Carbon dioxide capture and storage (CCS) in geological formations as clean development mechanism (CDM) projects activities (SBSTA)

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Abstract

Global climate change results in an urgent need for countries/governments to reduce their carbon footprints by adopting sustainable development methods. Sustainable empowerment through advancement of technology and science in the field of carbon capture and storage (CCS), presently considered as one of the most promising approaches to mitigate global warming at short and medium term. To mitigate this devastating effect of global warming, the CO_2 is captured from industrial utility and compressed either in supercritical form or sub-cooled liquid form for underground storage. The captured CO_2 is transported via pipeline or ships to the storage site and injected into deep saline aquifers, depleted oil and gas fields or unminable coal seams. It certainly is a technology worth looking at as it can affect our future climate change initiatives.

Coal is the dominant commercial fuel, accounting for almost 70% of the total energy consumption in India. Fossil fuel use is expected to continue to dominate energy supply in India for decades to come. India is a nation with a rapidly growing economy, achieving an 8.5% GDP growth rate in 2006 and 9.2% in 2007. This rise in economic growth goes hand in hand with an increase in the country's energy demand, which is currently met, as in many evolving economies, by fossil fuels. Both the Stern Review and The International Energy Agency's World Energy Outlook reports have listed Carbon Capture and Storage (CCS) as a carbon mitigation strategy for India.

1. Introduction

Carbon dioxide is regarded as one of the main greenhouse gases that is causing global warming and forcing climate change. In 2005 the CO2 concentration in the atmosphere was 379 ppm, which greatly exceeds the natural range of the last 650,000 years (180 – 300 ppm) (IPCC Feb. 2007). The primary source of the increase in atmospheric CO2 concentrations is from the combustion of fossil fuels. Both past and future anthropogenic CO2 emissions will continue to contribute to warming and sea level rise with grave implications globally. Developing countries are particularly at risk, as their infrastructures are most vulnerable to extreme events, and there is an expectation that climate change will worsen their food security, water availability and health, in addition to accelerating biodiversity losses (IPCC April 2007). India is a developing country that perfectly illustrates the nature of this challenge involved in developing its economy whilst also preventing dangerous climate change.

The vast majority of India's population (70%) lives in rural areas and directly employs more than 60% of the Indian population (IEA (2007). The Indian government plans to invest heavily in the rural sectors, seeking to achieve more than 4% agricultural growth per year over five years, according to the draft paper for the 11th national plan, which will run from 2007 to 2012 (T. Gibbs 2008). According to the Intergovernmental Panel on Climate Change (IPCC), some of the most severe impacts of climate change will hit India's agriculture and natural resources (IPCC April 2007). For example, Himalayan glaciers are amongst the fastest retreating in the world; glacial meltwater that feeds the major rivers on the sub-continent accounts for 37% of India's irrigated land, loss of this glacier meltwater could cause water shortages for 500 million people (IPCC April 2007).

Since a high proportion of India's energy comes from coal, and because the country's escalating fuel needs raise concerns around security of supply, Indian policymakers are taking a growing interest in promoting energy efficiency and renewables, as demonstrated by the recently launched National Action Plan on Climate Change (NAPCC 2008. Additionally, to meet the anticipated demand for electricity, the Indian government also plans to invest in nine coal-fired Ultra-Mega Power Plants (UMPPs), which have a power generating capacity of 4GW per unit i.e. 36GW overall. There are already secured bids and contracts with international partners for three of these UMPP, with construction set to start later in 2008 (Mott MacDonald, 2008). Considering that just over half of India's current CO_2 emissions are from large point sources (IEA 2007), it may be that such current and future sources could be a suitable starting point for capturing emissions, transporting them, and then storing them in porous rock as a mitigation strategy against dangerous climate change. Given this context, the aim of this paper is to present an overview of the current large point sources and the potential sites for geological storage in India, highlighting the opportunities, and the blockages, that could arise for implementing a carbon abatement technology such as Carbon Capture and Storage (CCS).

