Prospects and Challenges for CCS Technology Deployment in India

Dr.S.Anand Giri, Dr.Nidhi Tiwari

Abstract -- 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. Deployment of CCS technology could potentially allow developing countries to gradually shift away from fossil fuels for energy and industrial needs, as an interim measure, it could allow time for other alternative low-carbon technologies to be developed and deployed, permitting fossil fuels to be gradually phased out. This strategy could assist developing countries to transition to a low-carbon economy in the next 15–50 years. While CCS is potentially attractive to some developing countries, there has been limited development of demonstration projects in Africa, Asia, or Latin America due mainly to their high cost in the absence of expected profits or significant carbon financing. The International Energy Agency (IEA) estimates the total cost for a new average-sized coal-fired power plant that captures up to 90 percent of its CO_2 emissions to be US$1 billion over 10 years. Existing financing for CCS is grossly insufficient to enable demonstration projects in developing countries. The IEA CCS Roadmap proposes 50 CCS projects in developing countries in the next 10 to 20 years. As well as reducing the developing world's greenhouse gas emissions, accelerating CCS demonstration efforts can also improve technologies, increase efficiency, reduce uncertainty and risk, and initiate learning-by-doing at a lower cost than would be possible in the developing countries.

Index Terms— Climate change, Carbon Capture and Storage (CCS) technologies, the CCS Roadmap, developing countries, CO_2 storage capacity, challenges, CCS deployment.

1 Introduction

Coal is the main 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 and certainly coal will play a significant role in providing energy and electricity in India until 2050, at least, despite measures to significantly increase the role of other energy sources [1], [2]. Chinese companies have recently started planning and constructing pilot scale (and larger) CCS schemes. The Indian Government and industry has, however, tended to take a more cautious approach. Although there are some significant challenges, it seems likely that introducing CO_2 capture at Indian power plants could be technically feasible especially in locations where it is considered appropriate to apply 'capture ready' concepts for new build plants before CCS is deployed.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.For example, the Stern Review notes that:

"[CCS] is a technology expected to deliver a significant portion of the emission reductions. The forecast growth in emissions from coal, especially in China and India, means CCS technology has particular importance."

Carbon capture and storage schemes capture CO2 from power plants or industrial sites before that CO2 is emitted to the atmosphere. The CO2 is then compressed and sequestered, either underground, in a deep submarine environment, or by reacting it with silicate minerals to form carbonate minerals. Different technologies also can be adopted for accomplishing Carbon Capture and applying them to different industrial processes. Carbon storage involves pumping CO_2 into large porous reservoirs (for example saline aquifers, coal seams or oil and gas reservoirs) beneath the Earth's surface at depths greater than about 1 km. At these depths, the CO_2 is compressed such that it is in a liquid-like form (supercritical uid) and free of any gas phase. The aim is then for the supercritical CO_2 to be retained underground for long enough to be both safe and to solve the problem of human release of CO_2 to the atmosphere [6].

The IEA predicts that India will be in the top three emitters of the world by 2030 in terms of total CO_2 emitted each year and it is currently ranked sixth (IEA) In terms of per capita emissions, however, India's were one sixteenth of the US and one third of China's in 2004 (IEA 2007). Since just over half of India's current CO_2 emissions are from large point sources (IEA 2007), it is important to consider whether such sources could be a suitable starting point for reducing CO_2 emissions by capturing, transporting and then storing CO_2 in porous rock as a mitigation strategy against dangerous climate change in CCS projects[17],[18].

Carbon Capture and Storage (CCS) is the only way of preventing greenhouse gas (GHG) emissions reaching the atmosphere whilst still continuing to use fossil fuels. It is acknowl-

- *Author Dr.S.Anand Giri is Professor in Chemistry Deparetment, DIT School of Engineering, Greater Noida,U.P.India. PH-09827002068. E-mail: jatveda60@yahoo.co.in*
- *Co-Author Dr. Nidhi Tiwari is Associate Professor in Chemistry Department, Sun Engineering College, Chandkhuri, Durg,C.G. IndiaPH-09827944047 . E-mail: nidhitiwarii@rediffmail.com*

(*This information is optional; change it according to your need.)*

edged that in the foreseeable future, demand for energy will increase and future energy use at least to the mid-century will likely contain fossil fuels, thus CCS, along with other renewable energy technologies and nuclear power, will be needed in order to balance the supply and demand for energy, whilst maintaining energy security [5], [6]. However,some CO_2 emissions are intrinsic to particular industrial processes and as such, can only be reduced by abatement processes such as CCS [6]. Thus CCS is regarded as a key mechanism for mitigating the effects of climate change[3] and [4], [6], [7].

