Carbon Capture & Storage: Limiting Emissions at the Source

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Abstract

The aim of this paper is to shed light on the technology-‘ Carbon Capture and Storage(CCS) ‘ and discuss about its various aspects. It emphasises on the need for commercially up scaling this technology. It includes details about the different combustion techniques to separate out carbon dioxide from a mixture of gases, namely: 1) Pre Combustion, 2) Oxy-fuel Combustion and 3) Post Combustion. It gives insight on methods of carbon capture currently in use and the ones that may be used in the future. It further explores how and where the captured carbon dioxide can be stored.

Keywords: *Carbon Capture, Storage, Combustion, Climate Change*

Introduction

The biggest challengethat faces all the nations todayat large is undoubtedly Climate change. Billions of tonnes of CO_2which is released primarily by sources such as exhaust systems of industries worldwide and burning of fuel in engines of automobiles end up into the atmosphere. The fact that CO_2 can be absorbed by the trees and oceans brings much relief, at the same time evidence that the amount absorbed is just a fraction of the total emissions causes greater concern. Resultantly, billions of tonnes of CO_2 emitted each year still keeps on adding up – to the atmospheric concentrations as well as to the problem. It is no hidden fact that CO_2 being a major pollutant and greenhouse gas, has a significant share in contributing to rise in global temperatures or Global warming. To address this issue, nations came together for the Paris Agreement, 2015and pledged to take action to realise the goal of keeping the global temperatures within the 2°C limit. There is a lot of effort going on which can be seen in the form of the development in the field of renewable energy. However going by the statistics, renewable energy constitutes only 15-20 % of the total electricity generation worldwide while fossil fuels are at the upfront with a share of a startling 65%. What we can directly infer from this is that while efforts to incorporate renewable energy are appreciated, they are not sufficient. Until and unless there is ‘decarbonisation of the industrial sector’ the possibility of turning our major goals into a reality is far-fetched. What is required is a game changing technology to come to the rescue and aid in cutting emissions from the massive polluters –the fossil fuel powered plants.

Carbon Capture and Storage (CCS) - is exactly what needs to be done here, at this moment. The fossil fuels are burnt to boil water and generate steam which is subsequently used to run the turbines and generate electricity. In the process, enormous amounts of flue gases are also produced, CO_2 being an indispensable component, most of which finds no other escape except the atmosphere.

Needless to say there is an urgent need to bring CCS into effect as soon as possible. The hurdles that are being faced can be overcome by Research and Development which is going on to make CCS viable. The sooner we are able to put it into wide use, the more secure will our future be in the wake of a rising global urgency.

What is CCS?

Carbon Capture and Storage (CCS) is the process of trapping the CO_2 emitted from point sources like power plants that run on fossil fuels, and transporting it via pipelines to storage sites where they can remain for prolonged periods of time without causing any significant harm to the environment or living beings. In this way the CO_2,which would otherwise pose a multitude of environmental and health hazards by entering into the air, can stay deep under the earth'ssurface and also benefit like in Enhanced Oil Recovery (EOR) discussed later.

The three main components of CCS are:-

1. **Capture**

The separation of CO_2 from other gases by use of various separation techniques, absorption being currently in use, whilesother techniques still in the course of development.
There are three existing methods of carbon capture:-

I. Pre Combustion process

It is concerned with removing CO_2 in the initial stages of electricity generation.
Incomplete oxidation of the fuel, in this case coal, takes place resulting in formation of CO and H_2O. Further,water is allowed to come in contact with the syngas($CO+H_2$) which leads to oxidation of CO to CO_2. The CO_2 is removed and H_2 is used to run turbines for hydro power generation.

II. Oxy- fuel Combustion process

This process focuses on using pure oxygen in place of air for combustion. Now, in case of combustion in presence of air, the resultant flue gas also contains a major fraction of nitrogen. Separating CO_2 from the effluent gases requires quite a lot of energy . Hence, to make the separation step energy efficient, pureO_2 from the Air Separation Unit (ASU) is used for combustion and the reaction of hydrocarbons in fuel with O_2 leads to a two component mixture containing CO_2 and H_2O which can easily be separated using compression and cooling. The process is comparatively cleaner and gives a product gas stream that is exclusively CO_2.

III. Post Combustion process

It refers to separation of CO_2 from the flue gas. This is done by using the process of absorption in which a suitable solvent selectively absorbs CO_2 from the mixture in an exothermic reaction. The solvent containing CO_2 is then sent to the regenerator where it is heated to approximately 160°C so that a reverse endothermic reaction takes place and the bonds holding the solvent and CO_2 together finally break. The CO_2 is further processed and sent to storage while the solvent is cooled and sent to the absorption tower to be reused.

The choice of solvent depends on two major factors:-

1) Capacity - amount of gas that can be absorbed per unit mass of solvent
2) Energy efficiency- amount of energy required for separation of gas from solvent

Currently, thesolvent that's widely in use for carbon capture is Monoethanolamine (MEA) - the most suitable option on the basis of the above mentioned factors. However, the post carbon capture requires high costs for installation as well as operation. For instance, due to the corrosive power of the absorbents, the regenerators need to be made out of high quality materials for corrosion resistance.

At the same time, an estimated 20-25% of the plant's energy generation has to be diverted to the carbon capture unit to carry out the various processes involved, including solvent recovery.

