Study for the industrial implementation of membrane based SMR CO_2 Post-Combustion Capture Plants

Process design and techno-economic analysis of a membrane-based solution for a post-combustion CO_2 capture plant in an SMR plant (300 kg/day of H_2 product). The goal is to reach 90% recovery with 90% CO_2 purity through a technically feasible and economically competitive solution

THE CONTEXT

There is an increasing interest in on-site hydrogen production sites, in which hydrogen is produced at the exact point where it is going to be consumed, eliminating hydrogen compression and transport costs. This reduces hydrogen cost and its CO_2 footprint compared to traditional supply of hydrogen.

For these small on-site plants, there is going to be a mix between hydrogen produced by electrolysis and hydrogen produced by steam reforming (either from natural gas or biogas/ biomethane). Adding CO_2 capture in those plants will allow a further reduction of the CO_2 emissions. In case of using bio-feedstocks, a negative CO_2 footprint could be achieved (BEECS - Bioenergy with Carbon Capture and Storage). This is of paramount interest for those sectors in which significant reductions in CO_2 emissions are expected.

Currently there are not a lot of references for small and compact CO_2 capture plants. Most of the CO_2 capture plants at bigger scales use amines. The main aim of this service is to showcase the cost-effectiveness a membrane intensified CO_2 capture process in comparison with the conventional amine sorption processes.

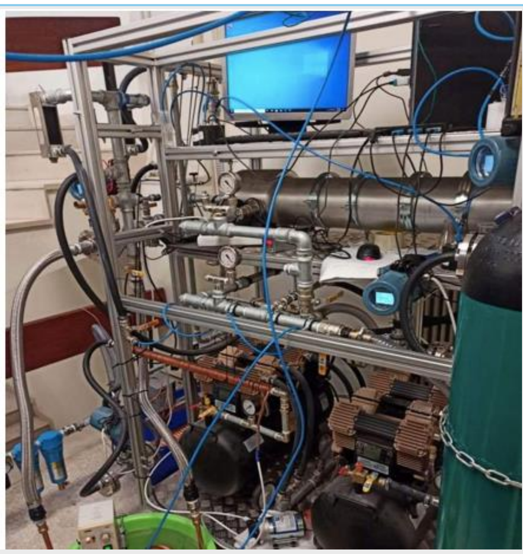

Figure 1. *The two-stage membrane section of the demo-unit designed and developed by HTF and Demokritos*

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THE CHALLENGE

The main objective of the Democase CO2_PCCP is to develop the flowsheet of a membrane-based CO_2 capture plant able to achieve 90% CO_2 recovery and 90% CO_2 purity in the post-combustion stream of an SMR plant.
The challenge is that the developed solution must be competitive both technically and economically against state-of-the-art solutions (e.g. amines).
The proposed solution will be able to be implemented in SR plants that use not only methane as feedstock, but also biomethane, biogas and bioethanol with relatively small modifications.
With the support of a positive techno-economic analysis, CO_2 capture plants based on membrane technologies will be appealing to different end users and will boost the implementation of membranes as a solution for post-combustion CO_2 capture.

TECHNIQUES USED

For the CO2 PCCP Democase the assigned INNOMEM members (FORTH, DEMOKRITOS and HTF) have used the following services and techniques:

- Process design.
- Modelling and flow sheet simulations of multi-stage membrane and hybrid systems.
- Obtaining CO_2 capture data using a TRL6 two-stage CO_2 capture membrane demo unit.
- Techno-economic analysis and market validation.

THE RESULTS

Multiple configurations have been studied focusing on 2-stage membrane systems, 3-stage membrane systems and hybrid systems that combine PSA and membranes.

- Target of >90% CO_2 purity has been shown qualitatively to be achieved with 2-stage membrane units.
- Elevated CO_2 recovery has been pursued with 2-stage membrane units, however 90% level has not been achieved.
- Targets of >90% CO_2 purity and >90% CO_2 recovery have been obtained using hybrid two-stage membranes /VPSA units to combine advantages of the membrane systems at high CO_2 concentrations with the advantages of VPSA sorption systems at low CO_2 concentrations.

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CONCLUSION

The preliminary results show that it is possible to achieve the targeted CO_2 purity and recovery with membrane-based CO_2 capture plants.

While 2-stage membrane systems are able to comply with the requested purity, they are not able to reach the desired recovery.

The most promising solutions are those based in 3-stage membrane configuration systems and those based in hybrid systems, combining the membrane unit with a VPSA system, to treat the low CO_2 product retentate stream from the first membrane unit.

A detailed techno-economical study is required for each particular case as the selection of the optimum solution varies depending on several factors such as feed composition and scale.

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