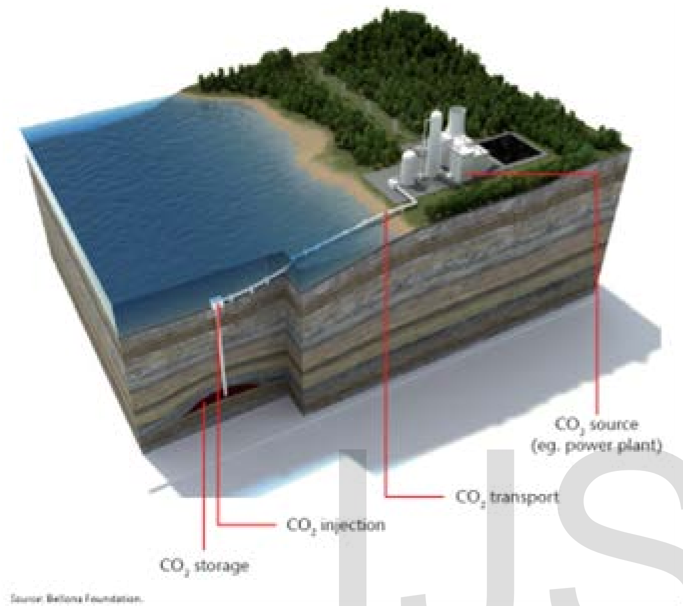

Fig.1 Carbon Capture and Storage (CCS)

2 CCS IN DEVELOPING COUNTRIES

Though number of programs and efforts are made to promote energy efficiency and deploy nuclear, renewable, and other low-carbon energy sources, many developing countries will still rely heavily on fossil fuel energy to power their development for decades to come. Therefore, there is a need for developing countries to create strategies that address fossil fuel emissions in a way that minimizes the costs of doing so, and consequently minimizes impacts to their national development goals.

Currently CCS is the only near-commercial technology proven to directly disassociate CO_2 emissions from fossil fuel use at scale. Its deployment could potentially allow developing countries to gradually shift away from fossil fuels for energy and industrial needs with relatively little disruption to their long-term development strategies. If deployed as an interim measure, it could allow time for other alternative low-carbon technologies to be developed and deployed, permitting fossil fuels to be gradually phased out. This strategy could assist developing countries to transition to a low-carbon economy in the next 15–50 years.

While CCS is potentially attractive to some developing countries, there has been limited development of demonstration projects in Africa, Asia, or Latin America due mainly to their high cost in the absence of expected profits or significant carbon financing. The International Energy Agency (IEA) estimates the total cost for a new average-sized coal-fired power plant that captures up to 90 percent of its CO_2 emissions to be US$1 billion over 10 years [1], [2], [6], [8]

Existing financing for CCS is grossly insufficient to enable demonstration projects in developing countries. The few available funds are either spread over the full array of low-carbon technologies, or fall short of the magnitude or the mandate needed to propel commercial-scale CCS demonstrations forward. Current carbon offset mechanisms are not sufficient to spur CCS deployment in developing countries in today's context either. Overall, existing CCS financing mechanisms help grow capacity, but their support is insufficient to leverage enough funding from capital markets to implement projects in a non-OECD context.

The IEA CCS Roadmap proposes 50 CCS projects in developing countries in the next 10 to 20 years. As well as reducing the developing world's greenhouse gas emissions, accelerating CCS demonstration efforts in non-OECD countries can likely also improve technologies, increase efficiency, reduce uncertainty and risk, and initiate learning-by-doing at a lower cost than would be possible in OECD countries. The captured benefits from doing so will be more significant the sooner acceleration in CCS development in developing countries begins.

2.1 CO_2 storage potential in India

The injection of CO_2 into suitable formations in large sedimentary basins is generally expected to involve for the permanent storage of CO_2. A detailed assessment of the storage potential, both in terms of quantity and integrity, is required for potential storage sites such as coal fields, oil and gas fields, and deep saline water-bearing reservoir rocks. 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) [13]. A recent assessment of coal mining operations in India gives a theoretical storage potential in deep coal seams of about 345 Mt. 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 [9].

