

Methanation of Biogas to Store and Distribute Green Hydrogen

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INTRODUCTION

Biogas contains large amounts of CO₂, to be at least separated to exploit biomethane, and possibly valorised. A first option is CO₂ hydrogenation to methane, also promising to transform an energy vector that is uneasy to handle (green H₂) into a valuable and worldwide-distributed fuel and feedstock (CH₄). A “power-to-gas” framework could then help to overcome the drawbacks of H₂ as an energy storage medium and to increase the continuity and general availability of different intermittent renewable energy sources. The aim of this work is to detail aspects of the methanation of CO₂ as a method for Carbon Capture and Utilisation using green hydrogen. Different options for the efficient direct conversion of CO₂ and H₂ into CH₄ (Sabatier reaction) are here explored both experimentally and through process design.

EXPERIMENTAL/THEORETICAL STUDY

Ni-based catalysts (5-20 wt%) supported over CeO₂, SiO₂, Al₂O₃ and ZrO₂ have been prepared by impregnation and co-precipitation. Testing has been done under practically relevant conditions at pressure up to 20 bar, with a stoichiometric H₂/CO₂ feed. Process design has been accomplished with Aspen Plus process simulator, considering the Sabatier reaction for the methanation of CO₂.

RESULTS AND DISCUSSION

We considered a small delocalised plant, identified in a biogas production facility. H₂ is considered as produced from water electrolysis fed with renewable power. A key issue is the strong exothermicity of the reaction. Our research explores the use of water vapour, added on purpose to the reactor as a thermal vector and later condensed. The simplest and most economical reactor arrangement is composed of a certain number of adiabatic beds (up to five) with intercooling. Alternative arrangement has been explored designing a fluidized-bed reactor, that allow better temperature control, but this led to incomplete conversion and was difficult to scale-up.

The possibility to use the methane already present in biogas as diluent (i.e. thermal vector to control the exothermicity) was also considered, offering the additional advantage to eliminate the otherwise needed and expensive CO₂ capture step.

This option is intended to improve the CH₄ yield and to meet the purity specifications for feeding the natural gas distribution grid. Possible poisons for the methanation catalyst, such as sulphides or nitrogen containing poisons, were considered and removed by proper pretreatment. Two options were further considered, one with preliminary CO₂ separation from biogas and methanation of pure carbon dioxide, the other on with direct treatment of the biogas stream.

At least 4 reactive stages for the methanation reaction were needed to get > 75% conversion. Either adiabatic or cooled catalytic beds were compared, operating at below 400°C, with an overall size of 10⁵ Nm³/day of synthetic methane.

CONCLUSION

The results show the feasibility of a methanation reactor suitable for the direct catalytic conversion of biogas from anaerobic digestion for the delocalized production of biomethane.

ACKNOWLEDGMENTS

The authors acknowledge Task 8.4.1 of the Agritech National Research Center, funded from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1032 17/06/2022, CN00000022).