WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 8.074
Volume 7, Issue 16, 189-202. Review Article ISSN 2277– 7105

CARBON SEQUESTRATION: A SOLUTION TO GLOBAL PROBLEM

Arushi Saxena and Pammi Gauba*

Department of Biotechnology, Jaypee Institute of Information Technology, A-10, Sector-62, Noida, Uttar Pradesh-201307.

Article Received on
12 July 2018,
Revised on 01 August 2018,
Accepted on 22 August 2018
DOI: 10.20959/wjpr201816-13117

***Corresponding Author**
Dr. Pammi Gauba
Department of Biotechnology, Jaypee Institute of Information Technology, A-10, Sector-62, Noida, Uttar Pradesh-201307.

ABSTRACT

Over the last 30 years there is a drastic increase of CO2 emission due to the combustion of fossil fuel and it is causing a major change in the environment such as global warming. It is assumed that this major change is accountable for the rise in global temperature resulting in glacial melting, rise in sea levels and ocean acidification. The various different energy sources are not sufficient to meet the values of the emission reduction and the climate change demands the emission reduction, the CCS technology can be used as a tool which can help in somehow decreasing the CO2 emission. In this technology, waste carbon dioxide is captured from large point sources such as fossil fuel stations, preventing it's release into the atmosphere. Basically, it involves three main stages in the CCS chain: Carbon reduction technologies, transport and storage. Primarily there are three classes of target reservoirs which are capable of sequestering large volumes of CO2: Saline formations, Depleted oil and gas fields and Deep coal seams. IPCC has given the approval to the technology and also it provides a way as a mitigation option for developing countries like India and has already been mitigated as an option for developed countries like America. Currently India has targeted 20% reduction in CO2 emissions by 2020. Progress of sequestration technology would surely assure ample, low-cost energy for the century, giving better alternatives. The aim is to study the processes involved in sequestering the carbon deeply and also to explore various carbon mitigation, sequestration technologies and potential in Indian context.

KEYWORDS: Acidification, Carbon Sequestration, IPCC, mitigation, Saline formations.

1. INTRODUCTION

Human and industrial development over the past years has resulted in a significant increase in fossil fuel consumption and CO2 emissions, causing a dramatic increase in the atmospheric CO2 concentration.[1] This increased CO2 is responsible for a momentous rise in global temperature over the past several years. If the temperature increase continues for the next few decades; may lead to glacial melting, rising sea levels, and ocean acidification. Large-scale sequestration of CO2 from the atmosphere is the pre-eminent panacea for the subsequent reduction of global warming.

Carbon dioxide sequestration has emerged as one of the key technology pathways for the reduction of greenhouse gases (GHG). Basically, Carbon Sequestration is the process of storing the atmospheric carbon dioxide removed from the atmosphere or before it enters the atmosphere.

There are two parts of Carbon sequestration: carbon capture and storage (Fig.1). Carbon capture involves the capturing of large quantities of carbon dioxide and finding a safe, secure and cheap place to effectively store the captured CO2. It is one of the most effective and promising ways to reduce the effect of global warming.[1]

