol, i.e. 2008 to 2012 (Gronkvist et al,2006b).Also, in the southern African context the potential increase in biomass ,whereby carbon is captured in 'perpetuity, is considered to be limited.

3.1 CCS in geological formulations

Leakage can occur due to a sudden release of CO2 because of the failure of an injection system,or any other unforeseen event, or through the gradual leakage that may occur because of undetected geological faults. The IPCC(2005) points out that leakage could be fatal for plants and subsurface animals. Groundwater could also be contaminated and small seismic events could be triggered . leakages in larger amounts to the surface could be

Fatal for humans and animals.

3.2 CCS in the ocean

The IPCC(2005) points out that adding CO2 to the ocean or forming pools of liquid CO2 on the ocean floor at industrial scals will alter the local chemical environment or the ocean. It further states that experiments have shown that sustained high concentrations of CO_2 would cause mortality of marine organisms with subsequent ecosystem consequences. More research is also required since the chronic effects of direct CO_2 injection into the ocean on ecosystems over large ocean areas and longtime scales have not yet been studied. Clearly CCS that aims to store CO_2 deep under the ocean is not yet a mature technology with a proven track record Lindeberg and Bergrno (2003) did pont out that deep water storage reservoir studies and simulations covering hundreds to thousands of year have shown that CO_2 will eventually dissolve in the pore water ;which will become havier and sink;thus minimize the potential for long term leakage. However , leaf et al (2003) describe ocean fertilization as dangerous since the long term effect of increasing CO_2, and the associated possible algae blooms, is simply not known.

3.3 CCS through mineral carbonation

Mineral carbonation will have environmental impacts according to IPCC(2005).Industrial fixation of one tone of CO_2 requires between 1.6
And 3.7 tonnes of silicate rock(IPCC,2005).the impacts of mineral carbonation are similar to those of large scale surface mines. These impacts include land- clearing decreased local air quality and affected water and vegetation as a result of drilling moving of earth and the grading and leaching of metals from minning residues (IPCC,2005).The net effect of mineral carbonation for CO_2 mitigation seems limited.

3.4 Alternatives to the conventional CCS approaches.

The above mentioned arguments are that current uses and storage options for the captured CO_2 have various issues from technical, environmental to legal uncertainties(Engelbrecht et al ,2004). The separation of CO_2 from industrial and enegy realated sources and transport of CO_2, although being challenging is possible at this stage. It is then only the third part of the IPCC CCS definition , the long term isolation from the atmosphere, which proves to be the limiting factor of current CCS projects, especially from a CDM point of view. It has also been argued that limited application exists for using CO_2 as an industrial feedstock. Finding new and innovative uses for CO_2 in a production environment has great potential for CDM eligibility.

Sims(2004) has subdivided CCS projects into physical and biological carbon sequestration technologies. Traditionally a biological CCS project will fall into the a forestation or reforestation CDM framework. Creating a hybrid CCS process where biological carbon sequestration could be an industrial process and not simply a forestation or reforestation would be advantageous. One such future CO_2 capturing technology is the growing of algae on an industrial scale as a CCS project. The algae will act as the medium which will capture the CO_2.An advantage of such as system will be that the algae could again be used as a source of fuel. The oil extracted from the harvested algae can be used to produce bio diesel. The calorific value of bio diesel from algae is 29 kj/g, which is some what lower than conventional diesel at 43kj/g and plant derived oils such as rapeseed oil at 39.5 kj/g.it may be possible to developed large scale ponds or other growth systems possibly using flue gases for the production of algae bio fuels. For industrial application scale up is necessary and research is ongoing to increase the algae yields obtained which in return will increase the amount of biodiesel produced.

In many parts of the world coal powered electricity generation will still play a major role in producing sufficiently electricity including countries such as china . sequestration technologies are currently expensive. But world pressure is mounting from organizations such as the commission of the European Unions(sainz 2006) to produce zero emission coal fired power stations. The development of an algae system for CCS project without the pitfalls of many other CCS technologies. Howe ever, it must be emphasized that such hybrid biological CCS projects do not address the long term storage of carbon. At some stage the physical and permanent storage of carbon has to be achieved.

