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Potential Scope and Limitations of Carbon Dioxide Capture and Sequestration Technology in India

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Abstract. Carbon dioxide (CO2) is the prime cause of global warming. The levels of CO2 in the earth's atmosphere are rising ever since the industrial revolution begun. Even today in India, most of the industries rely heavily on coal as their source of energy. Most of us are still concerned only with acquiring energy, irrespective of methodology involved. CO2 produced in the form of flue-gases is released without appropriate treatment which is adversely affecting the environment.
A range of actions that need to be undertaken includes Carbon Dioxide Capture and Sequestration (CCS) Technology. CCS is a process of separation of CO2 from Large Point Sources (LPSs), transport to a storage location, followed by long-term isolation from atmosphere. A portion of desired depletion can be achieved by improving energy efficiency owing to technological advancements, and the remainder might be achieved by moving on to renewable energy resources. In India, along with population explosion, there is rise in temperature due to global warming and to cope with the levels of CO2, we need to see what kind of technological options we have to solve the problem. The paper brings about the study of CCS, its advantages, cost effectiveness and related drawbacks in India.

Keywords: carbon dioxide, sequestration, global warming, drawbacks

1. Introduction

In India, domestic demands make up three quarters of the national economy [1]. In spite of this fact, since 2002, alongside the annual economic growth in India, there has been a manifold increase in the CO_2 emissions as well. Majority of India's energy comes from coal, and because the country's increasing fuel needs bring about issues regarding the supply, there is a growing interest in promoting energy efficiency and renewable sources, as demonstrated by the National Action Plan on Climate Change (NAPCC, 2008) [2]. This use of coal on a very large scale has added to the emissions. The value has mounted up to 75% and has been increasing further on. India is 4th largest CO_2 emitting country in the world. This is in contrast to the Organisation for Economic Cooperation and Development (OECD) countries where the emissions have decreased by a significant amount [3]. Considering that India is one of the developing countries, it would not be practically possible to bring about a drastic change in emission rates. Rather, an appropriate approach would be to introduce a technology which would steadily, but surely get the numbers down. This is when Carbon Capture and Sequestration (CCS) technology comes into the picture.

CO_2 can most appropriately be captured at locations where it is produced. The best suited examples includes sources such as thermal power plants and industries. Apart from these, the CO_2 capture using various techniques can be adapted to steel plants, cement works, ammonia gas processing industries and refineries, etc. The main aim of CCS is to reduce cost and increase the efficiency other than the technological aspects. The most economical and sort-after method used to store captured CO_2 is in compressed liquid form.

Another very important factor to be taken into consideration is the capital that would be required for the complete system to work smoothly. The major issue in deploying the CCS systems in Indian plants and

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industries is that, there is very little experience with getting all technological aspects and integrating it into one unit on commercial level. The domain of investment involved covers a wide range of costs, right from power generation to storage. The total estimate depends on a lot of parameters, primarily on the location of the source and thereafter on other aspects such as the capture technology employed, the facilities available and ease of accessibility to basic necessities such as raw materials, electricity, water, etc. Other than these, the characteristics of CO_2 storage sites and their distance from the source. In addition, estimates of the future performance of components of the capture, transport, storage, measurement and monitoring systems are uncertain. In India apart from these, the constant hike in price of electricity and fuel, namely petrol and diesel, also makes the estimations uncertain.

2. Literature Survey

In a survey conducted by United Nations, it estimated that total emissions in India rose to 1743 Mt CO_2 in 2008 from 1343 Mt CO_2 in 2004. Large Point Sources (LPSs) contributed to 64% of all India emissions. This steep increase in the emission levels made locating the sites for storage need of the hour. The storage in India can potentially be done at coal fields, sedimentary basins and oil and gas fields. The total storage capacity in oil and gas fields is estimated to be between 3.7 to 4.6 Gt CO_2 [4]. Another survey conducted indicates that the storage capacity of Indian coalfields is about 345 Mt CO_2. It was also found out that none of the individual coalfields in India has a storage capacity of 100 Mt CO_2 [5]. Moving on to the ocean storage capability and the criterion of necessary depth of 2500m is fulfilled by the Arabian Sea (average depth of 2734m) and the Bay of Bengal (average depth of 2600m) which lie on the western and eastern sides of peninsular India respectively. The map by GCCSI in Fig. 1, shows the sources of emission and the potential geological sites for the storage of CO_2. The basins have been categorized as good, fair and limited storage capability sites.

