ABSTRACT:

Integration of Membrane Gas Separation in CO_2 Hydrogenation for e-Fuels Production

L. Marsico[1], A. Brunetti[1], E. Catizzone[2], M. Migliori[2], G. Barbieri[1]
[1]National Research Council – Institute on Membrane Technology "E. Drioli" (ITM-CNR),
Via Pietro BUCCI, Cubo 17C, 87036 Rende CS, Italy
[2]University of Calabria, Chemical Engineering Catalysis and Sustainable Processes Laboratory,
87036 Rende CS, Italy

This work aims to demonstrate the potential of membrane separation as a key enabling technology for the energy transition by exploring its impact on CO2 valorisation and renewable H2 chemical storage for the production of e-fuels. The focus is on the simulation analysis of membrane separation processes of upstream and downstream of a catalytic reactor fed with biogas and H2 produced from surplus of renewable energy. The first proposed process integrates downstream membrane separation with CO2 hydrogenation into synthetic CH4 [1]. The integrated system achieves an overall CO2 valorisation close to 99% and a CH4 stream suitable for natural gas grid injection through the separation of CO2 and H2 and their recycle to the reactor. In a second configuration, membrane units are both upstream and downstream of a CO2 hydrogenation reactor for methanol production [2]. The upstream membrane separation of biogas produces a CO2-rich feed to the reactor and a CH4-rich stream for grid injection. The downstream membranes separate unreacted CO2 and H2, enabling their recycle to the reactor and preventing their purge. Approximately 97% of the CO2 is valorised into methanol, with nearly complete storage of the renewable hydrogen.

[1] L. Marsico, A. Brunetti, E. Catizzone, M. Migliori, G. Barbieri, Integrated membrane gas separation process for the valorisation of H2 and CO2 to biomethane, Renew. Energy 254,123693 (2025).
[2] L. Marsico, A. Brunetti, E. Catizzone, M. Migliori, G. Barbieri, Membrane-Integrated Process for Simultaneous Biogas Upgrading and Hydrogen Storage via Methanol, Int J Hydrogen Energy, 216, 153938 (2026).