4. Eligibility of CCS as CDM projects

CDM projects have to adhere to the sustainability criteria of the host country including legislative issues. Only a limited number of countries have specifically developed legal or regulatory frameworks for long term CO_2 storage (IPCC 2005). Laws that could be applicable to CCS include:

- Mining oil and gas operation;
- Pollution control;

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- Waste disposal;
- Drinking water ;
- Treatment of high pressure gases;
- Subsurface property rights.

According to the IPCC several treaties that potentially apply to CCS exist. There treaties include the London and OSPAR commissions(2004). It is important to note that the injection of CO_2 into the geological sub-seabed or the ocean was not considered during these treaties.

Uruha and camillo-hermosillab state that there are still unanswered questions about the cost, safety, sequestration alternatives. The lack of a proven track record when it comes to CCS projects is a fundamental shortfall of the current technological systems.

4.1 Problems utilizing the CDM with CCS projects

CCS is considered to be an end-of-pipe technology as CO_2 production is the result of upstream processes. If processes upstream of the CCS project are altered then less CO_2 could potentially be produced. Examples of such upstream process alterations include fuel switch applications and using more energy efficient equipment. It follows logically that if less CO_2 is produced, less CCS can be achieved. If emission reductions were claimed for CCS under the CDM framework it would imply that less emission reductions can be claimed. A possible perverse incentive is now generated as it could be more profitable not to make the upstream pollution reducing alterations. Furthermore, very specific questions arise if CCS projects are to be considered for CDM registration. These specific questions are discussed using CDM definitions and auditing terms (UNFCCC, 2007).

4.1.1 Accounting

The IPCC (2005) clearly states that the net capture and storage of CO_2 must be quantifiable. This seems like an obvious statement, but the implica tions are far reaching. For the net capture of CO_2 the values for physical leakage, project emissions and all other possible emissions must be deter- mined. This proves to be problematic for CCS projects. One reason may be that currently the limited CCS projects all involve geological storage (IPCC,2005). Subsequently, there is limited experience with the monitoring, verification and reporting of actual physical leakage rates and uncertainty factors. If accounting cannot be performed to a high degree of certainty, then the EB of the CDM will not allow registration of any CCS project as a CDM project.

4.1.2 Leakage

The IPCC (2005) reports that observations from engineered and natural analogues as well as mod- els suggest that the fraction retained in appropriate- ly selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1000 years. These figures inspire confidence in future applications of CCS. However, the IPCC (2005) adds that these CCS projects must be 'well-selected', '(well) designed' and '(well) managed geological storage sites'. The stated prerequisites are quite vague and are open to interpretation.

In terms of leakage the IPCC report (2005) does acknowledge that if continuous leakage of CO_2 occurs, it could, at least in part, offset the benefits of CCS for mitigating climate change. A new view is then highlighted that even if the storage of CO_2 is non-permanent the IPCC (2005) argues that some studies point out that there is a value to delaying emissions. If one can first stabilize current GHG production rates then incurring a penalty for future releases (leakages) of historic CO_2 storage can still have a net positive effect. Obviously the uncertain- ty of the future economic outlook, world political stability and available CCS technologies deter from the argument that future release of CCS sources is still advantageous.

Sedjo and Marland (2003) also suggest that ter- restrial sequestration might only be temporary. They argue that this temporary CO_2 reduction would not produce permanent carbon credits. They propose a system by which the temporarily sequestrated CO_2 reserves be used as a rented offset. A rented offset implies that a polluter can rent the off- set from non-permanent CO_2 sequestration projects for a period for which leakages are monitored and CO_2 sequestration thus guaranteed. Such a system of temporarily CO_2 sequestration rented by a polluter is often referred to as temporary carbon credits.

