CO_2 methanation: from laboratory to full scale validation

M. Percivale[a,b,c], P. Riani[a,d], E. Scrinzi[b], E. Gadducci[c], G. Camarda[c] & G. Garbarino[a,d]

[a] University of Genoa, DICCA and DCCI Departments, 16100 Genoa, Italy
[b] Materials & Processes Engineering, Baker Hughes, 50127 Firenze, Italy
[c] Climate Technology Solutions, Baker Hughes, 50127 Firenze, Italy
[d] INSTM UdR Genova, 16100 Genoa, Italy

E-mail: gabriella.garbarino@unige.it

In the field of Power-to-Gas technologies, the CO_2 methanation process ($CO_2 + 4H_2 \rightleftharpoons CH_4 + 2H_2O$) represents a promising solution for the transition from fossil to renewable resources. It allows the production of e-methane, a storable energy carrier, by coupling renewable hydrogen with captured CO_2 from several sources. In addition, a well-developed infrastructure can be exploited for storing, transporting, and injecting the e-methane into the grid.

The present study aims to assess the potential scalability of a CO_2 methanation plant from laboratory to full-scale operation using a bottom-up approach. Initially, several Ni-based supported catalysts were synthesized using the incipient wetness impregnation method [1,2,3]. To optimize the CO_2 methanation performance, the influence of various promoters and supports was evaluated. The catalysts were then tested in a laboratory-scale tubular fixed-bed reactor at 523-773 K and 1 bar and characterized before and after the experimental test. This enabled the investigation of catalytic activity and stability, intending to improve the catalytic formulation. To assess the scalability of these homemade catalysts, their catalytic performances were compared to those obtained with monoliths as support and a selected industrial catalyst [1].

Finally, a techno-economic evaluation of a CO_2 methanation plant was carried out, considering several scenarios. A biogas plant was considered as the CO_2 source, as an example of a potentially 'carbon negative' system. On the other hand, two of the most promising and innovative technologies on the market were evaluated for hydrogen production, i.e. AEM and SOEC, where AEM can operate at low and high pressure, while SOEC operates at high temperatures. For the CO_2 hydrogenation stage, a conventional cooled tubular reactor, operating at 573 K and 10 bar, was preliminarily considered [4]. In addition, different parameters were considered by assessing the electricity source and price, heat management strategies, and the possibility of operating with a dynamic supply of reactants flow rate. At present, results suggest that the considered system is not yet cost-competitive compared with fossil-based plants, however, the advancements towards higher technology readiness levels coupled with incentives are expected to significantly reduce SNG production costs. Thus, in a medium-term scenario, a change in terms of cost competitiveness can occur, considering also the maturation of such technologies.

Keywords: *CO_2 methanation, heterogeneous catalysis, techno-economic analysis, renewable energy*

[1] Garbarino et al., Appl Catal B (2019), 248, 286-297
[2] Riani et al., Appl Catal B (2021), 284, 119697
[3] Freccero et al., Appl Catal B (2024), 343, 123532
[4] Gorre et al., Appl En (2020), 257, 113967