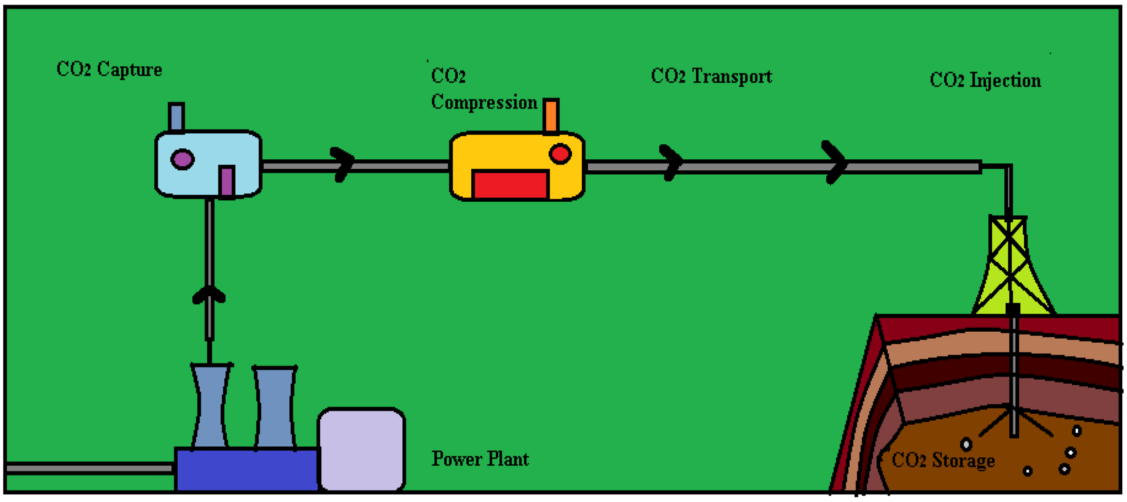


Fig 1: Carbon Capture and Storage (Basic technology involved in the process of carbon sequestration).

2. MEASUREMENT OF CO2 EMISSION

The net measurement of CO2 emission can be done by the help of Kaya's Equation which is

Net C = P×GDP/P×E/GDP×C/E-S(1)

In the above equation,[2]

P = is the population

GDP/P = is the gross domestic product per capita

E/GDP = is the energy generation per unit GDP

C/E = is the carbon intensity for the energy generation

S = is the sinking rate of carbon.

In order to examine the depletion measures for carbon emission, the last three terms, ***E/GDP***, ***C/E*** and ***S*** should be considered. The emission reduction possibilities can be classified into three groups accordingly,[2]

1. Reduction in the energy intensity (minimize the term, *E/GDP*).
2. Reduction in the carbon intensity for power generation (minimize the term, *C/E*).
3. Enhancement of the removal or sequestration rate of CO2 from the atmosphere (maximize the term, *S*).

- **REDUCTION IN THE ENERGY INTENSITY**

Reduction in the energy intensity involves an improvement in energy efficiency by the expansion of energy-saving devices and methodologies.

- **REDUCTION IN THE CARBON INTENSITY FOR POWER GENERATION**

Reduction in the carbon intensity for power generation means the reduction in the carbon dioxide emission per unit power generation. Use of fuel cells is included in this category due to their higher efficiencies.[2] This reduction can also be performed by switching energy resources from fossil fuels to renewable energy resources such as solar energy, wind power or biomass.

The above mentioned two categories are not - regret options because they have benefits not only in terms of alleviating global warming but also in terms of establishing a more sustainable society.

- **ENHANCEMENT OF THE REMOVAL OR SEQUESTRATION RATE OF CO2 FROM ATMOSPHERE**

In this third category further, two types of mitigation options are included; the enhancement of the natural sinking process and the direct discharge of CO2 into the ocean or underground.

3. Mitigation Potential of CO2 Emissions by Reduction of Energy and Carbon Intensity

In these, reductions amounts could be realized by improving the energy efficiency of appliances and equipment including windows, lighting, insulation, space heating, refrigeration and air conditioning. The development of building controls, passive solar design, integrated building design, and the application of photovoltaic systems are accounted for in the above potential reduction amount. In the transportation sector; the expansion of gasoline–electric hybrid vehicles, the expansion of fuel cell powered vehicles, as well as improvements in the fuel efficiencies of conventional engines. In the industrial sector; the improvement of the energy efficiency of industrial processes and the improvement of the material efficiency.[2]

4. General Aspects of the CO2 Sequestration Process

The carbon dioxide sequestration options are divided into two groups.

- CO2 fixation by the enhancement of natural sinking processes of CO2.
- Direct CO2 sequestration by artificial processes.

In the natural sinking processes of CO2, the formation of fossil fuels by photosynthesis and rock weathering.

In the direct sequestration options, CO2 produced from large point sources such as thermal power plants or the steel or cement industries, would be captured from the exhausted gases, and transported to an appropriate site, either in the ocean or underground, to be injected and sequestered in the form of CO2.