The non-permanence of biological sequestration is addressed in the issuance of long term carbon credits (lCERs) and temporary carbon credits (tCERs). CCS projects could possibly use the tCER/lCER structure to address potential non-permanence issues instead of defining a new type of carbon credit for CCS projects. It would then be the prerogative of the CCS project to prove that the CO_2 was not emitted to atmosphere in the same way as a biological sequestration project; it must be proven that the claimed biological sequestration mass still exists during the ex post carbon audit.

Currently the CDM EB only allows the use of tCERs/lCERs in biological sequestration projects.

The IPCC (2005) comes to the conclusion that irrespective of the position one takes about the long term storability of CO_2 there exists a maximum allowable, yet not quantified by the IPCC, amount of leakage that can be permitted for a CCS project.

4.1.3 Monitoring and verification

Any CDM project must monitor all emissions within the project boundary and the emission reductions must be verified. The monitoring and verification plan must conform to guidelines set by the UNFC- CC (2007).

4.1.4 Defining the project boundary

As in any CDM project one has to define the proj- ect boundary. A CCS project is no different. As with CDM the project boundaries should include the full range of operations taking place across the CCS project. This includes CO_2 capture, transport, injec- tion and storage. The possible physical extent of a CCS activity can potentially be problematic in defining the CDM project boundary.

5. Development of CDM methodologies for CCS

Currently no approved CDM methodology exists for CCS projects. Two new methodologies have been proposed (UNFCCC, 2007):

- NM0167 – The White Tiger Oil Field CCS proj- ect in Vietnam; and
- NM0168 – The capture of the CO_2 from the Liquefied Natural Gas (LNG) complex and its geological storage in an aquifer located in Malaysia.

5.1 NM0167 CCS project

According to the developer of this proposed project geological CCS technology will be utilized by the project to store anthropogenic CO_2 in an oil reser- voir off the coast of Dinh Co, Vietnam. It will involve the collection of CO_2 from combined cycle natural gas power plants in the Phu My (power) industrial area, and its transport, via a 144 km pipeline, to the injection site at White Tiger Oil Field (WTOF). The project is forecast to generate emis- sion reductions of approximately 7.7 million tonnes of CO_2 per year, after both phases one and two have been implemented, by permanently storing CO_2 in the storage structure. The project will result in the net storage of approximately 30 000 tonnes of CO_2 per day (9 000 tonne CO_2 per day for phase one and 21 000 tonne CO_2 per day for phase two) and the recovery of an average of 50 000 barrels of crude oil per day. CO_2 gas exiting with the recov- ered oil is separated and re-injected into the oil reservoir.

The EB of the CDM allows for public comments on proposed new methodologies.

Shell International Renewables B.V. posted some com- ments regarding NM0167. Some of the issues raised by Shell point out the difficulty in registering a CCS project as a CDM project.

5.1.1 Leakage

Shell points out that leakage should be treated as a project emission. The project development document (PDD) of NM0167 proposes cancellation of CERs in case of leakage of greater than 0.1% per year. Cancellation of CERs 'ex post' is not possible under CDM rules and should not be allowed according to Shell. The project developer and/or operator must deliver a volume of CERs to the Executive Board equal to the volume of any leak- age once the leakage has been verified. The approval of NM0167 is extremely doubtful due to this major deviation from the CDM auditing struc- ture in that NM0167 want credits to be potentially cancelled after issuing.

5.1.2 Long term leakage liability

Shell raised the interesting issue of long term leak- age liability in NM0167. Long term liability needs to be addressed for stored CO_2 beyond a crediting period as a CDM project is credited for one period of ten years or three periods of seven years. Shell wants the developer of the CCS projects to monitor and verify the quasi permanent state of the seques- trated CO_2 beyond the span of the CDM project registration. Gustavsson et al. (2000) address the issue of net residence time of sequestrated carbon; this is the amount of CO_2 not leaked. A specific time for post CDM project monitoring must be defined during which the project developers/operators/own- ers will be liable for all leakage. The liability time frame must be reasonable as to ensure the com- mercial viability of CCS projects. If leakage does occur the liable party must present a volume of CERs to the EB equal to the leakage that occurred.