Geological CO2 Storage Potential [8]

Estimated CO_2 storage potential in:

- Deep saline reservoirs (on and off shore) estimates ~ 360 $GtCO_2$
- Depleted oil and gas wells estimates ~ 7 $GtCO_2$
- Un-mineable coal seams ~ 5 $GtCO_2$
- Volcanic rock 200 $GtCO_2$

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CO_2 Storage Capacity of Indian Coal Mines

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[9], [10], [13]. 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 [9]. 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 km2 and corresponds to a volume of 550,000 km3 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 [16]. Thick sedimentary rocks (up to 4000 metres) exist below the basalt trap. 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 as well 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.

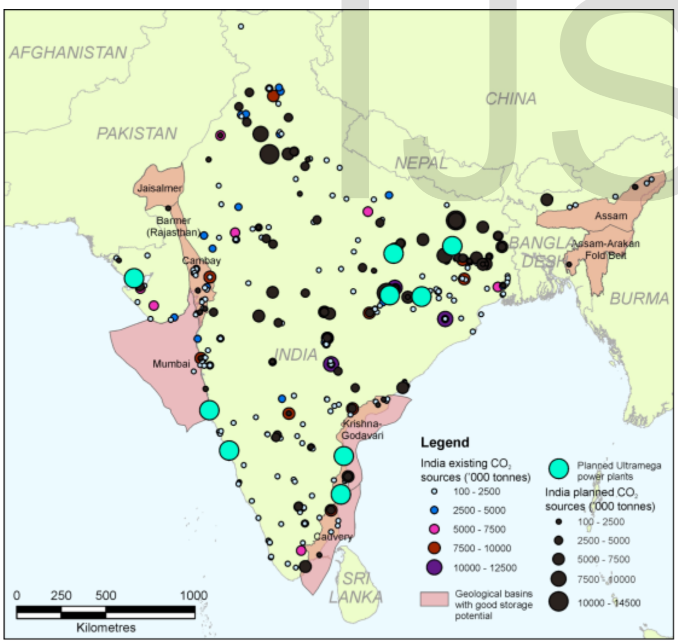

Fig.2.India's planned and existing CO2 sources in 2008, and geologi cal basins with good storage potential (source: IEAGHG 2008).

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. An IPCC special report on CCS published in 2005 identified a number of CO_2 capture options that are relatively close to commercial-scale deployment at power plants. An important consideration for current power plant construction activity is, therefore, whether plants should be made 'capture-ready'. A study of possible technical and economic performance of UMPP projects by Mott MacDonald[13], funded by the UK Foreign and Commonwealth Office, concluded that the essential requirements for capture-readiness should cost no more than 1% of the total capital required for these projects.

2.3 Indian Government engagement on CCS

As discussed earlier, the viability of CCS as an option for mitigating the risk of dangerous climate change depends on a range of non-technical factors, in addition to consideration of technical viability. A number of these factors are discussed with the stakeholder survey results presented in the next section. One important consideration is whether CCS can be politically acceptable and this section, therefore, reviews recent and current (July 2009) engagement on CCS by the Indian Government.

The Government of India is currently taking part in international initiatives, including the Carbon Sequestration Leadership Forum (CSLF), which was founded by the US in 2003. By 2006 India had signed a pact with the US on the FutureGen project and made a contribution of USD 10 million. The Indian Government has also hosted a series of international workshops on CCS and R&D challenges, starting with two held at the National Geophysical Research Institute, Hyderabad in 2006 and 2007. In January 2008, a joint workshop between the UK Department of Environment, Food and Rural Affairs (DEFRA) and the Indian Department of Science and Technology (DST) was held to look at the prospects of CCS technology in India. An outcome of this international dialogue has been the establishment of the Indian CO2 Sequestration Applied Research (ICOSAR) network by the DST. Despite Indian interest in CCS research, a number of studies have indicated that the Indian government shows minimal interest in CCS demonstration or policy [11], [12]. Viewpoints from the industries and government in these previous studies indicate that CCS is considered a "frontier technology" that needs to be developed further in developed countries first to bring down the cost through R&D and [11]

CCS Activities in India

- India is a member of CSLF & IEA GHG R&D Programme.
- It is participating in the Future Gen Programme.
- The Government of India has plans to invest in CCS related activities in the XI & XII Five Plan (report of the working group on R&D for the energy sector).