The viable sequestration options should have the following characteristics.[3]

1. A net reduction of CO2 emission.
2. Large potential capacity for CO2 sequestration.
3. Modest cost and energy penalty.
4. Long-term isolation of CO2.
5. Minimal environmental impact.

5. CO2 Sequestration Options by Natural Sinking Processes

The sequestration process by increasing such a sinking process could be realized by the enhancement of the net carbon flux to the ocean bottom in the form of organic matter produced by phytoplankton. Appropriate fertilization of limiting nutrients such as nitrogen, phosphate, silicate, and iron would stimulate an increase in the descending carbon flux to the deep ocean. Considering the transport of products in the coral reef to the deep ocean, the coral reef could contribute to the carbon sinking process.

6. Sequestration by Direct CO2 Injection

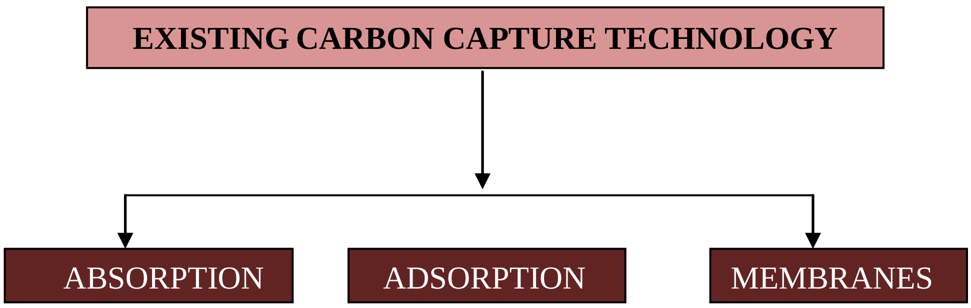
The main strategy in the direct sequestration options is,

1. Capture and separation of CO2 from point sources such as thermal power plants, the steel industry, and the cement industry.
2. Transportation of the captured CO2 to the disposal sites after proper treatment.
3. Injection of CO2 into the disposal site; either the ocean or underground

6.1 CO2 Capture and separation

CO2 is captured and separated from the flue gases before direct sequestration. The pre-combustion capture of CO2 would be conducted for the IGCC[2], where the fuels would be converted to CO2 and hydrogen with the help of shift reaction before combustion. It has been observed that the large energy consumption will naturally make the capture and the separation technique the highest cost sector in the process. By improving the capture and separation process the direct injection options become feasible. There are many numbers of existing capturing techniques[4] for CO2 (Fig.2), for example.

- Absorption/stripping
- Adsorption/desorption
- Membrane separation



1. Amines 1. Metal Organics 1. Fibres
2. Carbonates 2. Zeolites 2. Microporous
3. Ammonia
4. Hydroxide
5. Limestone

Fig.2. Representation of the existing carbon capture technology.

1. Absorption/stripping Process

In this process amine solution such as monoethanolamine (MEA), is a commercialized proven technique of CO2 capture. It is known as the most energy- saving and lowest cost processes. The CO2 recovery rate is 98% for MEA.[2]

2. Adsorption/desorption Process

In this process usage of porous solid adsorbents such as zeolites and activated carbon, and no reaction between the adsorbent and CO2 will occur during the separation process. The pressure swing adsorption (PSA) process is commonly used for the separation of CO2.

3. Membrane separation process

This process has an advantage over rest of other processes in terms of continuous and one stage separation processes. Membranes with high selectivity for CO2, over oxygen or nitrogen, have been developed. Porous membranes with supporting amine solutions are effective for the selective separation of CO2.

6.1.1 Other various options for CO2 capture

- Pre-combustion capture

It is the process for the treatment of synthesis gas (syngas)[4] which is composed of CO and hydrogen. Basically, in this method, the coal is gasified to produce a synthetic gas which is made from carbon monoxide and hydrogen. Later, the former is reacted with water to produce CO2, which is captured. The hydrogen is diverted to a turbine where it can be burned to produce electricity (Fig.3).