From the comments from Shell and the IPCC (2005) it becomes clear that there exists a lack of absolute certainty about the permanent CO_2 removal from the atmosphere from CCS projects. The CDM framework does not presently address long term liability. It thus becomes very difficult for a CCS project to be approved at the hand of the CDM framework if criteria not included in the cur- rent CDM framework is required/requested by organisations like Shell commenting on proposed new methodologies.

5.1.3 Monitoring and verification

Shell argues that in NM0167 clarity is necessary for monitoring and verification. It states that in NM0167 the methodology should include a scientific assessment of how the CO_2 behaves in the sub- surface and how it interacts with the storage formation in the long term. To ascertain the behaviour appropriate core testing and simulations must be performed. These tests and modelling techniques should address fluid transport, chemical reactions, and thermal and geo-mechanical aspects.NM0167 plans to use 4D seismic modelling (UNFCCC, 2007). Shell argues that 4D seismic may not provide in all instances an effective geophysical monitoring tool. Using only 4D seismic surveys to monitor seepage/leakage to surface may not be suf- ficient for monitoring. According to Shell, 4D may assist in determining significant movement of CO_2 depending on subsurface conditions. Several direct and indirect technologies might be simultaneously required to achieve a sufficient degree of confidence in monitoring.

In summary, doubts exist about the proposed CCS new methodologies regarding monitoring and verification. No new CDM methodology will be approved without a monitoring and verification plan that provides clarity and certainty to quantify the emission reductions achieved. The proposed new methodology NM0167 seems destined for non-acceptance until the monitoring and verification needs are met.

5.1.4 Project boundary

All project boundary issues must be resolved before any CCS project will be eligible for CDM registra- tion. Regarding CCS, Shell argues that the project boundaries should extend well beyond the edge of the injected CO_2 plume in the subsurface, and also the region around the plume for the purpose of monitoring. This argument induces uncertainty about what exactly will be the boundary for any CCS project that wants to register as a CDM project. As stated above having absolute clarity about the CDM project's boundary

5.2 NM0168 CCS project

According to the developer the purpose of the proj- ect is to recover CO_2 emitted from the PETRONAS LNG complex located at Bintulu, Malaysia, and inject it into an aquifer below the seabed offshore of Sarawak, Malaysia.

Malaysia is one of the major gas producing countries in the world and large amounts of the gas produced in the country is processed to LNG and exported to Japan and other countries for power generation and town use. LNG is known as a clean energy source, which emits less CO_2 than other fossil fuels, but the feed gas of LNG contains 3 to 6 mol% of CO_2, and this is currently removed by acid gas removal facilities and released to the atmosphere after incineration of its acid components with- out any recovery.

This project involves installing additional facili- ties to the LNG complex to compress the recovered CO_2 beyond the supercritical pressure. The lique- fied CO_2 will then be transferred to a new sub-sea facility and injected into an underground aquifer in the Pudina field. The CO_2 will then be stored in a safe and stable condition in underground geologic formations. This will reduce the CO_2 emissions to the atmosphere according to the developer. The consequence of this project is that the emission of CO_2 to the atmosphere can be reduced by 3 million tonnes CO_2 per year. A schematic diagram of the project activity is shown in Figure 3.

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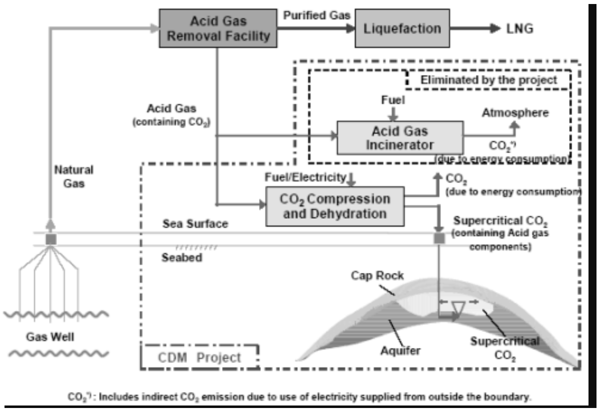

THE CCS PROJECT

Again public comment was received by the EB of the CDM from Shell. Exactly the same issues were raised by Shell as in NM0167 (see sections 5.1.1 to 5.1.4).

