

Converting bio-based cyclopentanone into jet fuel hydrocarbons

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The HIGFLY approach

In 2021 the International Air Transportation Agency (IATA) members agreed in a net zero CO₂ emission in 2050. To reach this goal the global production capacities of 300 million litres SAF in 2022 must be increased drastically. A potential production of 30 billion litres is a scenario for 2030.¹

In this context the H2020 project HIGFLY develops novel technologies and processes to contribute to the increasing demand on SAF. The starting point for the HIGFLY approach are sustainable feedstocks and second-generation biomasses which are processed to bio-based oxygenates like cyclopentanone. These precursors were condensed to larger molecules and subsequently hydrodeoxygenated to pure jet fuel hydrocarbons.

Liquid products from CPO self-condensation



Spent catalysts from condensation

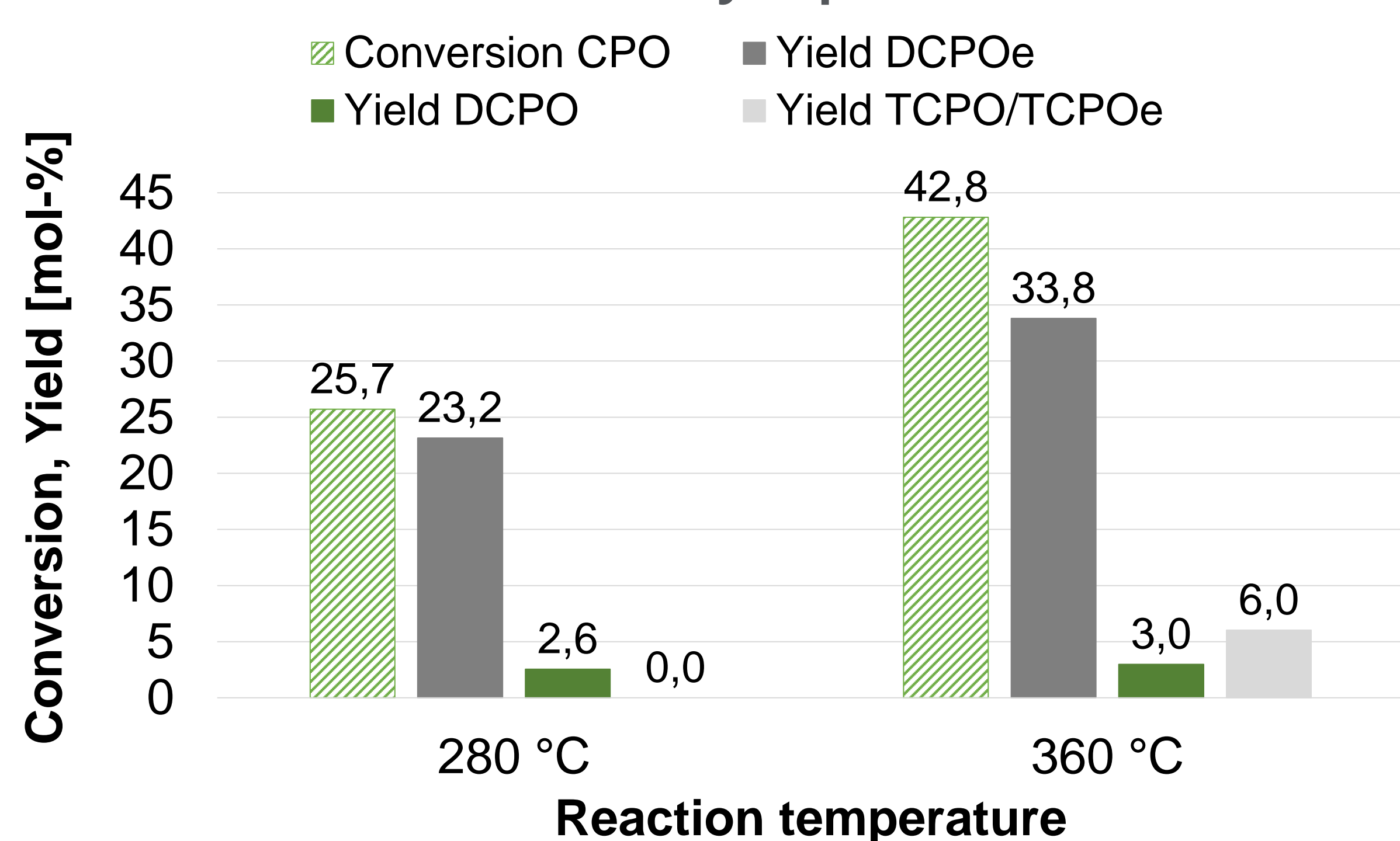


Gas phase condensation

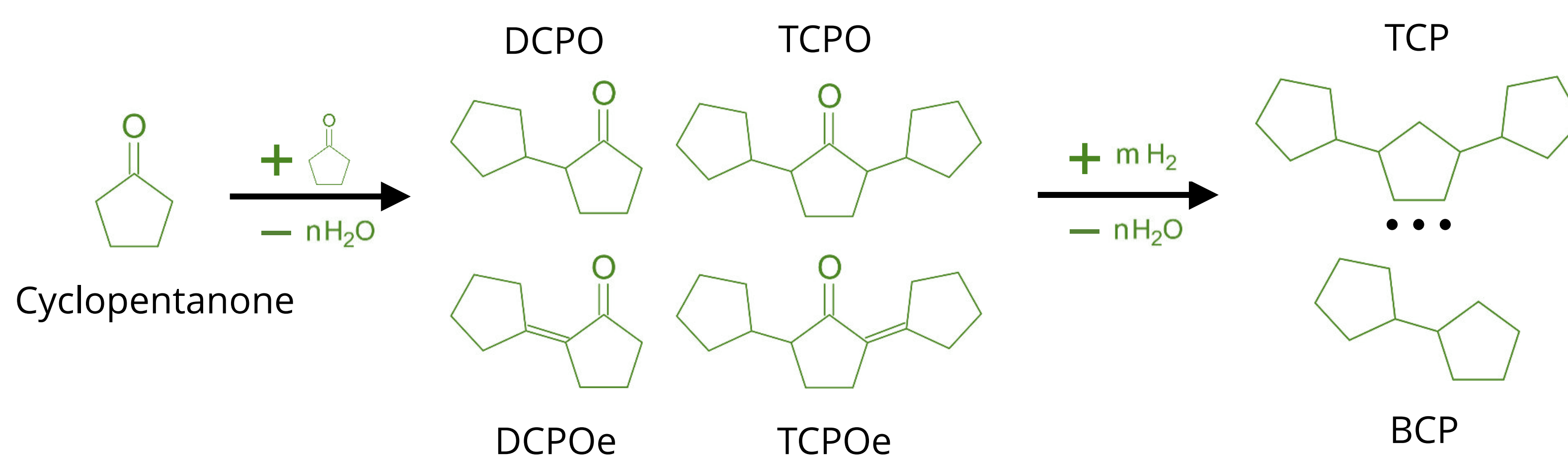
Fraunhofer UMSICHT investigated a high-temperature gas phase condensation for the synthesis of jet fuel precursors. Typical reaction parameters are 320 to 360 °C and a WHSV of 6 mmol g_{cat}⁻¹ h⁻¹. Different commercial and scientific catalyst have been tested for their performance and stability. Finally, a novel basic catalyst developed by Johnson Matthey was chosen for the process development.

As expected, the catalyst showed a significant higher CPO conversion at 360 °C compared to the results at 280 °C. Additionally, at 360 °C tricyclic molecules were formed. Each experiment shows a decreasing catalytic activity between 50 and 80 h time on stream.

