DME - Sustainable all-rounder for defossilization

Achim Schaadt, Silvan Feuerbach, Florian Nestler, Malte Gierse, Robert Szolak,
Fraunhofer ISE, Freiburg

Introduction

Hydrogen and its derivatives, such as methanol and dimethyl ether (DME), are essential for the defossilisation of the transport, industrial, and energy sectors. This is also addressed in the Hightech Agenda of the BMFTR. e-Fuels, chemicals, and energy carriers are various applications of DME, which are of significant relevance for future industrial value creation in Germany. Furthermore, Germany relies on the large-scale import of renewable energies, sustainable energy carriers, and raw materials for industry. Innovative technologies for the production of e-fuels also enhance Germany's geopolitical independence and resilience.

DME offers several advantages over other energy carriers, but there are still research gaps that need to be addressed. Fraunhofer ISE, which has long-standing expertise in the field of DME [1-7], addresses these topics. For example, Fraunhofer ISE has developed a novel process (INDIGO, patent filed) using reactive distillation, in which the thermodynamic reaction equilibrium is bypassed by coupling synthesis and distillation (see Fig. 1). INDIGO reduces energy requirements, plant complexity, and investment costs. In cooperation with our industrial partner, thyssenkrupp Uhde, the aim is to increase the technological maturity of this innovative and efficient process developed by Fraunhofer ISE for the production of DME and to prepare for its industrial implementation.

The hydrogen carrier ammonia, frequently discussed in this context, has a lower H_2 storage capacity compared to DME and requires significant water resources in sunny countries that often suffer from water scarcity [2]. The efficient transport of hydrogen via DME allows for large-scale global use of H_2, enabling a CO_2-neutral supply to the industry, transport sector, and energy economy. Additionally, the transport of hydrogen using DME would be conducted through a non-toxic, ozone-friendly, and non-hazardous hydrogen carrier.

Furthermore, DME, as a platform molecule, offers many applications: as an intermediate for further synthesis of aviation fuels, gasoline, and other refinery products, as well as for blending with LPG (up to 20% possible without user-side adjustments).

The proposed presentation will provide an overview of the opportunities and challenges of DME and draw conclusions regarding technology and economics.

Figure 1: PN50 distillation column with a total height of 7.5 meters at Fraunhofer ISE, serving as a platform for DME and SAF process development.

References

[1] Semmel, M.; Kerschbaum, M.; Steinbach, B.; Sauer, J.; Salem, O. (2023): Optimized design and techno-economic analysis of novel DME production processes. In Reaction Chemistry & Engineering. DOI: 10.1039/D3RE00333G.

[2] Schühle, P.; Stöber, R.; Semmel, M.; Schaadt, A.; Szolak, R.; Thill, S. et al. (2023): Dimethyl ether/CO_2 - a hitherto underestimated H_2 storage cycle. In Energy & Envi-ronmental Science 16 (7), pp. 3002–3013. DOI: 10.1039/D3EE00228D.0.

[3] Semmel, M.; Bogatykh, I.; Steinbach, B.; Sauer, J.; Repke, J.; Salem, O. (2023): Demonstration and experimental model validation of the DME synthesis by reactive distillation in a pilot-scale pressure column. In React. Chem. Eng. (8), pp. 2309–2322. DOI: 10.1039/D3RE00200D.

[4] Kubas, D.; Semmel, M.; Salem, O; Krossing, I. (2023): Is Direct DME Synthesis Superior to Methanol Production in Carbon Dioxide Valorization? From Thermo-dynamic Predictions to Experimental Confirmation. In ACS Catal., pp. 3960–3970. DOI: 10.1021/acscatal.2c06207.

[5] Semmel, M.; Steiner, L.; Bontrup, M.; Sauer, J.; Salem, O. (2022): Catalyst screening and reaction kinetics of liquid phase DME synthesis under reactive distillation conditions. In Chem. Eng. J., p. 140525. DOI: 10.1016/j.cej.2022.140525.

[6] Cholewa, T.; Semmel, M.; Mantei, F.; Güttel, R.; Salem, O. (2022): Process Intensification Strategies for Power-to-X Technologies. In ChemEngineering 6 (1), p. 13. DOI: 10.3390/chemengineering6010013.

[7] Semmel, M.; Ali, R. E.; Ouda, M.; Schaadt, A.; Sauer, J.; Hebling, C. (2021): Power-to-DME: a cornerstone towards a sustainable energy system. In Giuseppe Spazzafumo (Ed.): Power to Fuel. How to Speed Up a Hydrogen Economy: Elsevier, pp. 123–151.