2. How CCS works

When fossil fuels such as coal, natural gas or oil are burned or processed to produce energy or other petroleum based products, carbon dioxide (CO2) and other pollutants are generated as by-products. Presently, these emissions are released into the atmosphere in the form of GHGs. CCS is a process through which CO2 can be diverted from the atmosphere by capture and storage. "CCS is a waste management strategy for carbon dioxide. It does not reduce the production of CO2, but it provides a depository to keep it from harming the environment". The CCS process has three distinct elements. First, the emitted CO_2 is captured from industrial utility and compressed either in supercritical form or sub-cooled liquid form for underground storage. The captured CO_2 is transported via pipeline or ships to the storage site and injected into deep saline aquifères, depleted oil and gas fields or unmineable coal seams or through an industrial process that permanently fixates the CO2 into inorganic carbonates using chemical reactions or industrial use of CO2 for production of carbon compounds or chemicals.

2.1 Capture and compression

The most promising CO2 capture technologies are post-combustion and pre-combustion processes. In the more conventional post-combustion approach, CO2 is captured from the gases emitted from burning coal or natural gas to produce energy. The pre-combustion method is used when hydrogen and CO2 are stripped from natural gas. Hydrogen is used either to produce electricity (with only water as a byproduct) or in other industrial processes such as bitumen refining. The CO2 that is currently emitted into the atmosphere through both the pre and post combustion processes could be captured and made ready (compressed) for transportation to a suitable storage site. A third capture technique is oxyfuel combustion. Similar to post-combustion, the fuel is burned in pure oxygen which results in a much purer CO2 stream than when the fuel is burned in air.

2.2 Transportation

Once the CO2 is captured and compressed, it can be transported to storage sites either through pipelines or mobile transport facilities (trains, ships or trucks). Again, given the amount of CO2 that would be required to transport for storage, using pipeline facilities is the most feasible transportation option. Shipping of CO2 would be similar to shipping liquefied natural gas.

2.3 Storage

The final stage in the CCS process is long term storage of CO2. To achieve successful storage in terms of mitigating the damaging environmental effects of GHG accumulations in the atmosphere, such storage must be relatively permanent. Permanence means that the CO2 must not leak back into the atmosphere at any significant rate for hundreds of years. To achieve this kind of permanence of storage, injection of CO_2 must take place at depths in excess of 800 metres so that geological cap rock and other geochemical trapping mechanisms can prevent the gas from migrating back to the surface. These kind of geological formations are found both on and offshore in various locations around the world. Deep saline aquifers and depleted oil and gas reservoirs are generally considered the most suitable geological formations for long-term CO_2 storage. A possible storage location for CO_2 is at the bottom of deep sea beds. CO_2 can either be injected into the water column for dissolution or injected through pipelines to the deep sea bed. The CO_2 would then remain at the bottom of the sea bed in the form of a “lake” since liquid CO_2 is denser than sea water. Finally, injection of CO_2 into coal bed seams to recover methane is in the early stages of research and development. The advantage of this technology is that, because of the way CO_2 reacts with coal, once it is injected in the coal bed it is sequestered permanently. Also, the displaced methane gas can be recovered and utilized as an energy source.

3. Deployment of CCS in India

India is a large coal user and its demand is growing rapidly (IEA 2007). Approximately half of India's current annual CO_2 emissions of over 1300 Mt are from large point sources that are suitable for CO_2 capture. In fact, the 25 largest emitters contributed around 36% of total national CO_2 emissions in 2000; indicating important CCS opportunities (IEA GHG 2008). As a non-Annex I country to the United Nations Climate Change Convention, India has agreed to complete GHG emission inventories but is not required to meet an emissions reduction target. Further, because of the abundance of coal in India, combined with rapidly growing energy demand, the government of India is backing an initiative to develop up to 9 "Ultra-Mega Power Projects." This will add approximately 36 GW of installed coal-fired capacity in India. If the CDM Executive Board approves a CCS methodology, CCS projects could be certified for carbon trading under the Clean Development Mechanism, offering an important injection of funding that is needed. Shahi (2007) summarizes India's official position on CCS technology in the context of climate change.

