

# Profiles

## Post-combustion carbon capture – solid sorbents and membranes

'The aim is ... to find a process that is cheaper than solvent scrubbing processes'

This report on solid sorbents and membranes for post-combustion carbon capture begins with mesoporous and microporous adsorbents in which CO<sub>2</sub> adsorption is simply a physical process controlled by the pore characteristics of the sorbent. The addition of chemical functionality such as amine groups has been studied as a means of improving the performance of porous adsorbents is discussed in the following chapter. After that, regenerable solid sorbents are examined, mostly involving a chemical cycle of calcination/carbonation reactions to capture the CO<sub>2</sub> and then

'Membrane systems ... appear to be at an early stage of development'

release it as a pure gas while regenerating the sorbent. A chapter on membranes follows. The final chapter provides a brief discussion on techno-economic studies followed by some comments and conclusions.

The preparation of the report has revealed the considerable weight of research activities into solid sorbents and membrane systems for post-combustion CO<sub>2</sub> capture. The aim of much of this research is cost reduction: to find a process that is cheaper than solvent scrubbing processes. NETL has produced a figure which plots the cost

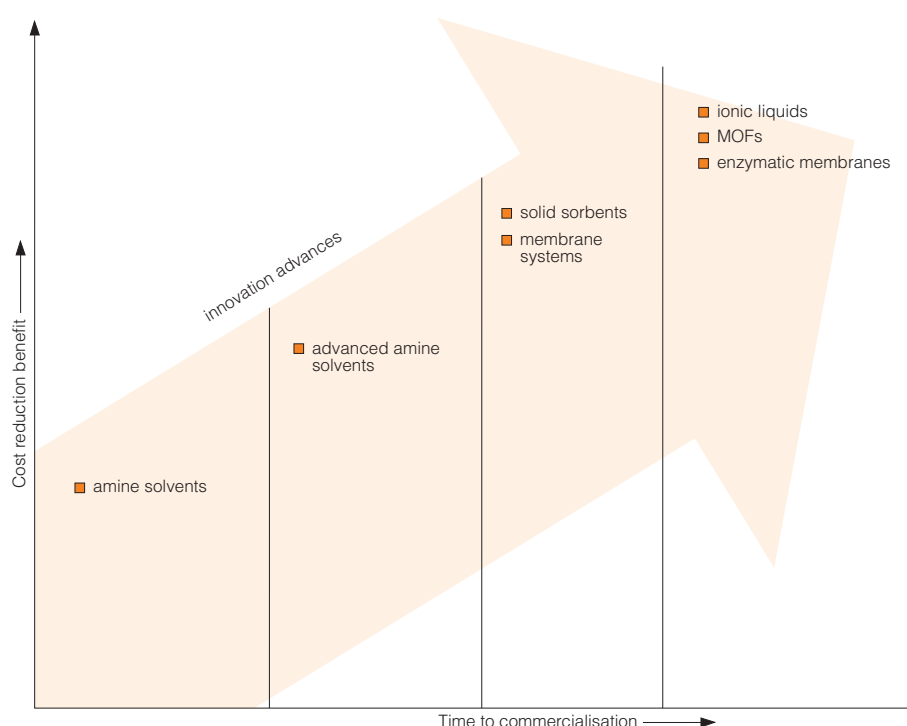
'There may be hopes for the future but there would seem to be considerable challenges as well'