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- Institute of Reservoir Studies is carrying out CO_2 capture and EOR field studies in Gujarat.
- NGRI is testing the feasibility of storing CO_2 in basalt formations.

3 CCS Deployment in India

India is a large coal user and its demand is growing rapidly [16] [19], [20].. 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 [9].

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 "Ultra-Mega Power Projects." This will add approximately 36 GW of installed coal-fired capacity in India. 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. 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 Future Gen 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.

4. Barriers to Deployment

The developing countries are facing some key challenges for the deployment of CCS. One of the most significant barriers to deployment is cost. In developed nations technology deployment is somewhat difficult due to cost, although additional energy expenses are economically feasible for the customer base. But in developing nations where a large percentage of the population do not have access to mains electricity, the cost of deploying CCS could be prohibitive. The problem of CO_2 emissions and climate change is a global one, needs a global solution. If the answer is CCS, then it needs to be cheaper. There are some ways of achieving this, for example, ensuring that the storage sites for the captured CO_2 are close to the sites where the CO_2 is generated, improvements in combustion and power-generation technologies, such as those being developed at Cambridge University, so that the capture of CO_2 is more efficient with reduced energy penalties. Another barrier is that of scale. Capture technologies have not been tested at the scale that would be required for a currently active, coal-fired power station (300-800 MW range [22]. The different parts of the CCS chain have not yet been used together in an integrated system, but this is required for deployment, otherwise heavy financial penalties may be incurred. The uncertainty surrounding CCS deployment is also a major challenge and is perceived to be mainly due to costs and liabilities should a storage reservoir leak CO_2.

The CCS Directive (2009/31/EC) specifies that a leakage is 'any release of CO_2 from the storage complex' which is the 'storage site and surrounding domain', and corrective measures must be taken if any leakage occurs. This places a financial burden on the operator until the liability is passed to the competent authority. The timescale for the transferral of liability in the UK has not been set, although Directive 2009/31/EC stipulates that it must be greater than 20 years unless evidence is supplied to indicate that the CO_2 has been permanently contained. The right regulatory framework needs to be set so that the financial burden placed on operators of storage sites is not prohibitive, but that negative environmental and

health impacts due to leakages are minimised. The key is to generate the right market conditions in order to allow the technology to be deployed and remain viable, and to take a realistic view on the risks of leakage from storage versus the risks of not deploying CCS in the first place. Lastly, the public communication of CCS is vital for commercial deployment. Previous projects have failed on the strength of public opposition with shortcomings in communication often to blame [22]. Early communication between project developers, stakeholders and the public, is important if a CCS project has to succeed [21].

4 Conclusion

It is acknowledged that the future energy supplies will likely depend on fossil fuels in India, and therefore Carbon Capture and Storage (CCS) is required to control atmospheric greenhouse gas (GHG) emissions. CCS Deployment in developing countries like India face Some key challenges and are concerned with a number of different issues. One significant challenge is cost, with the capture of CO_2 representing the largest share of this. Uncertainty of CCS deployment is also a major challenge and is widely perceived as being mainly due to costs and liabilities should a storage reservoir leak. Research at the Departments of Applied Mathematics, Theoretical Physics and Earth Sciences has addressed some of the concerns surrounding CO_2 storage and potential leakage from the storage site An important aspect of the CCS process is predicting a clear and scientifically grounded assessment of the risks associated with long-term CO_2 burial.

Public communication of CCS is also vital for commercial deployment. Current researches find that CCS technologies are yet not sufficiently well known or understood by the public and that there are gaps in the types of information mainly technological that are available and in the types of institutions

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specially corporations and Government actively providing information on CCS. Another challenge is that the technology has not yet been tested at the commercial scale and therefore the associated risks may not have been fully characterised. However, unless the technology is commercially deployed, the full technological capability will not be understood. Research is also conducted into the economics of CCS because cost is a major issue. The right regulatory framework needs to be set so that the financial burden placed on operators of storage sites is not prohibitive. It is necessary to generate the right market conditions to allow the technology to be deployed and remain viable when competing with other low-carbon energies.

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