In today's scenario, Capital cost and Energy requirements are the major factors inhibiting the commercial set up of CCS plants. However, these can be overcome through consistent research which is already happening in the following fields:-

a. **Use of better materials:**
    1) Metal Organic Frameworks(MOFs): They are porous nanomaterials which have very high absorption capacities due to extraordinarily large internal surface area of pores.
    2) Crystals: Made up of copper silicate named as SGU-29, they have affinity for both CO_2 and water just that both are adsorbed at different sites in the crystal. They are useful for adsorption in presence of water.

b. **Use of better solvents:**various solvents are being tested for their capability of absorption like potassium carbonate and chilled ammonia.

c. **Use of alternate processes:**

1) Adsorption: Use of substances like Activated Carbon to adsorbCO_2 on the outer surface

2) Membrane separation:Using the pressure difference across synthetic membranefor movement of components

3) Cryogenic distillation: Cooling the mixture that leads to solidification of CO_2 and subsequent compression and removal

The biggest advantage of Post Capture technique as compared to Pre Capture and Oxy-fuel combustion is the ease with which the carbon capture unit can be retrofitted within an operational power plant, pointing to the tendency of adoption in power plants worldwide.

2. Transport

Post capture, the CO_2 is transported to suitable storage sites using pipelines that can stretch up to hundreds of kilometres. The CO_2 is then injected to the exact location i.e. the coal seams etc. or more beneficially, utilised to extract oil from close to depletion oil reserves in what is known as Enhanced Oil Recovery.

3. Storage

This is the final step in the entire carbon capture process. There are various factors that need to be considered before selection of a suitable site as well as the post selection and storage. An ideal site should be safe and at minimum risk of possible seismic activities to avoid any major catastrophe. Once it is ensured, the next step is to constantly keep a close watch on the CO_2 contained by the sites. This is done by using monitoring techniques like Seismic monitoring, Surface monitoring, Sub-surface monitoring, etc. This is essential so that any unforeseen leakage can be detected and requisite action can be taken to avoid CO_2 from escaping into the atmosphere and posing any major threat.

Various storage sites have been identified as potent for carbon storage:

1) Non-functional Oil and Gas fields

The reserves which are no longer capable of fossil fuel extraction and are lying useless can be put to use by functioning as storage sites. The CO_2 is injected using wells deep within the earth, below impermeable rocks so that it can stay there for as long as possible, more than hundreds of years. This is very similar to the natural way in which fossil fuels or stored inside the earth and its possibilities have been well explored and are also being exploited currently.

2) Coal seams

The coal seams that have run out of their potential and are no longer of economic use can be used for this purpose. The CO_2 that is injected diffuses onto the surface of coal by the process of adsorption.

3) Saline aquifers

The deep occurrences of saline water can prove to be of enormous capacity in terms of containing CO_2. When CO_2 is injected at such great depths, the specific gravity assumes smaller values. The difference in densities of CO_2 and aquifer makes CO_2 rise under the force of buoyancy. This requires a trap which can prevent CO_2 from escaping.

Naturally occurring formations can serve this purpose for example, Impermeable rocks that can seal the CO_2 permanently (Structural trapping).

Due to motion within the reservoir, some fraction of the CO_2 may also get trapped within the soil where it becomes locked forever (Residual trapping)

Prolonged existence of CO_2 in the aquifer can lead to its dissolution with the aquifer brine (Solubility trapping)

If the CO_2 is trapped for sufficiently great time periods like centuries, the consequence maybe the conversion of the gas into carbonates, on reaction with the minerals present in the brine. These carbonates may become one with the rock assuming permanent forms.

Another Alternative: Enhanced Oil Recovery

It is a method of increasing the field's productivity by using secondary techniques like Thermalinjection, Chemical injection or Gas injection. The latter is where CO_2captured from power plants is being put into use currently. When CO_2 is injected into the reserve, it pushes the oil upwards. Also, it may help decrease the viscosity of the oil by diffusing in it, which automatically lends the oil greater fluidity, enabling smooth extraction. Most of the CCS plants installed across the globe are using CO_2 for this purpose effectively.

Conclusion

As is completely evident from the vast knowledge and information about Carbon Capture and Storage, ranging from the solvents and processes to possibilities of storage, the world is well versed with what the technology is all about and how it can be employed. Certainly, there are no speculations needed still to decide if the technology has something significant to offer. CCS has enormous potential to prove itself as a promising technology. It is not novel but has been there for decades, only that no significant steps have been taken to adopt these technologies worldwide which may be due to the barriers that come in the way. According to the International Energy Agency (IEA), to realise the Paris Agreement goals, an estimated number of 3000 CCS plants will be required to be fully operational by 2050. However, the current status is only 22 plants have been set up, by far all across the globe, more than half of which are in the United States, none in India. CCS is indisputably the ultimate requirement and necessity if the Climate Change goals, more specifically a reduction of almost 50-80% in current global emissions are to be achieved by 2050. Without CCS, the cost of meeting global targets will increase manifold. Going by the statistics of plants in function, 1 million tons of industrial CO_2 emissions from a power plant can be scraped off the atmosphere by implementing CCS on commercial scale. The barriers stated can be overcome by the gifts of Research and Development. Evidence shows how it has opened up passages for CCS to become a reality. The Boundary Dam in Canada has proved to be the first commercial up scaling of CCS by using the Post Combustion Capture technologies in 2014. Tracing steps back to our own nation, Tuticorin thermal power station in Southern India has succeeded in turning the CO_2 emitted from its boiler into Baking soda- in what is seen as a magnificent example of Carbon Capture and Utilisation. As is truly said,"Necessity is the mother of invention"- in the wake of the obligation to meet global targets, development will increase in the upcoming scenario and more promising technologies like CCS will be a part of the world force battling grave issues like Climate Change.

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