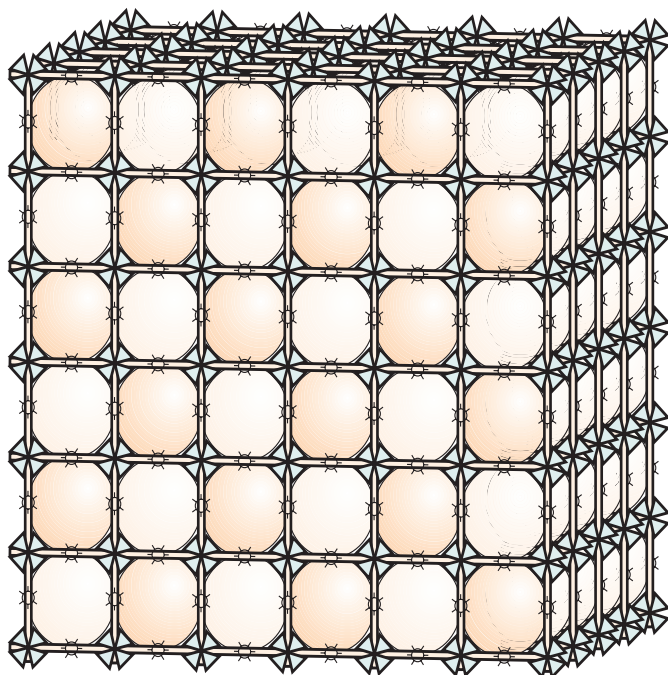
reduction benefits against the time to commercialisation, although both the benefits and the time are not specified.

Simple porous solid sorbents such as activated carbons and zeolites are probably not well-suited to post-combustion CO<sub>2</sub> capture. Their CO<sub>2</sub> capacities and their CO<sub>2</sub>/N<sub>2</sub> selectivities are not very high and they would need to use expensive pressure swing adsorption processes or variants of PSA. The much higher CO<sub>2</sub> capacity metal organic frameworks (MOFs) and their derivatives look promising but are at an early stage of development. They would need to be produced quite cheaply on a very large scale to be used for CO<sub>2</sub> capture in power plants and they need to be proven to work with real flue gases.

Functionalised solid sorbents, especially immobilised amine sorbents, would seem to be a logical improvement upon simple mesoporous adsorbents. However, the results of much research has not been that encouraging. It would appear that the increase in CO<sub>2</sub> capacity by the functional groups seems to be offset by the reduction of porosity caused by the functional groups filling the pores. The development of functionalised amine sorbents will depend on improving characteristics such as high thermal stability, excellent CO<sub>2</sub> stability, high CO<sub>2</sub> adsorption capacity, easy CO<sub>2</sub> desorption, and reversible regeneration.

Dry, regenerable, solid sorbents have the great advantage of being cheap, especially if they are based on natural limestone. Even their loss of capacity with cycling does not seem to be that worrying if it remains at about 20–30%





*Crystal structure of a MOF*

after ~30 cycles. This capacity is still higher than that of the simple and the functionalised porous adsorbents. However, a more obvious problem is the high volume of fresh sorbent needed to counteract the decay in sorbent capacity especially when using natural limestone. The requirements for fresh limestone feed seem to be of the same order as the coal requirements of a plant. This would certainly limit their use for retrofitting plants unless there is a great deal of stockpile space available and probably a nearby cement plant to take the calcined waste lime produced. The key factors in the further development of solid processes are the cost and durability of the reactive solids, along with the development of technology to manage the large solid circulation rates.

Membrane systems for post-combustion CO<sub>2</sub> capture also appear to be at an early stage of development and possibly better-suited to use in pre-combustion applications. Their placing in the same column as solid sorbents in the figure seems quite optimistic. Again, there is a need for testing with real flue gas under power plant conditions. Membrane separation processes provide several possible advantages over other conventional separation techniques; a membrane combining high flux, high selectivity and high stability is not realistic at this stage but mixed-matrix membranes provide hopes. Further, membrane

processes as energy saving, space saving, easy to scale-up, could be the future technology for CO<sub>2</sub> separation.

The potential success of solid sorbents and membranes will depend on whether it is true that only limited evolution is expected in the development of chemical absorption based on amines and that significant developments will be made in the development of adsorbents and membranes. There is scope for continued research especially concerning their behaviour in real coal fired power plant conditions. Certainly, there may be hopes for the future but there would seem to be considerable challenges as well.

Each issue of *Profiles* is based on a detailed study undertaken by IEA Clean Coal Centre, the full report of which is available separately. This particular issue of *Profiles* is based on the report:

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