6. The potential of CCS

In 2004, the Department of Minerals and Energy commissioned the CSIR to quantify the potential for CCS projects in South Africa and the immediate neighbouring countries (Engelbrecht et al., 2004). The findings of the study have been summarised elsewhere (Mwakasonda and Winkler, 2005). CCS projects require high concentration and pressurised CO2 streams from point sources. According to this study, using data from 2000, 249 Mt per annum of the 427 Mt per annum of CO2 produced originated from point sources, i.e. 58% of all sources. Eskom, the main electricity supplier in the region, and Sasol, a large petrochemical indus- try, accounted for 218 Mt per annum or 88% of the point source CO2. The remaining 31 Mt per annum of point source CO2 was produced by the metal industry and diverse industries. Figure 4 indicates the geographical location of the CO2 point sources in Southern Africa. The CSIR study indicates that most CO2 in Southern Africa is diluted except for the significant quantity of pure CO2 from Sasol facilities that do not need to be enriched; the clean, storable Sasol CO2 amounts to 30 million tons per year. This makes these streams much more viable for CCS from a cost-perspective. Enriching diluted CO2 streams, together with transportation and storage in potentially suitable geological locations, would be costly. For example, between 7 and 15 South African cents per kilowatt-hour for new coal gasification power plants with a baseline cost of about 30 cents per kWh has been estimated (Stephens and van der Swaan, 2011). Apart from the study of Stephens and van der Swaan, very little research has been published on the cost associated with CCS projects in the Southern Africa region; the project- specific nature of CCS makes it difficult to apply for- eign studies to Southern African conditions. A fur- ther costing study must provide a breakdown of the cost associated with capture, transport and storage.

Table 2 summarises the sequestration potential for the different sinks in South Africa including data regarding leakage to the atmosphere (Engelbrecht et al., 2010).

The CSIR study only considered conventional biological sequestration strategies and did not include the novel algae cultivating process referred to before. The areas that are potentially most 1 600 million total anic storage appears reasonably well tested, but the CSIR lists the following as concerns regarding this method of CCS for the South African context.

- The cost, both in terms of energy usage as well as financial cost, need more understanding;
- The applicability of international treaties on the usage of marine reserves and on the discarding of waste materials into the sea needs to be inves- tigated further; and
- The consequences of ocean fertilization are not known at present and it is recommended that South Africa stay informed regarding interna- tional developments.

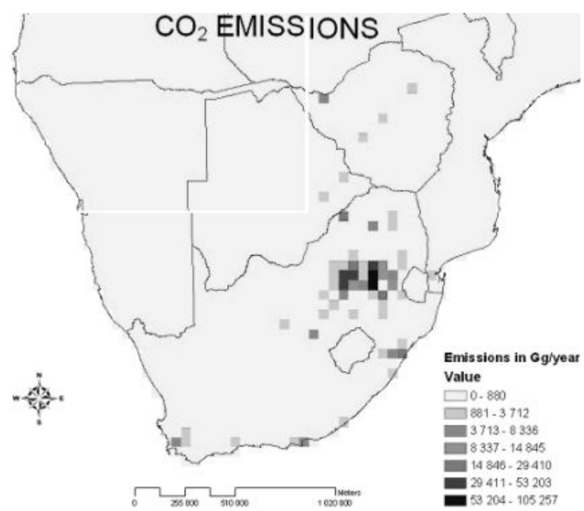

Figure 4: point source emissions of CO2 in Southern Africa

Further studies are required to quantify and understand the potential of CCS in exhausted gold and other mines, and for enhanced gas recovery in Southern Africa. Enhanced oil recovery using CO_2 is also not a viable option in South Africa and the neighbouring countries since very little oil reserves are present.

