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Achieving BECCS with chemical looping combustion

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Ivana Staničić[1*], Tobias Mattisson[1], Joakim Brorsson[2], Anders Hellman[2], Magnus Rydén[1], Judit Fortret Casabella[1], Gajanan Dattarao Surywanshi[3], Jonatan Gastaldi[1], Anders Lyngfelt[1]

[1] *Department of Space, Earth and Environment, Division of Energy Technology, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden*
[2] *Department of Physics, Division of Chemical Physics, Chalmers University of Technology*
[3] *Department of Chemistry and Chemical Engineering, Chalmers University of Technology*
**e-mail: stanicic@chalmers.se*

Introduction

There are currently no multi-national incentives to promote negative emissions and BECCS. At the same time negative emissions are needed on a significant scale and need to be implemented rapidly. The question is if there are ways to accelerate deployment of BECCS rapidly without short-term policy instruments. Chemical looping combustion (CLC) has some pervasive characteristics, which could mean that the technology can be implemented for heat and power production at low economic risk, even in current market conditions. Chemical looping combustion, as displayed in Fig. 1, can burn biomass and biobased waste, with the generated CO_2 obtained inherently in pure form.[1] The technology has been demonstrated in >50 pilot units and most recently up to 5 MW.[2] There are some compelling reasons why we believe the technology can be viable today, and we provide our thoughts below.

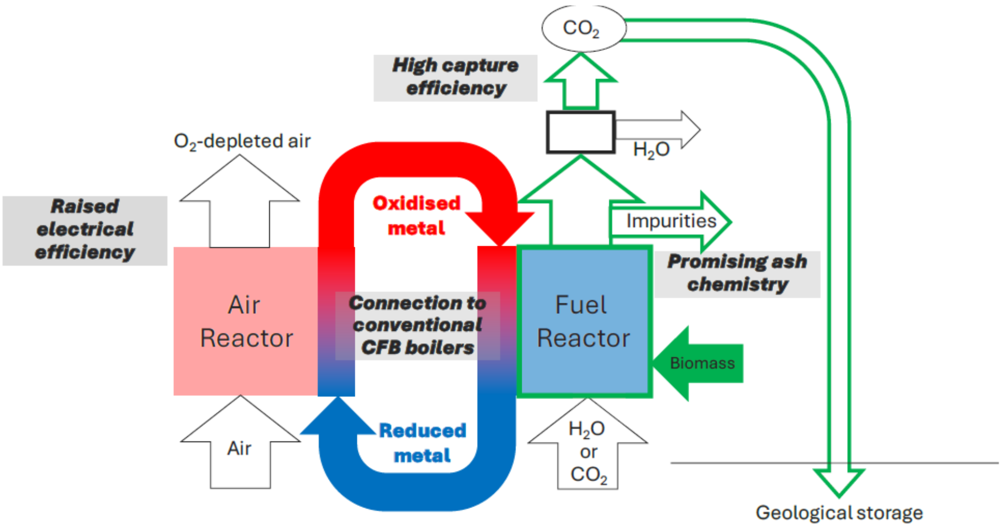

***Figure 1**. Schematic overview of BECCS with chemical looping combustion.*

1. Low energy penalty for carbon capture

The first advantage with CLC comes from splitting the combustion into two steps using solid metal oxides, called oxygen carriers. The particles are oxidised in the air reactor (AR) before being transported to the fuel reactor. In the fuel reactor (FR), fuel is converted to CO_2 and H2O using oxygen delivered by the oxygen carriers. After condensing the steam from the flue gas, a highly concentrated CO_2-stream is obtained suitable for carbon capture and storage as illustrated in Fig.1. Thus, CO_2 can be captured without the large energy penalty of competing technologies. Additionally, a high fraction of volatiles in biomass fuels is an advantage when utilised in CLC, as oxygen carriers can react directly with these gases providing a high CO_2 gas yield. Lastly, the effluent from the AR should be free from impurities as long as no char leaks from the FR with the solids circulation.[3]

2. Raised electrical efficiency

An additional benefit of decoupling reduction and oxidation is that impurities are primarily concentrated in the FR, and impurities are thus avoided in the AR. This implies that CLC could result in a significant reduction in the maintenance costs, as well as higher electrical efficiency, as steam is produced in the ash-free AR. The feasibility of such improvements was investigated by a techno-economic analysis of CLC in an existing CHP plant in Skövde, Sweden.[4] The study concluded that it is possible to raise the steam temperature and electricity output, and that CLC is associated with a lower capture cost and energy penalty compared to an MEA process.

3. Connection to conventional CFB boilers

Almost all CLC pilot units are designed based on interconnected fluidised beds, and in fact, most of the designs for upscaling are based on circulating fluidised beds, but with an added fuel reactor. For instance, Lyngfelt et al. proposed a 200 MW_{th} CLC design composed of two CFB boilers that enables flexible operation, thus the unit can be used both as a conventional CFB without CO_2-capture, but also in “CLC-mode” when conditions for CO_2 capture and BECCS are viable.[3] For an end-user, the added cost for the fuel reactor should be low, but would enable a multi-purpose and flexible operation reducing both technical and economic risks.

4. Promising ash chemistry

Agglomeration and high-temperature corrosion are common problems in conventional CFB boilers, and especially for biomass and biobased waste. CLC differs from conventional combustion as the oxygen carrier can capture impurities that are responsible for high-temperature corrosion, without forming sticky compounds. Both iron- and manganese-based oxygen carriers have been examined extensively and shown to capture problematic impurities.[5] Due to this, less metal chlorides are expected to form compared to conventional combustion, which has positive implications for corrosion.[6]

Conclusion

CLC has many advantages, besides low carbon capture costs, low energy penalty and promising chemistry of impurities there are also important features such as increasing the steam temperatures and electrical efficiencies in combination with the similarities to conventional CFB boilers that can drive BECCS deployment and play an important role in the energy transition in reaching net zero targets by 2050.

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