The Department of Science and Technology, Technology Bhawan in New Delhi launched the Indian CO_2 Sequestration Applied Research (ICOSAR) network in 2007 to facilitate dialogue with stakeholders and to develop a framework for activities and policies studies. CCS research in India includes CO_2-EOR scoping studies that are being carried out in mature oil fields; acid gas from the Hazira processing plant to be injected and reservoir properties (fluids, injection depth) indicate project feasibility. There have been economic assessments of capture costs; for example, IGCC and high ash coal without capture is 21% more expensive than pulverized coal and 12% higher than Ultra Super Critical (Sonde, 2007). IGCC costs become 63% higher with capture than without capture (Malti Goel, 2007).

India has joined a number of international efforts to advance the development and dissemination of CCS technologies. These include participation in the Carbon Sequestration Leadership Forum and the International Partnership for a Hydrogen Economy (IPHE), joining the US on the Government Steering Committee for the US FutureGen project, the US Big Sky CCS partnership, and the Asia Pacific Partnership for Clean Development and Climate. CCS workshops and knowledge sharing events have been organized, including the IWCCS-07 in Hyderabad and the 2006 CSLF meeting in Delhi. However, India's official position has not favoured the assessment of CO_2 storage potential in India or the implementation of a zero-emissions fossil-fuel power plant given the higher cost and technical uncertainties associated with CCS technologies.

3.1 CO_2 storage potential

Estimates for the geological storage potential in India are in the range of 500-1000 Gt of CO_2, including on-shore and off-shore deep saline formations (300-400 Gt), basalt formation traps (200-400 Gt), unmineable coal seams (5Gt), and depleted oil and gas reservoirs (5-10 Gt) (Singh et al., 2006). A recent assessment of coal mining operations in India gives a theoretical storage potential in deep coal seams of about 345 Mt (see Table 1). It should be noted that none of the fields that contribute to this value have the ability to store more than

100 Mt. CO_2 storage in deep coal seams is still in the demonstration phase (IEA GHG 2008).

Table 1. CO_2 Storage Capacity of Indian Coal Mines

Depth of coal beds	Coal grade/category	CO_2 storage Capacity
0-300m	All grades of coal	Nil
300-600	Coking Coal Superior grade non coking coal Mixed (Superior: Inferior 1:1) Inferior (E-G) grade Inferior under thick trap	Nil Nil 10% 30% 50%
600-1200	Coking coal Superior non coking coal Mixed grade (1;1 ratio) Inferior grade under trap	Nil Nil 50% 100%

Source: IEA GHG 2008

Analysis of oil and gas fields around India shows that relatively few fields have the potential to store the lifetime emissions from even a medium-sized coal-fired power plant. However, recently discovered offshore fields could provide opportunities in the future. The potential for CO_2-EOR needs to be further analysed on a basin-by-basin basis; it is not possible to develop a suitable estimate today (IEA GHG 2008). Deccan Volcanic Province, the basalt rock region in the northwest of India, is one of the largest potential areas for CO_2 storage. The total area considered is 500 000 km^2 and corresponds to a volume of 550,000 km^3 with 13-20 different flow units. It reaches 2000 metres on the western flank. Storage volumes are in the range of 300 Gt of CO_2 (Sonde, 2006). Thick sedimentary rocks (up to 4000 metres) exist below the basalt trap. In order to model the long-term fate of CO_2 injection in such mineral systems, geo-chemical and geo-mechanical modelling of interaction between fluids and rocks is required.

There is considerable potential for CO_2 storage in deep saline aquifers, particularly at the coast and on the margins of the Indian peninsula, particularly in Gujarat and Rajasthan. Figure 1 shows this and also demonstrated aquifer storage potential in the areas surrounding Assam, although these reservoirs are 750 -1000 km from five large point sources, each with annual emissions greater than 5 Mt. Therefore, CO_2 storage may prove costly due to transportation expenses.

The Indo-Gangetic foreland is an important potential storage site (Friedmann, 2006). The Ganga Eocene-Miocene Murree-Siwalik formations are fluvial sandstones that have good storage potential as deep saline formations. Their high salinity and depth prevents from an economical surface use. The Ganga area has a basin area of 186,000 km^2, with a large thickness of caprock composed of low permeability clay and siltstone (Bhandar et al., 2007).

The proximity of the sources to the potential storage site makes it a good candidate for a pilot project.

