Profiles

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Hybrid carbon capture systems

In most discussions of systems for capturing CO_2 coal fired power plants, three options are described. These are:

- post-combustion capture;
- oxyfuel combustion;
- pre-combustion capture.

Briefly, post-combustion capture uses chemical solvent sorbents although solid sorbents and membranes have also been studied. Oxyfuel combustion is a process that eliminates nitrogen from the oxidant by burning the fuel in a mixture of oxygen and a CO_2-rich recycled flue gas resulting in a product flue gas containing mainly CO_2 and water. Chemical looping combustion (CLC) is considered by some to be a special case of oxyfuel combustion. In chemical looping combustion metal oxides are used to provide oxygen. Pre-combustion capture involves reacting a fuel with oxygen or air and/or steam to give mainly a 'synthesis gas (syngas)' or 'fuel gas' composed of carbon monoxide and hydrogen. The carbon monoxide is reacted with steam in a catalytic reactor, called a shift converter, to produce CO_2 and more hydrogen. CO_2 is then separated, usually by a physical or chemical absorption process, resulting in a hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells. The three systems are shown in schematic form in the figure. All these systems have been reviewed in published IEA Clean Coal Centre reports.

However, Favre and others (2009), comparing post-combustion capture with oxyfuel combustion noted that: *Surprisingly, the two options . . . have always been seen as distinct and, somehow, competing*.

Recently, there have been signs that this is no longer the case. Some researchers have realised that it may be possible to pick and choose among the elements of the main CO_2 capture systems and develop hybrid systems which are possibly cheaper and more energy efficient. Most hybrid systems are at a very early stage of development compared with the conventional methods with much of the research aimed at evaluation or modelling. The report provides a brief survey of these proposed systems comprising:

- post-combustion capture with oxygen enriched combustion;
- regenerable sorbents (calcium looping) with oxyfuel combustion;
- post-combustion capture in IGCC plants;
- gasification with oxyfuel;
- gasification with chemical looping.

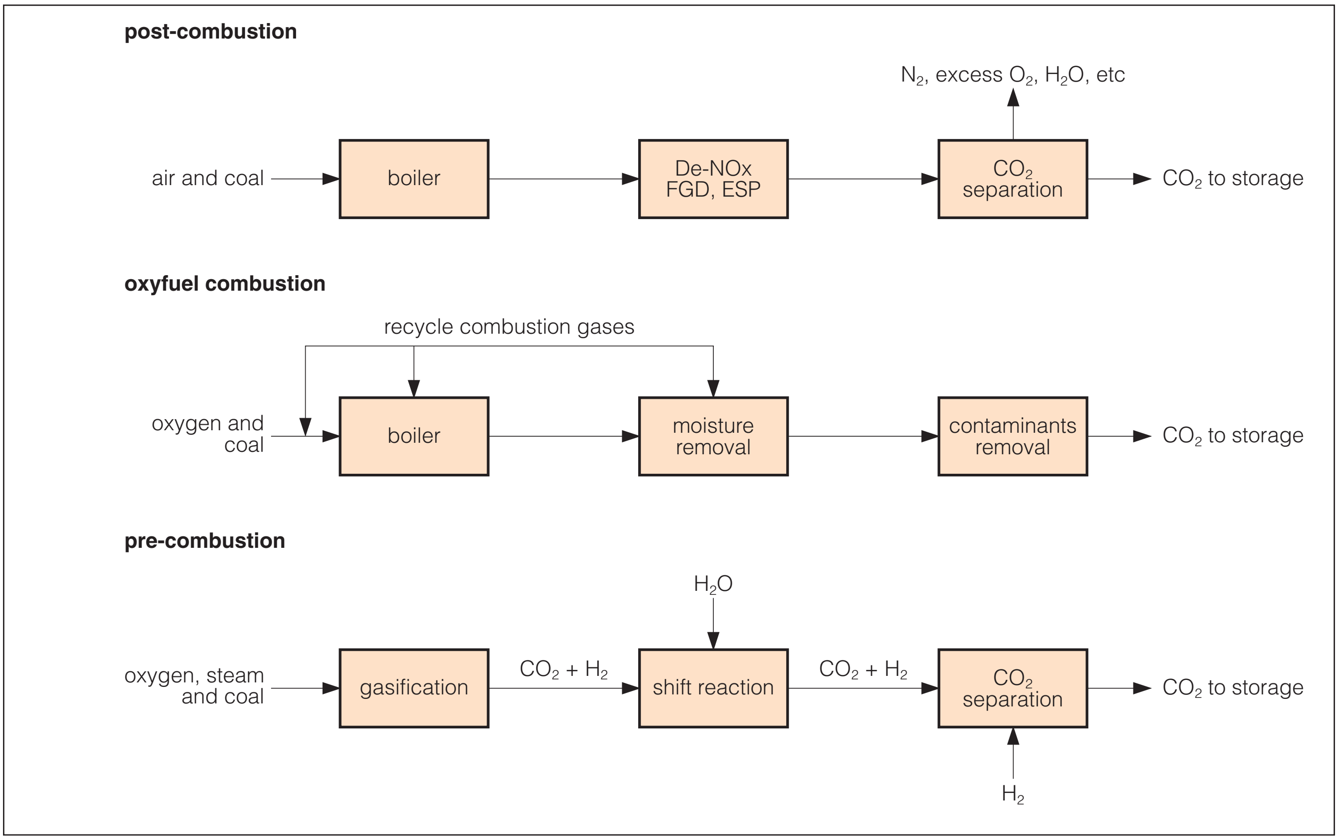
The consideration of hybrid capture systems is evidence that the capture of CO_2 need not necessarily be limited to the three 'conventional' strategies. However, the hybrid capture systems are mainly concepts that have not been physically studied or tested. An exception is the use of oxyfuel combustion for the calcination step in carbonate looping capture. This, though, is probably the least hybrid system of those considered.

As conceptual systems, they can offer thermodynamic advantages but there can be added complexity. So, for example, in combining post-combustion capture with oxygen enriched combustion, the reduced energy requirements for CO_2 capture is offset by the release of more reaction heat and a lower quantity of gas to exchange heat with.

As noted above, regenerable sorbents (carbonate looping) is the system that has made most headway, especially with the establishment of the 1.7 MWth La Pereda pilot plant. Again, although the thermodynamics of the system appear favourable, the plant complexity is higher than in competitive technologies such as full oxyfuel combustion or amine-based post-combustion capture.

The situation is similar when combining post-combustion capture with IGCC plant. The need for high levels of integration might lead to reduced flexibility and reduced availability of the plant. If chemical solvent capture is used then the heat needed for solvent regeneration may lead to lower efficiencies than pre-combustion capture with physical solvents.

Some of the concepts studied involve processes and components that are still under development, for example, syngas chemical looping may encounter engineering challenges. It has also been reported that, due to high capital investments and operating costs, the CO_2 avoidance



CO_2 capture systems

costs for CLC systems have been found to be exceptionally high. But again, it has also been concluded that the energy penalties are lower compared with more conventional capture technologies.

Based on the limited number of what are largely conceptual studies a general conclusion is that, to be successful, hybrid systems must not only be thermodynamically superior but they need to avoid introducing both higher cost and increased engineering complexity. However, the existence of hybrid capture concepts means that capture systems may not have to be limited to the trinity of post-combustion, oxyfuel combustion, and pre-combustion.

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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