

Innovative CO₂-capture technologies

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Abstract

Carbon capture and utilization/storage is an effective pathway for reducing CO₂ emissions from point sources, in particular in sectors with hard-to-abate CO₂ emissions, such as cement and lime production or waste incineration. Here, novel technologies using solid materials operating at a high temperature, such as carbonate looping (CaL) and chemical looping combustion (CLC), stand out as energy-efficient and cost-effective technologies compared to energy-intensive post-combustion capture methods based on liquid solvents.

CaL is a post-combustion CO₂ capture technology that uses lime as a sorbent in a dual-fluidized-bed reactor system. Its high-temperature operation enables effective heat integration resulting in a low thermodynamic penalty. Moreover, the process benefits from the use of limestone, a low-cost and widely available material, and the spent sorbent can be utilized for lime or cement production. CaL has been successfully demonstrated in several pilot plants, including the 1 MW_{th} pilot plant at TU Darmstadt. In the ongoing research project CARMEN, a mobile CaL unit has been designed and will be deployed at five industrial sites in Germany – including two waste-to-energy plants, a cement plant, a lime plant, and a paper mill – to demonstrate the feasibility of CaL under real flue gas conditions.

CLC is an oxy-combustion process with intrinsic CO₂ separation using metal oxides to transfer oxygen from the air to the fuel, thereby avoiding the need for a costly air separation unit. CLC has also been successfully tested at pilot scale, including the 1 MW_{th} pilot plant at TU Darmstadt. Within the LOUISE project, the application of CLC for CO₂ capture from waste-to-energy plants has been investigated. First CLC tests with an industrially available SRF were carried out at both 150 kW_{th} and 1 MW_{th} scale. CO₂ capture rates exceeding 95% were consistently achieved across scales. A techno-economic evaluation on the integration of a CLC system at the industrial park Frankfurt Höchst suggests that the operating costs of CLC are 40 % lower than with amine scrubbing, although economic viability is highly sensitive to future regulatory developments, carbon pricing, and SRF gate fees.