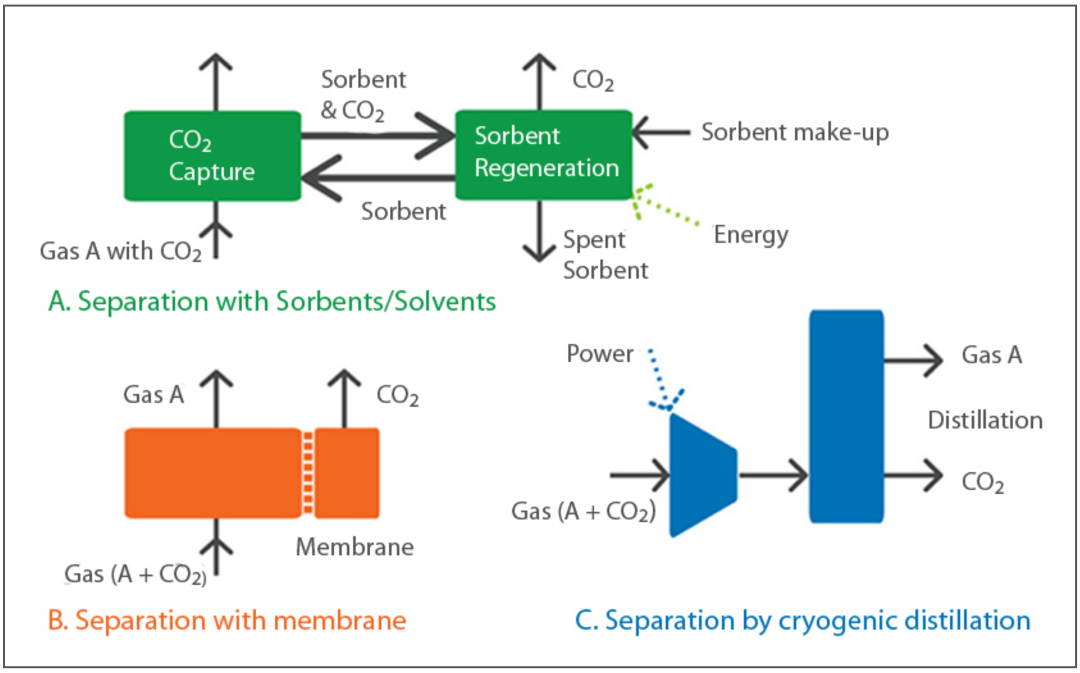
Three basic methods to separate gases



Separation with sorbents/solvents

Solvents

- Amine scrubbing technology was established over 60 years ago in the oil and chemical industries, for removal of hydrogen sulphide and CO_2 from gas streams Commercially, it is the most well established of the techniques available for CO_2 capture although practical experience is mainly in gas streams which are chemically reducing, the opposite of the oxidising environment of a flue gas stream.
- There are several facilities in which amines are used to capture CO_2 from flue gas streams today, one example being the Warrior Run coal fired power station in the USA where 150 t/d of CO_2 is captured.
- Mono-ethanolamine (MEA) is a widely used type of amine for CO_2 capture. CO_2 recovery rates of 98% and product purity in excess of 99% can be achieved. There are, however, questions about its rate of degradation in the oxidising environment of a flue gas and the amount of energy required for regeneration
- Improved solvents could reduce energy requirements by as much as 40% compared to conventional MEA solvents. There is considerable interest in the use of sterically-hindered amines which are claimed to have good absorption and desorption characteristics.
- The conditions for CO_2 separation in pre-combustion capture processes will be quite different from those in post-combustion capture. For example, in a coal IGCC process, modified for capture, the CO_2 concentration would be about 35-40% at a pressure of 20 bar or more. In that case, physical solvents, such as Selexol®, could be used for pre-combustion capture of CO_2, with the advantage that the CO_2 can be released mainly by depressurisation, thereby avoiding the high heat consumption of amine scrubbing processes. However, depressurisation of the solvent still results in a significant energy penalty.

Sorbents

- Solid adsorbents, such as zeolites and activated carbon, can be used to separate CO_2 from gas mixtures. In pressure swing adsorption (PSA), the gas mixture flows through a packed bed of adsorbent at elevated pressure until the concentration of the desired gas approaches equilibrium. The bed is regenerated by reducing the pressure.
- In temperature swing adsorption (TSA), the adsorbent is regenerated by raising its temperature. PSA and TSA are commercially practiced methods of gas separation and are used to some extent in hydrogen production and in removal of CO_2 from natural gas.
- Adsorption is not yet considered attractive for large-scale separation of CO_2 from flue gas because the capacity and CO_2 selectivity of available adsorbents is low. However, it may be successful in combination with another capture technology.

Membranes

- Gas separation membranes allow one component in a gas stream to pass through faster than the others. There are many different types of gas separation membrane, including porous inorganic membranes, palladium membranes, polymeric membranes and zeolites
- Membranes cannot usually achieve high degrees of separation, so multiple stages and/or recycle of one of the streams is necessary. This leads to increased complexity, energy consumption and costs.
- Several membranes with different characteristics may be required to separate high-purity CO_2. Solvent assisted membranes are being developed to combine the best features of membranes and solvent scrubbing. Much development is required before membranes could be used on a large scale for capture in power stations

Cryogenics

- CO_2 can be separated from other gases by cooling and condensation. Cryogenic separation is widely used commercially for streams that already have high CO_2 concentrations (typically >90%) but it is not used for more dilute CO_2 streams.
- A major disadvantage of cryogenic separation of CO_2 is the amount of energy required to provide the refrigeration necessary for the process, particularly for dilute gas streams. Another disadvantage is that some components, such as water, have to be removed before the gas stream is cooled, to avoid blockages.
- Cryogenic separation has the advantage that it enables direct production of liquid CO_2, which is needed for certain transport options, such as transport by ship. Cryogenics would normally only be applied to high concentration, high pressure gases, such as in pre-combustion capture processes or oxygen fired combustion.