Unlike in the USA, Canada and Europe, no experience exists currently in South Africa regarding CO_2 sequestration in geological structures. For geo- logical storage a porous rock formation covered by an impermeable formation is ideal. The CO_2 is then pumped into the porous rock and the impermeable cover will prevent CO_2 from escaping to the atmos- phere. Cloete (2006) conducted a study to quantify the geological storage potential in Southern Africa, focussing on South Africa (see Table 3).

From the studies of the CSIR and Cloete (2006) it would seem that, at present, limited opportunities exists in South Africa, and indeed Southern Africa, for CCS projects.

s.n.	Label	Geological name	Storage capacity
1	A	Northern Vryheid formation	183 Gt
2	B	Southern Vryheid molten & clarens formation	80 Gt
3	C	Molten & clarens formation	24-48 Gt
4	D&E	Molten ,burgersdrop & katberge formation	Undefined

Conclusion

The CDM of the Kyoto Protocol is a financial incen- tive intended to make economically marginal greenhouse gas (GHG) prevention projects more feasible. Carbon dioxide capture and sequestration (CCS) is a possible GHG mitigating strategy. The United Nations (UN) defines a CCS project as a process consisting of three phases: the separation of carbon dioxide from industrial and energy-related sources; transportation of the carbon dioxide to a storage location; and long-term isolation of the car- bon dioxide from the atmosphere. This paper sub- sequently reviews the maturity of CCS technologies and current CCS projects; the applicability of CCS as a GHG reducing technology; the eligibility of CCS projects for the CDM; the current activity and development of CDM methodologies for CCS accreditation; and the potential of CCS in Southern Africa.

Research is currently being conducted in each of three phases of a CCS project; however, not all the phases have mature technology at the same confi- dence level. Also, there are limited industrial scale projects that integrate all of the three aspects of CCS. The limited CCS projects and the relatively new implementation thereof imply that CCS proj- ects do not have a historical track record in terms of the effective CO_2 mitigation of these integrated processes. Nevertheless, even if CCS projects only offer temporary mitigation of CO_2 it might still be advantageous to slowing down the effects from GHG emissions. It can be argued that the slow release of CO_2 from historic CCS projects will be more beneficial than the enormous continuous pro- duction occurring presently. This argument is only true if the future production of CO_2 will be globally reduced.

In the CDM context the slow release of CO_2 is known as leakage. To account for this, researchers want to include concepts such as long term liability, temporary certified emission reductions (CERs) and/or CER cancellation. These concepts are not in the current CDM framework. To include these con- cepts, implies that the CDM framework must be modified. Until these modifications occur it is unlikely that CCS projects, with the pitfalls that require these modifications to the CDM framework, will be registered as CDM projects.

The quantification of the adverse effect from CCS projects on the areas where the CO_2 is to be stored is also needed. It is already apparent that CCS could harm the initial surroundings of the sub- strate CO_2. The argument could be made that CCS simply shifts air pollution, GHGs, to the oceans or geological sources and that it does little to limit pol- lution. On the other hand, even if geological and ocean storage of CO_2 does have some negative effects the prevention of global warming from GHG emissions could be a much more substantial posi- tive environmental contribution. Further research is required to quantify the trade offs presented between mitigating CO_2 from the atmosphere at the possible detriment of the areas of storage. Only then will CCS projects be deemed more viable for the CDM context.

The application of CCS projects in Southern Africa also seem to be limited due to the legal and environmental issues that exist regarding the dis- posal of pressurised pure CO_2 streams and the fact that existing point sources are mostly diluted and the distances to storage sites are often large. The consequence is a major cost obstacle to the imple- mentation of CCS projects.

It is concluded that the CDM is unlikely to ben- efit the implementation of CCS projects in the near future.