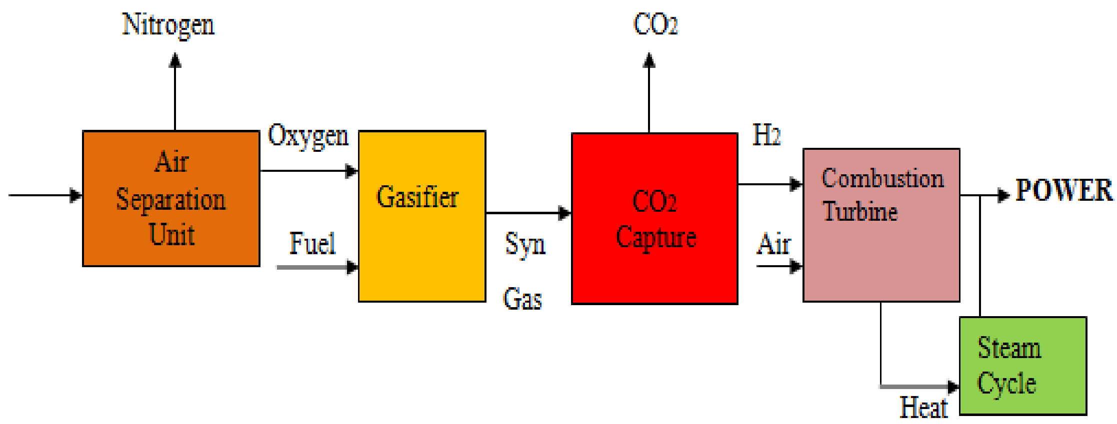


Fig 3: Representation of the basic principle involved in Pre-combustion CO2 capture.

- Post-combustion capture

It is the process which involves removal of CO2 from flue gas, which comes from the thermal power plant combustion chamber. It is done by bubbling the gas through an absorber column packed with liquid solvents that preferentially take out the CO2. It appears likely to give lower total electricity costs than pre-combustion capture for natural gas plants (Fig.4).[5]

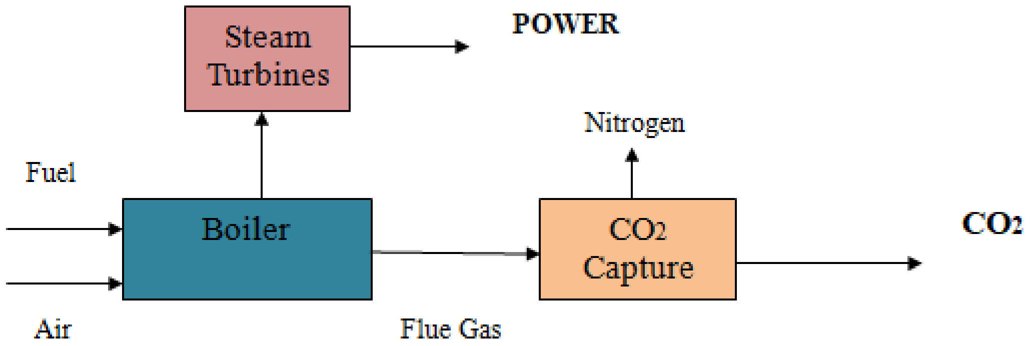


Fig 4: Representation of the basic principle involved in Post-combustion CO2 capture.

- Oxyfuel

This combustion is an assuring technology for capturing the CO2 from fuel gas or to modify the combustion process so that the flue gas has a high concentration of CO2 for easy separation. In this process, fuel is burned in a combustion chamber in the environment of pure O2 (Fig.5).