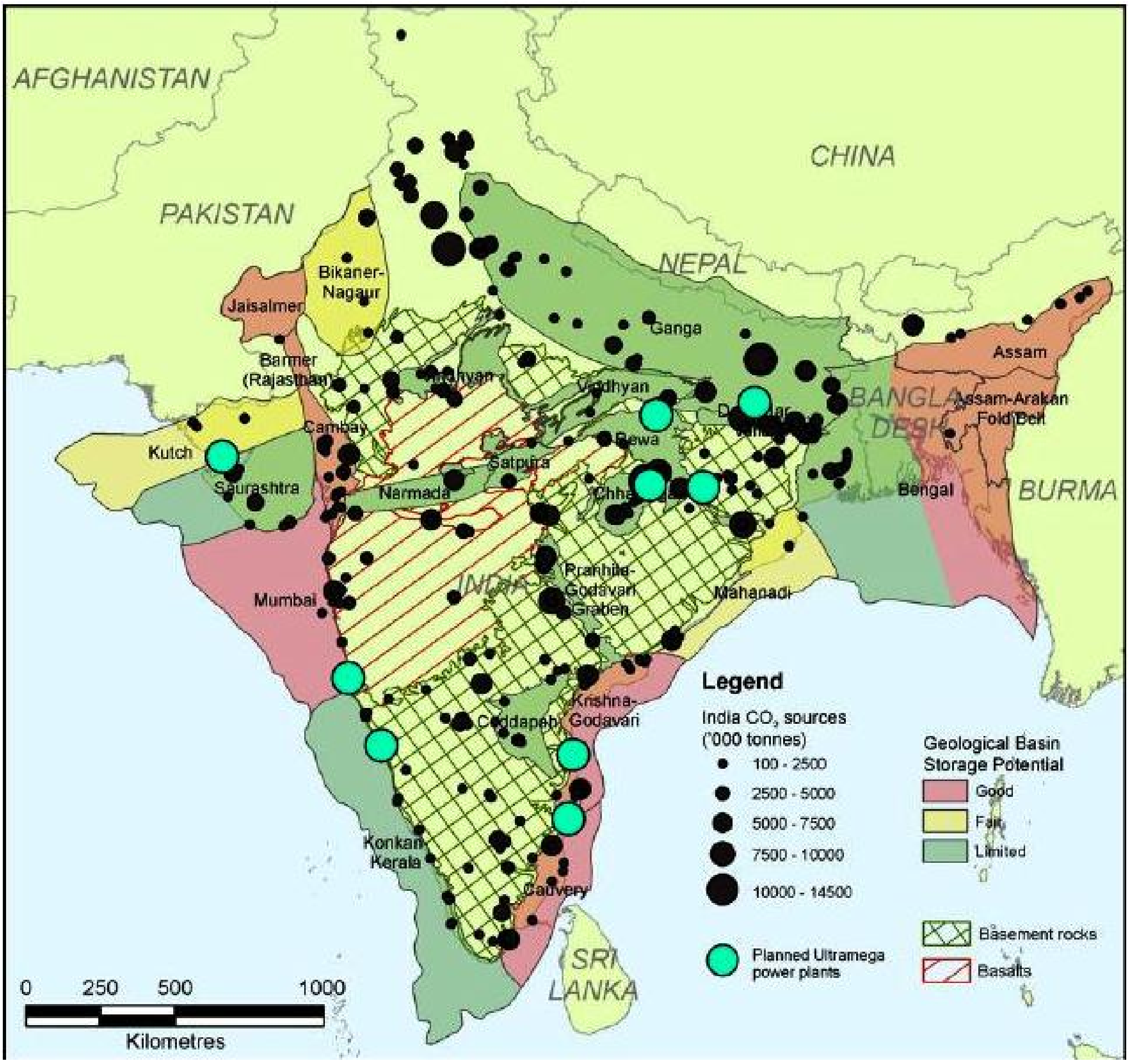

Figure 1: Present and future sources of CO2 and geological basins with storage potential (Source: .*A regional assessment of the potential for CO2 storage in the Indian Subcontinent.* IEAGHG R&D Programme Report (2008), Cheltenham, UK).

