Solar World Congress 2025

Solar Hydrogen Derivative Methanol Production

SolMeth24 Project

Summary

Recently there has been a growing global focus on alternative fuels such as hydrogen and its derivatives like ammonia and methanol in the climate change discourse. Methanol production from synthesis gas is a commercially proven technology that currently mainly utilizes both natural gas and coal as feedstock. However, when produced from green hydrogen and sustainable CO_2, methanol is one of the most promising energy carrier molecules for a decarbonized economy. Methanol can namely not only be used directly as a fuel, but is also a versatile chemical feedstock for industry. The project SolMeth24 aims to produce green methanol with a capacity of approx. 7500 tons/year using solar energy and a 10 MW electrolyser in order to contribute to a low-carbon future.

Keywords: green hydrogen, green methanol, solar energy

1. Introduction

An energy economy centred on hydrogen and its derivatives is being developed to lower CO_2 emissions and non-fossil fuel production, as a potential remedy for the growing problems caused by conventional fossil fuels, and is now more important than ever. Hydrogen and alternative fuels like ammonia and methanol have become important players for a low-carbon future as the world struggles with the need to switch to cleaner and more sustainable energy systems. Methanol is a versatile chemical feedstock for industry used in many everyday products, including plastics, paints, cosmetics and can also be used directly as a fuel e.g. for shipping [1]. Today, methanol synthesis is commercially available in numerous variants and predominantly utilizes fossil fuels as the primary energy source. The mature conventional technology for methanol production is the catalytic conversion of hydrogen and carbon monoxide from coal- or natural gas-derived synthesis gas into methanol in fixed-bed reactors at high pressure. Depending on the catalyst supplier, the synthesis reaction is normally carried out at around 40 to 100 bar and 200 to 350 °C [2]. The catalyst systems used for methanol synthesis are usually mixtures of copper, zinc oxide, and aluminium oxide [2]. Some advances have also led to new catalysts based on carbon, and platinum, or based on materials such as zeolites, organometallic frameworks and base metals [3] and very recently indium oxide–based catalysts (In_2O_3) as well as Cu/ZnO/MnO/KIT-6 (porous silica) have gained growing interest as next-generation catalysts [4]. Other potential methods, such as electrochemical and photochemical processes, the membrane reactor and the slurry phase reactor, are still under research [5]. The choice of the synthesis route is a crucial step for the low-carbon future, in which methanol can be used as a fuel and as a raw material for the products that are conventionally obtained from fossil fuels. This is possible by producing green methanol from green hydrogen, itself generated by water electrolysis for example, and from captured CO_2. Practical data from pilot plants for methanol production using CO_2 and hydrogen is still scarce. Despite some laboratory and pilot plant tests, long-term pilot plant studies on catalyst deactivation and optimal operating conditions are still lacking. In addition, efforts to develop reactor concepts that improve the equilibrium yield of the process should be intensified.

2. Objectives and methodology

The concept proposed here to produce approx. 7500 tons per year of green methanol uses a 10 MW electrolyser powered by green electricity from a solar thermal system and is also available for other components of the facility. The overall methanol synthesis line not only requires a high capacity factor, but also offers the possibility to utilise waste heat streams at different temperatures along the process chain. With regard to the origin of the CO_2, the project's first phase utilizes carbon dioxide captured from the flue gases of nearby industrial sites. In a second phase, the carbon dioxide will come from direct air capture. Thus, the bilateral project SolMeth24 enables to bridge the gap between research on the one hand and the commercial realization of a German-Australian supply chain for solar-generated methanol on the other hand. The results of this first demonstration plant utilizing Concentrated Solar Thermal technology will serve as a basis for scaling up to a commercial size to enable the export of green methanol to Germany.

The integration of the subsystems into an overall system represents an innovation that entails various adjustments of components and its interfaces. It is planned to develop, model and ultimately optimize concepts for process integration. The development and evaluation of these concepts will be flanked by the possibility of small-scale tests in a pilot plant. This pilot plant offers significant advantages. It is designed to mirror the large-scale industrial process and the final choice of technology, while allowing considerable freedom in research, development and optimization: reaction conditions, catalyst formulations and process parameters can thus be investigated and evaluated before moving to industrial scale. The pilot plant will also serve as an interface for knowledge exchange, collaboration and technology transfer between science, research and industry. The insights gained from these experiments contribute to the development of efficient and environmentally friendly methanol production technologies.

Given the novelty of large CCU systems, integrating renewable electricity and heat generation as well as hydrogen and methanol production, there is a knowledge gap regarding the optimal design and operating conditions. Therefore, another objective aims to provide robust simulations and modelling, a techno-economic study and a life cycle analysis that will help to understand the impact of dynamic operation in the context of renewable energy availability and the opportunities to improve energy efficiency and methanol costs.

3. Planned work

The techno-economic assessment and a sensitivity analysis obtained from this work can be used to identify opportunities such as innovative heat integration strategies. These opportunities can be evaluated and possibly implemented together with the technical partners. Thus, this work contributes to strengthening the cost-competitiveness of solar methanol compared to its fossil counterparts. Furthermore, thanks to the models developed, it will be possible to quantify the environmental impact of solar methanol through a life cycle analysis (LCA) focusing on greenhouse gas emissions. Thus, the most impactful contributors to its carbon footprint can be identified and, if possible, reduced in the initial development stages. The data available at the end of the project is expected to be of great importance for the marketability of this technology.

4. Conclusion

Methanol produced from renewable energy sources has the potential to significantly reduce carbon emissions in the chemical industry and the shipping sector. Contributing to a low-carbon future, the SolMeth24 project intends to generate green methanol with a capacity of roughly 7500 tons/year using solar energy and a 10 MW electrolyser. A small-scale pilot plant as replication of the large-scale industrial process will also be designed and act as a bridge for technology transfer between science, research, and industry. Furthermore, an economic and ecological assessment of the concept determines the potential for enhancing energy efficiency and lowering the cost of solar methanol.

5. References

[1] Prats-Salvado E., Monnerie N., Sattler C., 2021. Synergies between Direct Air Capture Technologies and Solar Thermochemical Cycles in the Production of Methanol. Energies, 14 (16) 4818, doi: 10.3390/en14164818.

[2] Ullmann's Encyclopedia of Industrial Chemistry, 2000. Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA.

[3] Azhari N. J. et al., 2022. Methanol synthesis from CO_2: A mechanistic overview, Results in Engineering, 16, 100711. https://doi.org/10.1016/j.rineng.2022.100711.

[4] Ye J., Dimitratos N., Rossi L. M., Thonemann N., Beale A. M., Wojcieszak R., 2025. Hydrogenation of CO_2 for sustainable fuel and chemical production, Science, 387, 6737. https://doi.org/10.1126/science.adn9388.

[5] Cuia X., Kæra S. K., 2020. A comparative study on three reactor types for methanol synthesis from syngas and CO_2, Chemical Engineering Journal, 393, 124632. https://doi.org/10.1016/j.cej.2020.124632.