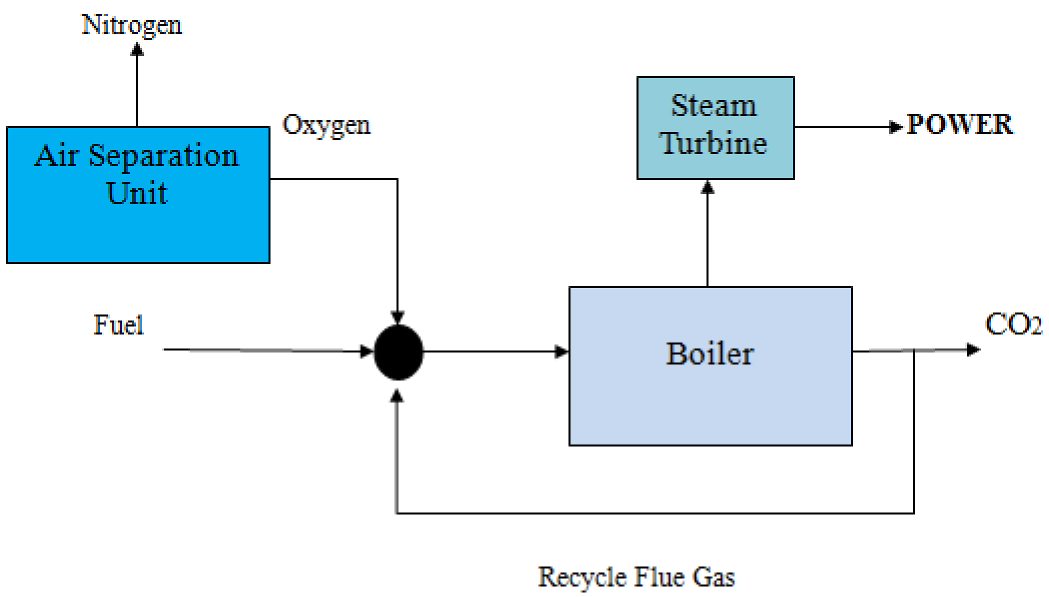


Fig. 5: Representation the basic principle involved in Oxyfuel combustion CO2 capture.

6.2. Ocean Sequestration

Marchetti *et al.*, 1977[6] was the one who proposed the concept of ocean sequestration in the early 1970's. The main purpose is to enhance such a transport process of CO2 into the deep ocean by pumping it down directly. The major worry about ocean sequestration research activities are.

1. The development of effective CO2 pumping methods.
2. Accurate prediction of the fate of the sequestered CO2 (including impact assessment on the marine ecosystem).

There are several options for pumping CO2 that can be categorized in terms of the form of the CO2 upon discharge: gaseous, liquid, solid and hydrate.

In the sequestration option of liquid CO2, The discharge of liquid CO2 into the ocean at depths of greater than 500nm. The gaseous CO2 after capturing is liquefied under high pressure and low temperature conditions. Then the transfer of liquid CO2 into the ocean is done. There are two types of sequestration options for liquid CO2 sequestration depending on the discharge depth, dissolution at an intermediate depth (500-1500m) and the storage of liquid CO2 in the deep ocean (> 3000m).

The major concerns that have been raised in these studies are.

- The hydrodynamic behaviour of liquid CO2 upon injection (~ 1m scale)
- The fate of the liquid CO2 drops in the ocean
- Prediction of the large–scale behaviour of dissolved CO2
- Estimation of the biological impact due to decreases in pH as a result of CO2 dissolution in the seawater.

6.3. Underground Sequestration

In the underground sequestration, the captured CO2 from the flue gas is injected into the sedimentary rocks. This option is considered more technically feasible than the ocean sequestration option because the underground CO2 injection process has a value-added benefit i.e. EOR (Enhanced Oil Recovery). The advantages of the underground sequestration options are.

- The technique of the injection process into the ground has already been established in EOR or CO2 injection into natural gas fields.

- There is a huge capacity of potential sequestration sites, which are more easily accessible than the deep ocean.
- The biological phases underground are much less complicated than that of the ocean.

6.4. Mineral Carbonation

Carbonation is the reaction between a metal oxide bearing material and CO2 and can be expressed by the following reaction.

MO + CO2 ↔ MCO3 + heat (2)

Here M is the (metallic) element such as calcium, magnesium or iron. The above reaction is exothermic and the heat released is dependent on the metallic element bearing mineral.

In situ mineral carbonation is closely connected to the underground storage option as it involves the injection of CO2 into underground reservoirs. The basic difference is that in situ mineral carbonation aims at producing a reaction with the CO2 to form carbonates with alkaline-minerals present in the geological formation.[7]

Major benefits of mineral carbonation are as follows.

