

INTRODUCTION TO CARBON CAPTURE AND STORAGE TECHNOLOGY Integrated Research and Action for Development (IRADe) New Delhi

There have been concerns about climate change due to increase in concentration of green-house gases (mainly CO₂, CH₄, and N₂O) in the atmosphere. CO₂ is the most important greenhouse gas, emitted to atmosphere due to combustion of fossil fuel to meet power and energy requirement and is responsible for two-third of greenhouse effect. In the year 2005 the atmospheric concentration of CO₂ was 380 ppm. The current pace of economic growth and concomitant energy consumption will rapidly increase CO₂ concentration in atmosphere. The likely impact of GHG gas at 550 ppm is likely warming of atmosphere by 4.5° C.

The scientific community world-wide is developing process to mitigate the impact of greenhouse gases. Industries are incorporating new technology to make their process more efficient while optimizing energy use, there by reducing CO₂ emission. These efforts will be insufficient, as in future demand of fossil fuels in India will increase rapidly to sustain growing population, higher economic growth, and continued use of carbon based fuel for energy requirement. Carbon capture and storage technology, (CCS) is emerging as a viable alternative. Currently in the development stage, CCS estimated potential to reduce GHG emission is generating Research & Development worldwide.

CO₂ capture and storage (CCS) involves following distinct processes:

- **Capturing** CO₂ from the gas streams emitted from fossil fuel combustion,
- **Transporting** the captured CO₂ to the place of storage.
- **Storing** CO₂ underground in deep saline aquifers, depleted oil and gas reservoirs etc., with monitoring of storage site.

As per IPCC special report on CCS, 2005 there are nearly 8000 large stationary point sources that account for most of the global GHG emissions. Out of these 5000 point sources are in the power sector accounting for 35% of global emissions. Therefore the stationary sources like power plants are good candidates for CCS. The remaining 65% of global emissions are emitted by billions of household small industries and moving vehicles, which are too difficult to capture and monitor. Available technologies in CCS have a potential to capture up to 85-95% of the CO₂ from power plant emissions with 10-40% increase in the consumption of electricity.

The developments in carbon capture technology also incorporate technical improvements to enhance efficiency of power plants. The research in this area has developed innovative schemes. There are three generic process routes for **capturing CO₂** from fossil fuel combustion power plant:

- ♦ Post combustion capture
- ♦ Pre combustion capture
- ♦ Oxy-fuel combustion

Each of these processes involves the separation of CO₂ from a flue gas stream.

Post combustion capture involves the separation of CO₂ from flue gas. The preferred technique at present is to scrub the flue gas with a chemical solvent (usually an amine), which reacts to form a compound with the CO₂. The compound is then heated to release the solvent and high purity CO₂. The flue gas is cooled and treated to remove reactive impurities (e.g. sulphur and nitrogen oxides, particulate material) before scrubbing. Otherwise these impurities will react preferentially with the solvent causing unacceptable rates of solvent consumption and corrosion of the plant.

A significant amount of energy is needed to regenerate the solvent. Energy is also needed to compress the CO₂ for transport, which reduces the net electricity output of the plant. One advantage of the post combustion route is that it can continue to generate electricity if there is a problem with the CO₂ amine unit where as pre-combustion cannot.

Carbon Capture and Storage

Pre combustion capture involves reacting fossil fuel with oxygen or air, and steam, to produce a fuel gas consisting mainly of hydrogen and carbon monoxide. Carbon mono oxide of the fuel gas is then reacted with steam in a catalytic shift converter to produce more hydrogen and CO₂. The CO₂ produced during the process is separated/ captured. The hydrogen rich fuel gas can be used in boilers, gas turbine combined cycle plant. The process can be applied to fossil fuels e.g. natural gas. Oil or coal, but with the latter two fuels additional facilities are needed to remove impurities such as sulphur compounds and particulates. The disadvantage of pre-combustion (Integrated Gasification Combined Cycle) plant has the separation upstream of the rotating power generation equipment so any problems in the upstream “chemical plant” will result in a loss of electrical output.

Oxy-fuel combustion involves burning fuel in an oxygen/ CO₂ mixture rather than air to produce a CO₂ rich flue gas. Generally the oxygen is derived from an air separation unit, and the oxygen/CO₂ mixture is produced by recirculating some flue gas to the combustor. The oxygen/CO₂ mixture is needed to control flame temperature, which would be too high if combustion took place in pure oxygen. Some novel processes seek to avoid the need for an air separation unit, which has a high energy demand. For example chemical looping uses a metal oxidation reaction to separate oxygen, with subsequent reduction of the metal oxide to provide the oxygen needed to burn the fossil fuel. Oxy-fuel combustion can be applied to boilers and gas turbine, although a different design of gas turbine would be needed to work with highly concentrated CO₂ which rules out retrofit to existing GTCC stations.

Oxy-fuel combustion produces a highly CO₂ enrich flue gas that in principle enables simple and low-cost CO₂ purification methods to be used. Also, because combustion occurs in a low nitrogen environment, the formation of nitrogen oxides (NO_x) is greatly reduced. However, it has a disadvantage of having an air separation plant, which is expensive and requires a considerable amount of energy to operate.

These technologies have been in use for decades in various forms but not simultaneously and not on a large scale. CO₂ is injected in the oil and gas fields for enhanced oil recovery Timely research and development efforts would be advantageous in the long run for developing future cost effective technologies.