References

Beyond Petroleum (BP) (2007). Putting carbon capture technologies to work in Algeria. www.bp.com, accessed 1 June 2007.

Bode, S., Jung, M., 2005. Carbon dioxide capture and storage (CCS): Liability for non-permanence under the UNFCCC. Hamburg Institute of International Economics (HWWA) discussion paper, no. 325, www.hwwa.de, accessed 1 June 2007.

Brent, A.C., Heuberger, R., Manzini, D., 2005. Evaluating projects that are potentially eligible for Clean Development Mechanism (CDM) funding in the South African context: A case study to establish weighting values for sustainable development criteria. Environment and Development Economics 10 (5): 631-649.

Bru, J.G., 1996. The pioneering Sleipner West project. Euroil 7 (12): 39-40.

Capoor, K., Ambrosi, P., 2007. State and trends of the carbon market 2007. World Bank Institute, http://car- bonfinance.org/, accessed 1 June 2007.

Cloete, M., 2006. Draft framework for geological and mineralogical storage of CO_2 in South Africa. Council for Geoscience, South Africa.

Engelbrecht, A., Golding, A., Hietkamp, S., Scholes, B.,

Geotimes, 2007. Geotimes: Earth, Energy and Environment News, www.geotimes.org/mar03/wey- burn.jpg, accessed 1 June 2007.

Gnansounou, E., Dong, J., Bedniaguine, D., 2004. The strategic technology options for mitigating CO_2 emis- sions in power sector: assessment of Shanghai elec- tricity-generating system. Ecological Economics 50 (1- 2): 117- 133.

Grönkvist, S., Bryngelsson, M., Westermark, M., 2006a. Oxygen efficiency with regard to carbon capture. Energy 31 (15): 3220- 3226.

Grönkvist, A., Möllersten, K., Pingoud, K., 2006b. Equal opportunity for biomass in greenhouse gas account- ing of CO_2 capture and storage: A step towards more cost-effective climate change mitigation regimes. Mitigation and Adaptation Strategies for Global Change 11 (5-6): 1083-1096.

Gustavsson, L., Karjalainen, T., Marlandc, G., Savolainend, I., Schlamadingere, B., Apps, M., 2000. Project-based greenhouse-gas accounting: guiding principles with a focus on baselines and additionality. Energy Policy 28 (13): 935-946.

Illman, A.M., Scragg, A.H., Shales, S.W., 2000. Increase in Chlorella strains calorific values when grown in low nitrogen medium. Enzyme Microbiology Technology 27 (8): 631- 635.

Intergovernmental Panel on Climate Change (2005).

IPCC special report on carbon dioxide capture and storage: Full report, www.ipcc.ch/activity/srccs/index.htm, accessed 1 June 2007.

International Energy Agency (IEA), 2002. The IEA GHG Weyburn CO_2 storage and monitoring. Greenhouse Issues, 61, www.ieagreen.org.uk/ghissues.htm, accessed 1 June 2007.

International Energy Agency (IEA), 2007. CO_2 Capture and Storage. CCS-CDM Methodology Working Group, www.co2captureandstorage.info/networks/CCS-CDM.htm, accessed 1 June 2007.

Leaf, D., Verolme, H.J., Hunt, W.F., 2003. Overview of regulatory / policy / economic issues related to carbon dioxide. Environment International 29 (2-3): 303-310.

Lindeberg, E., Bergmo, P., 2003. The long-term fate of CO_2 injected into an aquifer. Proceedings of the 6th International Conference on Greenhouse Gas Control Technologies I: 489–494, Kyoto, Japan.

Mwakasonda, S., Winkler, H., 2005. Carbon capture and storage in South Africa. Chapter 6 in: Bradley, R., Baumert, K., Pershing, J., (eds.). Growing in the greenhouse: Protecting the climate by putting devel- opment first. World Resources Institute: 94-109.

OSPAR Commission (2004). Welcome to the OSPAR Commission. www.ospar.org/eng/html/welcome.html, accessed 1 June 2007.