1. It is the environmental friendly and virtually permanent trapping of CO2 in the form of carbonated minerals by using abundant mineral resources such as Mg-silicates.
2. It provides a leakage-free long term sequestration option, without a need for post storage surveillance and monitoring once the CO2 has been fixed. (In one of the recent study, Teir et al.[8] investigated the stability of calcium and magnesium carbonate when subjected to an acidic aqueous environment. The conclusion of the study was that Ca/Mg carbonates should be resistant enough to prevent local environmental effects at a mineral carbonate storage site).
3. This is the only CO2 sequestration option available where large underground reservoirs do not exist and ocean storage of CO2 is not feasible, e.g. Finland and Korea.
4. Another benefit of mineral carbonation is that, the carbonation process could proceed without energy input, but this has not yet been accomplished but is proved theoretically.

7. INDIA CCS: A CASE STUDY

India’s total GHG emissions in 2007, with the involvement of land use, land-use change, and forestry (LULUCF), were 1727.71 million tonnes of CO2 equivalent, and gross CO2 emissions were 1497.03 million tonnes. The CO2 generation per capita was 1.3 tonnes/capita when not considering LULUCF.[9]

It is estimated that around 66% of India's gross CO2 emissions came from the energy sector in 2007, with electricity generation alone computing roughly 48% of the gross emissions.[9] The industrial sector accounted for most of the remaining CO2 emissions, with 27% of the total emissions (Fig.6).

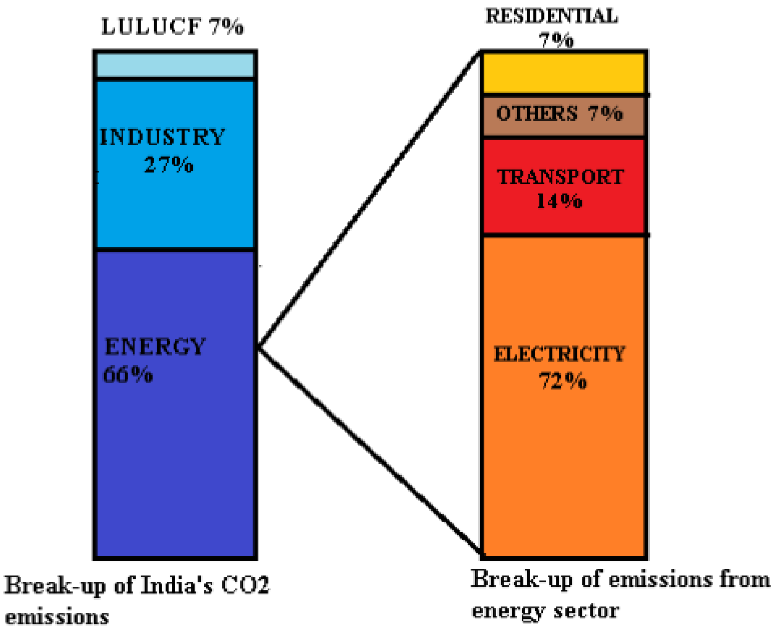


Fig. 6: Representation of the break-up of India's CO2 emissions and of emissions from the energy sector.

According to India's Integrated Energy Policy, India's CO2 generation in 2031-32 is expected to be in the range of 3.9 and 5.5 billion tonnes, depending on India's economic growth, energy and carbon intensity of the economy, the share of renewable in India's energy mix, and other factors.

7.1 CURRENT CCS ACTIVITY

Most Research and Development (R&D) activities related to CCS occur under the Department of Science and Technology (DST) of the Indian Ministry of Science and Technology. A list of few projects significant to CCS approved by the Inter-Sectoral Science & Technology Advisory Committee (IS-STAC) of the DST is shown below in Table 1.

