CO_2 CAPTURE BY CHEMICAL LOOPING PROCESSES USING C-FUELS

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According to the IPCC[1], warming of the climate system is unequivocal and this is mainly consequence of the increase in the CO_2 concentration in the atmosphere. In addition, "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history". These emissions are mainly consequence of the burning of C-fuels, mostly fossil fuels, which result in a net increase in carbon concentration in the atmosphere, soil and oceans. In fact, the natural carbon cycle in the earth is being affected. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions. The measures considered for the reduction of CO_2 emissions to the atmosphere include the improvement in the use and generation of energy, the use of nuclear energy, the boost of energy generation from renewable sources and the CO_2 capture and storage (CCS).[2]

Recently, the Paris Agreement approved a more ambitious target about CO_2 emissions urging to hold the global average temperature increase to well below 2 ºC by 2100, and to pursue efforts to limit the temperature increase to 1.5 ºC above preindustrial levels. According to the IPCC[3] predictions, CO_2 emissions should peak by 2020 and then decrease to negative values by the end of the century. Among the different options, most low-carbon scenarios rely on the integration of CCS technologies with the use of renewable C-fuels, which it is known as Bio-Energy with CO_2 Capture and Storage (BECCS). In fact, BECCS arises as the unique solution able to reach negative emissions and at the same time to obtain energy. Figure 1 shows the carbon emissions balance for the different concepts in energy generation from different C-fuels. Obviously, the implementation at high scale of CCS technology is necessary and within it the development of advanced CO_2 capture processes with reduced costs is highly encouraged. In this sense, Chemical Looping (CL) is a second generation CO_2 capture technology able to obtain high purity CO_2 streams at low cost and energy penalties for different applications including combustion for heat&electricity generation or syngas/H_2 production.[4,5]

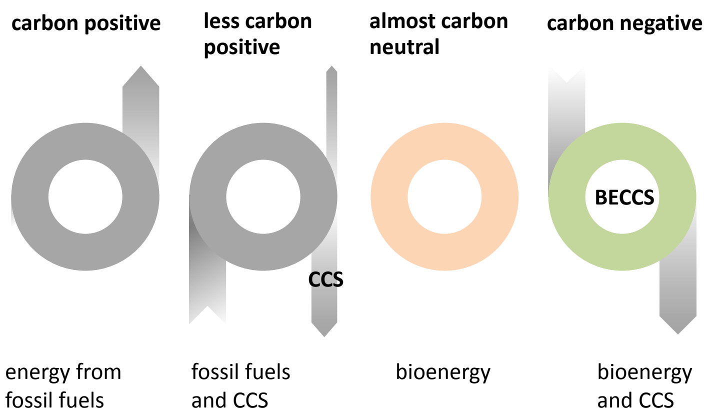

Figure 1. Carbon emission balance for different C-fuels and technologies. Adapted from IPCC.

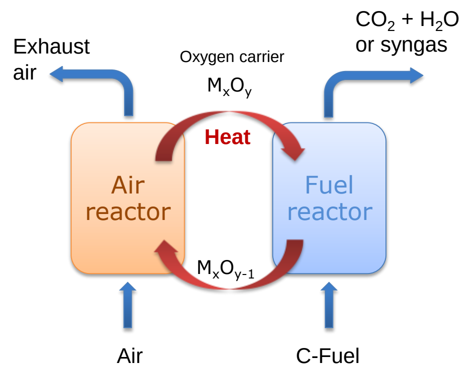

Figure 2. Chemical Looping concept.

Chemical Looping technologies include those cycling processes that use a solid material as oxygen carrier containing the oxygen required for the conversion of the fuel (fuel reactor), see Figure 2. The depleted oxygen carrier material is reoxidized before to start a new cycle in another reactor (air reactor). The technology is highly versatile since can be used with C-fuels of different state (gaseous, liquids and solid), origin (fossil or renewable), and final purposes including the combustion for heat&electricity generation (Chemical Looping Combustion -CLC-; in situ gasification CLC, iG-CLC; Chemical looping with oxygen uncoupling, -CLOU-), or the syngas/hydrogen production (Chemical Looping Reforming, -CLR-; Chemical Looping Gasification, -CLG-; Chemical Looping coupled with Water Splitting, -CLWS-).

This work summarizes the state of the art of the Chemical Looping technology, including the development of oxygen carriers, operation in existing facilities, and future research and prospects for the different processes. It also includes a techno-economic evaluation of the CL process in comparison with other competing CO_2 capture processes.

The CL technology has gained a lot of experience during last 20 years, especially for the use of fossil fuels. Currently there are about 30 pilot plants ranging from 0.5 kW_{th} to 4 MW_{th} that account for more than 5000 hours of operational experience, and stands at a technical readiness level (TRL) of 6. Relevant milestones reached include the demonstration of the possibility to reach 100% of CO_2 capture and 100% of fuel conversion for gaseous fuels, the proof of concept of the CLOU process, and the possibility to obtain high H_2 yields at autothermal conditions including near complete CO_2 capture.

A special mention deserves research on coal combustion as this fuel will play a significant part in the mix of energy production in the near future, being one of the major sources of CO_2 emissions in large power plants. However, the use of renewable feedstocks such as biomass represents an increasing option within the context of the BECCS technologies. In fact, some of the new CL technologies such as CLR, CLG are currently gaining interest in order to produce syngas that could be converted into liquid fuels or hydrogen to be used in the transport sector. It has to be remembered that this represents about one third of the total carbon emissions into the atmosphere.

Up to now, no showstoppers for the implementation of the CL technology at high scale has been detected. The future challenges to its improvement include the development of the pressurized operation, the process scale-up to increase the TRL and maturity of the technology, and the development of long-life oxygen carriers, among others. In any case, CL represents an interesting option within those technologies able to provide solutions to the greenhouse gas effect in the earth.

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