MATESA Report Summary

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Periodic Report Summary 1 - MATESA (Advanced Materials and Electric Swing Adsorption Process for CO2 Capture)

Project Context and Objectives:
Carbon capture and storage (CCS) is one of the technological solutions to decarbonize the energy market while providing secure energy supply. So far, the cost of CCS is dominated by the CO_2 capture, reason why new capture techniques should be developed.
Adsorption techniques have already been evaluated for CO_2 capture. So far, the main drawbacks of this technique are the energetic demand to regenerate the adsorbent and obtain high purity CO_2. However, the utilization of commercially available materials was employed in the former evaluations. New materials with targeted properties to capture CO_2 from flue gases can improve the performance of adsorption processes significantly.
The vision of MATESA is to develop an innovative post-combustion capture technique termed as Electric Swing Adsorption (ESA) by using hybrid honeycomb monoliths to selectively remove CO_2 from flue gas streams. The hybrid honeycombs will be manufactured by combining an electrically conductive matrix with a high CO_2 loading material like zeolites and metal-organic frameworks. The electricity in the ESA will be used to partially regenerate the adsorbent, releasing the CO_2 at high purity. Indeed, a game-changing innovation in MATESA is the development of a regeneration protocol where electricity is only used to efficiently increase the CO_2 purity and further regeneration is carried out with low-grade heat available in the plant. The predicted energy savings of the developed process may transform this CO_2 capture process in a key component to make CCS commercially feasible in fossil fuel power plants going into operation after 2020.
In order to realize a proof of concept of the proposed process, a strong component of the project will deal with the development of a hybrid material that is able to selectively adsorb CO_2, conduct electricity, result in a low pressure drop and have reduced environmental impact. The development of such a material is important for MATESA and will also have a significant impact to increase the energy efficiency of pre-combustion CO_2 capture and other energy intensive gas separations.
Project Results:
A detailed description of the advance of the project in the different work-packages follows. For a more detailed report, please refer to Deliverable 1.4.
WP 2: modelling. This WP started by defining the boundary conditions that will be employed in the project (Deliverable D2.1). These conditions were provided for coal and natural gas-based power plants.
A set of overarching key performance parameters was also established (Deliverable 2.2): levelized cost of electricity (LCoE) and cost of CO_2 avoided. Among second-level KPIs, there are the net electric efficiency and the carbon capture ratio.
Two different ESA modelling approaches were followed: a detailed transient 3D model and a simplified transient 1D model. Both models comprise the mass, energy and momentum balances. The 3D model is much more complex to implement but also has the ability to provide more detailed information about the phenomena that take place in the process.
The initial 1D model was submitted in Deliverable 2.3 and for accuracy, stability and convergence reasons the model needed to be modified. The version that will be used in WP5 will be the 1D model used in Deliverable 2.5.

Workpackage 3. Zeolite ZSM-5 was selected for the reference material. Additionally, two metal-organic frameworks (MOFs) were selectioned: Ni-CPO-27 and UTSA-16. The bio-activated carbon that will be used for the extrusion will be obtained by carbonization of beer residues (Deliverable 3.2). The Australian source of activated carbon will be brown coal.
The initial scale-up of the MOFs to 10g (Deliverable 3.1) was performed for CPO-27 and UTSA-16. The scale-up of UTSA-16 to > 100g has been achieved (Deliverable 3.3).
A reference material honeycomb with 78% of zeolite ZSM-5 was produced and shipped to partners within the consortium for further testing.

Workpackage 4. The materials characterization comprises: the adsorption capacity, the diffusion of reactants and the heat of adsorption. Also, the stability of the materials should be tested. Adsorption properties of ZSM-5 zeolite was measured (Deliverable 3.1). As initially planned, at least two MOF materials were prepared (CPO-27 and UTSA-16). Both MOFs prepared were tested in at least 160 cycles of heating and cooling and adsorption / desorption. No deactivation

was observed in breakthrough experiments.
Regarding the development of the ESA unit, the system is ready and its full description was shown in Deliverable 4.5. The unit can accommodate up to four columns and make combinations of pressure, temperature and electric input.

Workpackage 5. The thermodynamic analysis of the ESA process has been reported in detail in Deliverable 5.1. The initial analysis has shown that heat integration of the streams is very important and that water pre-removal might be necessary.
The benchmarking of the technology developed in MATESA will be done for Natural Gas Combined Cycle (NGCC) and Advanced Supercritical Pulverized Coal plant (ASC). The report of the European Benchmarking Task Force (EBTF) is taken as reference document because it is widely known and resulted from a consensus between academia, research centres and industry. The detailed report has been presented in Deliverable 5.2.

Workpackage 6. The LCA methodology defined will be within the framework established in the norm ISO 14040. The boundaries of the system include the extraction of materials that are necessary to build the entire plant, the energy used for the manufacture of the components, their ensemble and utilization. The LCA parameters will be calculated considering that the life of the CCS plant is 25 years.
The first screening of the technology has been performed and compared to the amine technology (Deliverable 6.2). The results indicate that according to the initial evaluation, the LCA of the ESA is positive in many impact categories. Indeed, it was demonstrated that is possible to use LCA methodology to achieve better recipes on MOF synthesis.

Potential Impact:
The project aims to produce an energy-efficient technique for post-combustion CO2 capture with energy penalty lower than 7% for NGCC plants and 9% ACS plants. The main result of MATESA will be to prove a hybrid ESA process in TRL 4 conditions to fairly benchmark it to other existing processes. It has been shown by initial thermodynamic analysis that integration of ESA with available heat sources will play a key role in determining the final amount of energy required by the process.
Moreover, another important result of the project is related to the production of hybrid honeycombs that can be used in other applications to increase energy efficiency of separation processes. In this sense, particular attention is given to the processing of MOF materials to honeycomb monoliths, a task that has still not been achieved without seriously damaging the structure and surface area of the MOF. Within MATESA, the initial results obtained are encouraging. A demonstration of such a potential can help deploy a new market for these materials and reduce its cost, which will be ultimately beneficial to reduce the CO2 capture investment.
Within the project it has been found that with the assistance of LCA it is possible to achieve more environmentally friendly conditions for synthesis of MOF materials that can help reduce the overall environmental footprint of new capture technique like ESA. This is very important provided that the generation of hybrid materials is a key step to deploy ESA as an alternative technique and a good starting point for environmental performance will help in its benchmarking with mature and already established techniques.
So far, the area that has advanced the most is related to the preparation of novel materials. Once that a reference material is available, process development and integration can be realized and improved towards a process that can be boosted by a better advanced material with higher cyclic capacity to remove CO2 from post-combustion flue gas streams.

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Subjects

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