

Publishable summary

The MSTESA project dealt with a hybrid temperature swing adsorption (TSA) technology based on the utilization of two sources of heating: steam and electricity. The technology was at very low Technology Readiness Level (TRL) at the beginning, fundamentally limited by the available materials.

In the project, we have developed several hybrid materials based on a conductive binder based on carbon and on an active phase of a CO₂ selective material. Such active phase were zeolites (ZSM-5 and zeolite 13X) and metal-organic frameworks (CPO-27-Ni and UTSA-16). All hybrid materials were produced by extrusion. For production of the MOF materials, its successful scale-up to batches with homogeneous properties at scales > 100 g was made. Although the extrusion of MOF materials was successful, the final product material has a very low capacity towards CO₂. The zeolite honeycombs kept their original capacity with the possibility of using them for processes for CO₂ capture.

Simultaneously to material developments, the hybrid process was developed. The project started by pure ESA simulations (heating only with electricity) with hypothetical hybrid materials allowing to define a proper ESA cycle to produce CO₂ with a purity of 95% and a capture rate of 90%. The estimation of many transfer coefficients were made based on results obtained from 3D modelling from the honeycomb monoliths.

Additionally it was possible to use the life-cycle assessment (LCA) to estimate the environmental impact of the CO₂ capture process. An interesting approach of the LCA analysis was indeed made for understanding the importance of the chemicals used in the large-scale synthesis of novel materials.

The main results from the project indicate that a hybrid ESA process is able to capture CO₂ from natural gas combined cycles (NGCC) flue gases with an initial concentration of about 4% and concentrate it to > 95% purity with over 90% capture rate. This can be done with materials based on zeolite 13X and UTSA-16, provided that the properties of the original powder materials are not damaged by the process to shape them into monoliths. The energy required to capture the CO₂ is higher than the amine scrubbing process used as reference for benchmarking. Moreover, the process suffered for a large energy consumption from fans to speed up the heating and cooling of the monoliths used. Overall, the Specific Primary Energy Consumption for CO₂ Avoided (SPECCEA) is 9.05 MJ_{LHV}/kg_{CO2} compared with 3.36 MJ_{LHV}/kg_{CO2} for amine scrubbing using MEA.