4. CCS and CDM

CCS deployment in India will need the following steps of the CDM project cycle to be carried out before a sustainable and viable CCS-CDM model is envisioned:

1. Project Appraisal
2. Approval & Validation
3. Implementation, Monitoring & Verification
4. Carbon Credits issued

These levels will involve all the stakeholders of the economy, namely the Government, Project Developers, Technology Providers, Financing Body and the CDM experts.

4.1 Project Appraisal

The project appraisal stage of the CCS-CDM project will entail establishing a *Baseline* and *Additionality* for the CCS technology. For this it will be important to define the project boundaries that will identify the source and sink of the CO_2 that has been captured through CCS technology. Since major part of the storage of captured CO2 will be done under bedrocks and aquifers, defining a well-defined boundary for the CCS project will be a daunting task, requiring extensive study of the geological formations and dynamics of the region.

Fixing the baseline for CCS-CDM project will be unique for every project, since the point CO_2 sources and potential storage locations are rarely at coincidental places, as shown in figure 1.

The next step in project appraisal is the verification against leakage of CO_2 from the storage locations. Since the possibility of CO_2 storage in India are located in the on-shore and off-shore deep saline formations, basalt formation traps, unmineable coal seams and depleted oil and gas reservoirs; the cost involved in the verification against leakage will be costlier than that in other CDM projects. The Project Appraisal should also consider the permanence of the containment, mainly the possibility of the captured GHGs to be released in the atmosphere in the future. Since the permanence of CCS cannot be established up to 100%, it will become important to establish liabilities in case of premature seepage of the captured CO_2[8].

After the contract between the buyer and seller has been signed, mentioning the ownership, intellectual property, responsibility, price and technology transfer; the parties will negotiate the various terms related to the crediting period. Crediting period in case of CCS project can be of a *renewable-crediting type* with longer crediting time, since the CCS technology has long economic lifetime and once fully implemented will not need significant technological changes for years. There can be long periods during which the CCS projects can be considered *additional*, that is as a technology that is not business-as-usual investment.

The next step in project design is the identification and mitigation of risks involved with the CCS project. The main risks identified are the following[10]:

1. **Project Risks**: common to conventional projects
2. **Political Risks**: common to conventional projects
3. **CDM Risks**: unique to CCS-CDM projects

We will focus mainly on the CDM risks that are unique to such projects. Some of the prominent CDM risks are the non-approval of the CDM Executive board of the CCS technology led CDM projects, pricing of the CERs, technology-risks in this technology intensive CCS project. To mitigate these risks, it is important to start the project as early as possible and with the collaboration of the two main parties of the project: the CDM expert and the CCS technology expert. The volatility of the pricing of CERs can be taken care of by locking in the CER prices with the use of CER Derivatives[11]. Sometimes the price risks involved with the CDM projects lead to discounting of CER prices, that is unfavourable to the CDM developers[12]. The last step in project appraisal will be the preparation of a detailed Project Appraisal Document.

4.2 Approval & Validation

The CCS project will need approval of Designated National Authority. This body will ensure that the goals of the project are commensurate with the climate-change mitigation aims of the Government. The DNA will also determine if the CCS project is beneficial for the local community. The project should not be just a technological show-case, but must be a value-addition to the existing knowledge of Climate change mitigation.

After approval from the DNA, the Project Appraisal document will be sent to the Operational Entity for validation. The OE will verify the Kyoto Protocol requirements and the environmental impact of the CCS technology. It will also validate the baseline proposed for the CCS project in the Project Appraisal document.

4.3 Implementation, Monitoring and Verification

After registration with the CDM executive committee, the CCS project can be executed. But the implementation of the technology-intensive CCS project can take a longer time than most of the existing CDM projects. The project developers will be require to simultaneously monitor the CO_2 emission reductions. This monitoring should be done for the CO_2 emitted during and after the implementation o f the CCS project[13]. The results of the monitoring should be verified by an independent body. This body will issue certificate stating the amount of CO2 reductions and its ownership.

4.4 Carbon Credits issued

The CDM Executive Board will consider the recommendation of the independent body certifying the reduction of GHG and will release queries for the concerned parties. After these steps, CERs are issued according to the Project Appraisal document.

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