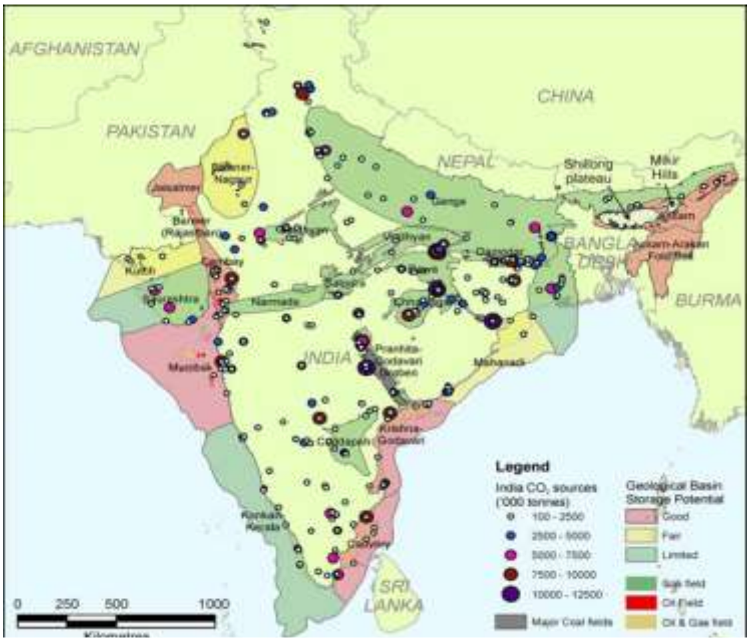

Fig. 1: Geological Basin Storage Potential in India (Courtesy GCCSI)

CO_2 capture from combustion processes is rather expensive and energy-consuming, while CO_2 separation from natural gas wells is in general easier and cheaper. Approximating 1 US$ to be equal to ₹ 61, today's typical cost of CCS in power plants ranges from ₹ 1830-5490/tCO_2 or even more, depending on technology, CO_2 purity and site. This cost includes capture ₹ 1220-4880/tCO_2; transport ₹ 61-610/tCO_2 per 100 km; storage and monitoring ₹ 122-305/tCO_2. The impact on electricity cost is ₹ 1.22-1.83/kWh. Assuming reasonable technology advances, projected CCS cost by 2030 is around ₹ 1525/tCO_2, with impact on electricity cost of ₹ 0.61-1.22/kWh. CO_2 separation cost from natural gas wells may be as low as ₹ 305-915/tCO_2 [6].

3. Methods

The ultimate objective of reducing the CO_2 concentrations in the atmosphere at a level that keeps the climate systems away from the dangerous anthropogenic interference takes place in 3 steps as mentioned earlier, i.e., capture, transport and storage. Making the study elaborate, the capture of CO_2 is taken into consideration followed by the methods of transportation and storage of the same.

3.1. Capturing CO_2

CO_2 finds its way into the atmosphere in numerous ways. In India, most of it is emitted by large stationary sources and rest by mobile sources in comparatively smaller quantities. These emissions are mainly from the combustion of fossil fuels, dominantly coal, used for power generation, industrial processes, and the other fossils fuels used in transportation, residential and commercial buildings. CO_2 is also emitted during certain industrial processes like cement manufacture or hydrogen production and during combustion of biomass. The main purpose of capturing is to produce a concentrated stream of CO_2, so that it can be transported to storage sites at high pressures. The reason for concentrating the CO_2 stream is to make it economically feasible. Transportation of CO_2 in dilute form would make it unrealistic and impractical in context of the required capital. The main application of CCS is at the large stationary sources as capturing CO_2 directly from small and mobile sources has so far proven to be very complicated and expensive too. The capture directly from atmosphere would not be discussed in the paper as the concentration is less in ambient air (around 380 ppm) by a factor of 100 times as compared to flue gases [7]. Minimization of emissions from these large point sources can have a drastic impact