Table 1: List of DST projects related to CCS (References from [10] to [14])

S.NO.	Project title	Organisation	Year approved	Duration (years)
1.	Modelling and simulation of Carbon Recycling Technology through conversion of CO_2 into useful multi-purpose fuel	Rajiv Gandhi Technological University, Bhopal	2007-08	3
2.	Sequestration of carbon dioxide (CO_2) into a geological environment (Gas Hydrate): Laboratory Studies	National Geophysical Research Institute (NGRI), Hyderabad	2007-08	3
3.	Carbon Dioxide Sequestration through Culture of Medically useful Micro-algae in Photo-bio-reactor linked to Gas Outlets of Industries	Department of Botany, Andhra University, Vishakhapatnam	2008-09	3
4.	CO_2 Sequestration using Micro algae- Efficient use of CO_2 from Bio-hydrogen production facility	AMM Murugappa Chettiar Research Centre, Chennai	2008-09	3
5.	Mechanism and the dynamic of carbon storage in the Sundarban Mangrove	University of Calcutta, Kolkata	2009-10	3
6.	Marine cyanobacteria a promising candidate for carbon-dioxide sequestration with multiple utilization	Bharathidasan University, Tiruchirappalli	2009-10	3
7.	Development of screening criteria for saline aquifers and other geological sinks	Global Hydro geological Solutions, New Delhi	2010-11	3
8.	Carbon sequestration by mineral carbonation in cement kiln dust	Indian Institute of Technology, New Delhi	2010-11	3
9.	CO_2 sequestration studies on the volcano-sedimentary succession of the eastern Deccan volcanic province	University of Delhi, Delhi	2011-12	3
10.	Mineral CO_2 sequestration by carbonation of industrial; Alkaline solid residues	Anna University, Chennai	2011-12	3

7.2 CAPACITY ESTIMATION

India's position in GCCSI CCS Development Lifecycle.

There is a tool named as the CCS Development Lifecycle developed by the Global CCS Institute which helps in the locating the country's present position with respect to CCS development. It has been recognised that a country may operate simultaneously in multiple parts of the lifecycle, because different aspects related to CCS may develop to different extents at different rates[9] (Fig.7).

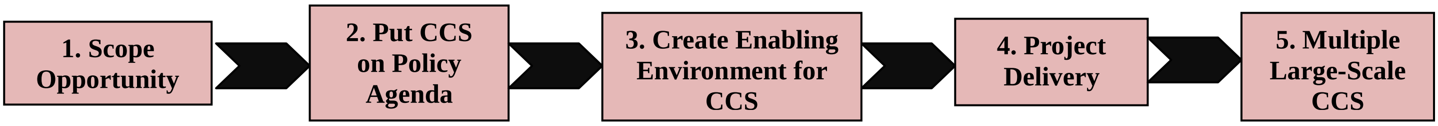


Fig 7: Representation of the Global CCS Institute CCS development lifecycle.

It has been observed that India lies mostly in Stage1 since the potential of CCS as a method for emissions reduction in India is fairly well known. There are elements of Stage 2 - putting CCS on policy agenda - being undertaken. For instance, there is some awareness within policymakers of CCS, and good awareness of the technology as a mitigation option within an industry. There are forums where governments and business leaders are discussing the potential of CCS for India.

8. OBSTACLE TO CCS APPLICATION IN INDIA

The following are the principal barriers to CCS deployment in India.

- One major barrier to CCS deployment in India is the lack of accurate geological storage site data since before capture technology can be installed in power plants or other sources, the location, capacity, permeability, and other characteristics of the sinks must be known.[9]
- The issue of CCS drastically increasing the cost of electricity while reducing net power output is often cited as being one of the biggest barriers to the acceptability of CCS in India.
- Deployment of CCS on a large scale requires specialized manpower and suitable infrastructure, which may not be available in India at present.
- Legal issues related to the land acquisition; groundwater contamination, CO2 leakage, etc. need to be addressed before any large-scale transport and storage of CO2 can be permitted.[15]
- Monitoring the stored CO2 to assure against leakage is essential if the central purpose of CCS implementation is to be fulfilled. Ensuring rigorous monitoring is needed over long time scales and techniques developed internationally in this area need to be introduced to Indian stakeholders.