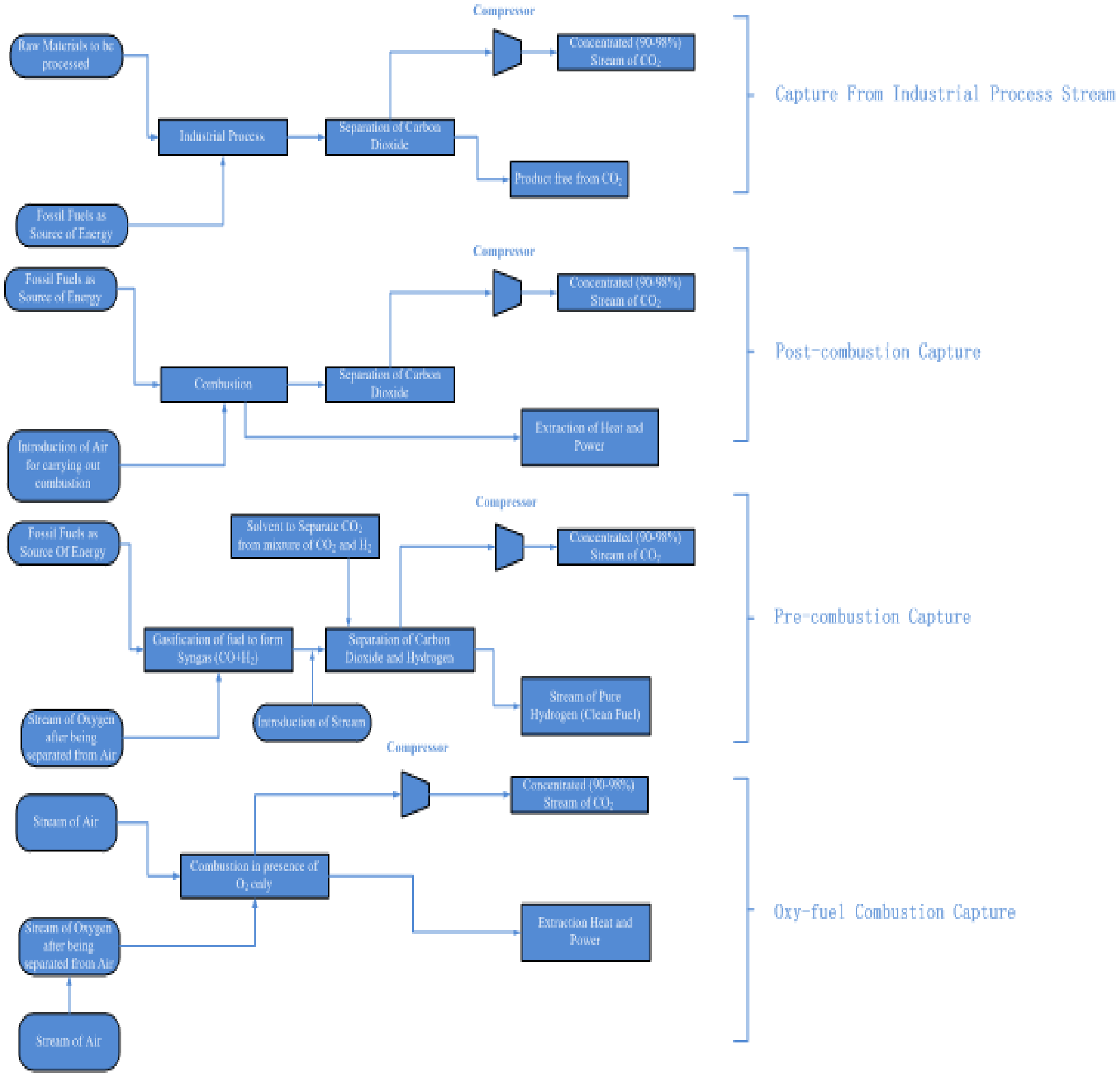

Fig. 2: Schematic Representation of Various Capture Systems

towards lowering the CO_2 levels. Currently, four capture systems are available whose schematic representations are shown in Fig. 2 and are as follows:

- Capture from industrial process streams
- Post-combustion capture
- Pre-combustion capture
- Oxy-fuel combustion capture

There are various technologies available for gas separation which are integrated into the basic capture system. For example, separation with sorbents [8], solvents [9], separation with membranes [10], etc. The study of which is beyond the scope of this paper.

3.2. Storage Of CO_2

The storage is widely divided into two categories:

- Geological Storage
- Ocean Storage

The Geological Storage can be defined in broad terms as the storage of CO_2 underground. The sites for storage are mainly, sedimentary basins, depleted oil and gas reservoirs, coal seams and saline aquifers. The sedimentary basins should have adequate porosity and thickness for storage, a confining unit to avoid leakages, a stable geological environment along with the criterion which takes into consideration societal issues like development, economy, public education and attitudes. Basins formed in the mid-continent locations and along the edges of the continent are the most suitable due to their structure and stability [11, 12]. The Oil and Gas fields find their application in storage because the studies revealed that, trapped CO_2 did not escape for a very long period of time. These are also selected because they do get affected as they already contained hydrocarbons. Coal consists of voids which enables it to behave like an adsorbent. Hence, coal mines are considered viable sites for storage [13]. Saline aquifers are storage sites consisting of sedimentary rocks with high concentrations of dissolved salts. These are considered as potential sites due to its abundance and unsuitability in case of agriculture or human consumptions [14]. Currently, the geology of saline aquifers are less understood compared to other storage sites. On the other hand, the Ocean Storage can be defined as the storage in the ocean at great depths or on the sea floor. When CO_2 is injected to great depths, due to high pressure, formation of solid hydrates ($CO_2.6H_2O$) takes place [15]. These hydrates either sink to the bottom or can also dissolve into the ocean.

3.3. Transportation Of CO_2

Transport of CO_2 is that stage, where the CO_2 captured from LPSs is sent for final storage at geological or ocean storage sites. Transport, in spite of being done before storage, is discussed later because the mode of transportation depends largely on the capture locations. The two major modes of transport are tanks, pipelines and ships. Transport through pipelines is further divided into two types namely:

- Land Pipelines
- Underwater Pipelines

While taking the transportation system in consideration, a whole set of rules and regulations are formulated and followed for public safety that governs pipelines and shipping. The transport through pipelines is analogous to the transport of natural gas, oil, condensate and water over distances of thousands of kilometres. The CO_2 stream that would be passed through pipelines needs to be free of hydrogen sulphide (H_2S) gas to restrict corrosion [7]. In case of transport through ships and tankers, it is being already done for liquefied natural gas and petroleum gases. Same is being done for CO_2 but on smaller scales. CO_2 can be transported in either solid, liquid or gaseous form. The gaseous form would require large facilities, hence, they are commonly compressed and even liquefied. Solidification can be done but it requires higher amounts of energy compared to other options, resulting to higher costs. In the future, managing committee of the various power plants may find the CO_2 transport component one of the leading issues in their decision making.

4. Results and Discussions

The development and advancements in the technological aspects of Carbon Capture and Storage, promises to play a major role in mitigating the Green House Gas (GHG) emissions. Considering the current Indian geological and socio-economic structure and scenario, CCS seems to have fewer advantages and more limitations. Limited geological storage options and little study about saline aquifers and ocean storage makes the situation a little tricky.

Few concerns rise to the surface when we plan a transition of CCS from being an idea on papers to Indian power plants and industries. To bring a few of these concerns into light, they are the risks related to technological failures, collateral ecological damages, risk of leakages, uncertainty of technology performance, monitoring requirements linked with Clean Development Mechanism (CDM) and non-availability of effective guidance and regulatory tools at national and global levels on affordable terms.

The important thing to keep in mind currently is to take immediate steps. The best example with which its importance can be explained is the saying that, prevention is better than cure. Even if immediate actions are taken, rise in temperature would continue for a few years until the CO_2 balance in the eco-system and the climatic conditions come back to normal.