9. CONCLUSION

Today's urgent need for substantive CO2 emissions reductions could be satisfied more cheaply by available sequestration technology. Carbon Sequestration in forests soils has a potential to decrease the rate of enrichment of atmospheric concentrations of CO2. Geological carbon storage appears to be a safe, effective means of achieving reduction of atmospheric carbon dioxide emissions while maintaining the benefits of fossil fuel use. All existing technologies have their own advantages and limitations but their reliability, stability and removal efficiency are main challenges. There is a great need for understanding the existing technology to improve the performance and reduce the cost and energy required for CO2 separation. Further development of sequestration would assure plentiful, low-cost energy for the century, giving better alternatives ample time to mature.

10. ACKNOWLEDGEMENT

I would like to show my gratitude to the department of biotechnology of my Institute for sharing their truthful & illuminating views on a number of issues, their helpful guidance, supervision, useful suggestions that helped me to overcome the difficulties during the completion of this paper.

I would also like to use this opportunity to convey my thanks to everyone who supported me all through this review paper. I am grateful for their aspiring guidance, invaluably constructive criticism and friendly advice.

11. REFERENCES

1. Eric H. Oelkers and David R. Cole. "Carbon Dioxide Sequestration: Solution to a Global Problem", 2008; 305-310.
2. Yamasaki A," An overview of CO2 Mitigation Options for Global Warming – Emphasizing CO2 Sequestration Options", Journal of Chemical Engineering of Japan, 2003; 361-375.
3. Lackner K S, "A Guide to CO2 Sequestration", Department of Earth and Environmental Engineering, 2003; 300.
4. Mondal MK, Balsora HK, Varshney P "Progress and trends in CO2 capture/separation technologies: A review", Department of Chemical Engineering and Technology, 2012; 431-441.
5. Patware P, Thakur G, Rawat P, Sudhakar K, "A Roadmap For" Carbon Capture And Sequestration' In The Indian Context: A Critical Review", Department of Energy, MANIT, 2013.
6. Marchetti, C., "On Geoengineering and the CO2 problem", Climate Change, 1977; 59-68.

7. Sipilä J, Sebastian T, Zevenhoven R,” Carbon dioxide sequestration by mineral carbonation Literature review update 2005-2007”, Åbo Akademi University Faculty of Heat Engineering Laboratory, Helsinki University of Technology, Laboratory of Energy Engineering and Environmental Protection, 2008.
8. Teir, S., Eloneva, S., Fogelholm, C.-J., Zevenhoven, R.,” Stability of calcium Carbonate and magnesium carbonate in rainwater and nitric acid solutions”, Energy Conversion and Management, 2006; 3059-3068.
9. TERI, “India CCS Scoping Study: Final Report”, The Energy and Resources Institute, 2013; 42.
10. Inter-Sectoral Science & Technology Advisory Committee, Department of Science and Technology, Government of India. Inter-Sectoral Science & Technology Advisory Committee Project List (2007-08). Available at: <http://www.dst.gov.in/scientific-programme/projectlist/2007-08/is-stac-07-08.pdf>.
11. Inter-Sectoral Science & Technology Advisory Committee, Department of Science and Technology, Government of India. STAC/IS-STAC & PROBE Pilot Program Project List 2008-09. Available at: <http://www.dst.gov.in/scientific-programme/projectlist/2008-09/isstac08-09.pdf>.
12. Inter-Sectoral Science & Technology Advisory Committee, Department of Science and Technology, Government of India. IS-STAC Projects Funded 2009-10. Available at: <http://www.dst.gov.in/scientific-programme/projectlist/2009-10/isstac09-10.pdf>.
13. Inter-Sectoral Science & Technology Advisory Committee, Department of Science and Technology, Government of India. IS-STAC Projects Funded 2010-11. Available at: <http://www.dst.gov.in/scientific-programme/projectlist/2010-11/isstac10-11.pdf>.
14. Inter-Sectoral Science & Technology Advisory Committee, Department of Science and Technology, Government of India. IS-STAC Projects Funded 2011-12. Available at: <http://www.dst.gov.in/scientific-programme/projectlist/2011-12/isstac11-12.pdf>.
15. Frledmann S. J.,” Geological Carbon Dioxide Sequestration”, Carbon Management Program, Lawrence Livermore National Laboratory, 2007.