5. Conclusions

For the development of CCS in India to progress, it is vitally important that surveys of India's deep geology and potential CO_2 storage sites are carried out. A risk assessment of the long term leakage and collateral ecological damage should be carried out alongside testing and taking up projects for assuring the technological reliability and cost efficiency. For example, CO_2 from flue gas of ammonia plant could be captured and stored. This would give the experience necessary for operating CCS systems, and data on the performance and effectiveness of the storage sites that are available. With the help of Clean Development Mechanism (CDM), the future CCS projects should be reviewed and accordingly necessary guidelines should be framed. This would be of great help in monitoring and evaluating the possibilities and limitations linked to these projects. The most important factor would be figuring out a financing system to make emission mitigation a reality. CCS should be viewed as a medium term option in India's GHG emissions reduction strategy as of now because of the above mentioned limitations. Increased use of renewables and energy efficiency are more likely to be effective in the short term.

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7. References

[1] Damodaran H., How India's growth story differs from China's. In: *The Hindu Business Line*, 2011.

[2] NAPCC, *National Action Plan on Climate Change*. Prime Minister's Council on Climate Change, Government of India, 2008.

[3] Oliver JGJ, Janssens-Maenhout G and Peters JAHW, *Trends in global CO2 emissions; Report*. The Hague: PBL Netherlands Environmental Assessment Agency; Ispra: Joint Research Centre, 2012.

[4] Garg, A., M. Kapshe, P.R. Shukla, and D. Ghosh: Large Point Source (LPS) emissions for India: Regional and sectoral analysis. *Atmospheric Environment* 2002, **36**: 213-224.

[5] Holloway S., Garg A., Kapshe M., Singh A. Kumar, Mahmood M. A., Khan S. R., Kirk K. L., Vincent C. J., Williams J. and Gale J., *GIS as a Tool for Mapping CO2 Sources and Storage Sites, in Carbon Capture and Storage: R&D Technology for Sustainable Energy Future*, Eds. Malti Goel, B. Kumar and S. N. Charan, Narosa Publishing House, Delhi, 2008:97.

[6] Energy Technology Analysis, *CO2 Capture and Storage, A key carbon abatement option*. International Energy Agency (IEA), 2008.

[7] IPCC: IPCC Special Report on Carbon Dioxide Capture and Storage. *Prepared by Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge University Press, 2005: 106-109.

[8] Kohl, A.O. and R.B. Nielsen: *Gas purification*, Gulf Publishing Co., Houston, TX, USA, 1997.

[9] Chakma, A., P. Tontiwachwuthikul, Designer Solvents for Energy Efficient CO2 Separation from Flue Gas Streams. *Greenhouse Gas Control Technologies*. Riemer, P., B. Eliasson, A. Wokaun (eds.), Elsevier Science, Ltd., United Kingdom, 1999: 35-42.

[10] Herzog, H.J., Public Understanding for CO2 Sequestration – A multinational Comparison, *International Workshop on CO2 Geological Storage*, Japan, 2006.

[11] Bachu, S., Screening and ranking of sedimentary basins for sequestration of CO2 in geological media in response to climate change, *Environmental Geology* 2003, **44**: 277-289.

[12] Bradshaw, J., Bradshaw, B.E., Allinson, G., Rigg, A.J., Nguyen, V., Spencer, L., The potential for geological sequestration of CO2 in Australia: preliminary findings and implications for new gas field discovery, *APPEA Journal* 2002: 25-46.

[13] Shi, J-Q., S. Durucan, 2005: A numerical simulation study of the Allison Unit CO2-ECBM pilot: the effect of matrix shrinkage and swelling on ECBM production and CO2 injectivity. *Proceedings of the 7th International Conference on Greenhouse Gas Control Technologies (GHGT-7)*, Vancouver, Canada, vol. I, 2004: 431-442.

[14] Lindeberg, E. and P. Bergmo, 2003: The long-term fate of CO2 injected into an aquifer. *Proceedings of the 6th International Conference on Greenhouse Gas Control Technologies (GHGT-6)*, J. Gale and Y. Kaya (eds.), Kyoto, Japan, Pergamon, vol. I, 2002: 489–494.

[15] Loken, K.P., and T. Austvik, 1993: Deposition of CO2 on the seabed in the form of hydrates, Part-II. *Energy Conversion and Management* 1993, **34**(9-11): 1081-1087.