Conversion and Yields of cyclopentanone condensation



Condensation and Hydrodeoxygenation reactions



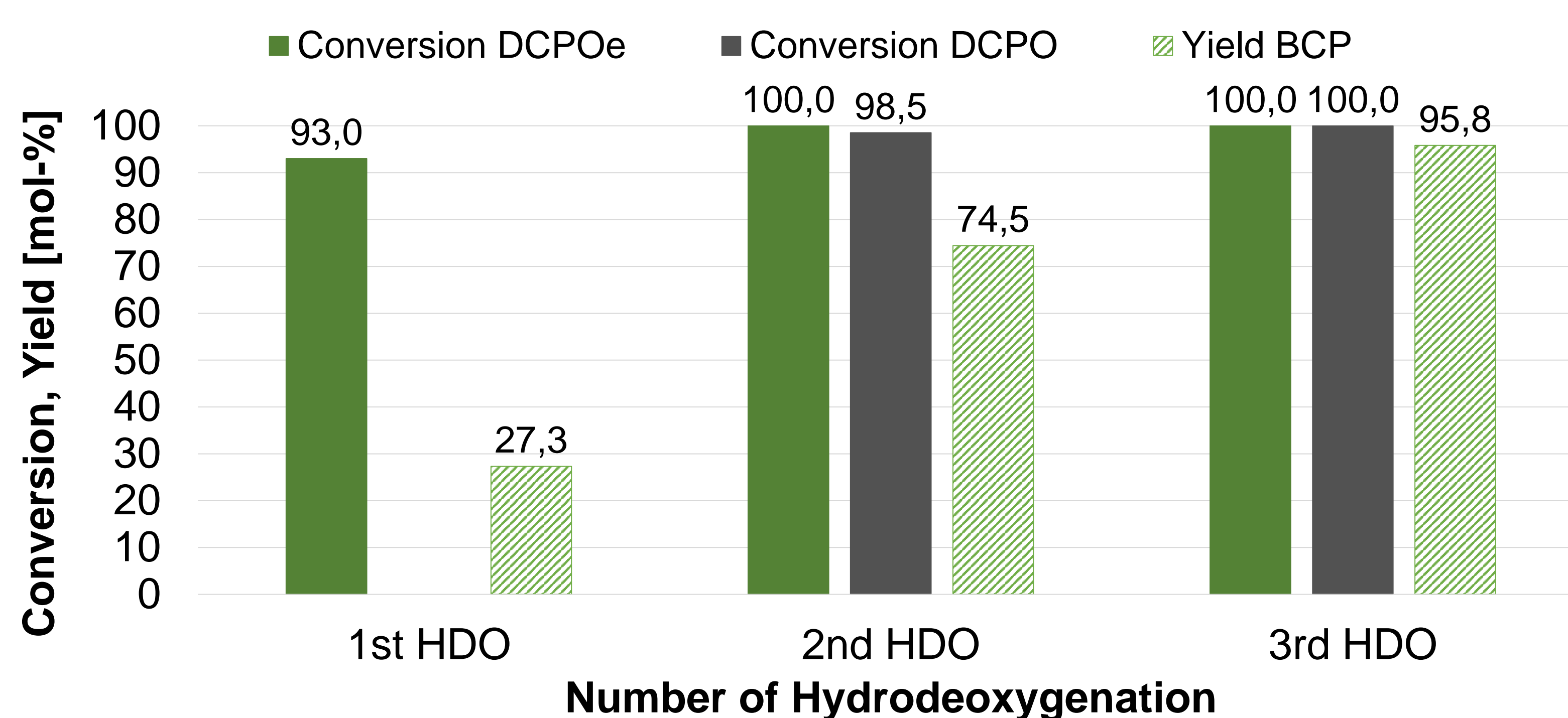
Continuous hydrodeoxygenation

The bicyclic C₁₀ and tricyclic C₁₅ jet fuel intermediates were hydrodeoxygenated in a bench-scale plant. To obtain relevant results regarding future large-scale application the plant was revamped with a gas recycle to analyse accumulation of side products i.e. from cracking.

The intermediates were hydrodeoxygenated three times at identical conditions which are 270 °C reaction temperature, a WHSV of 10 h⁻¹ and 50 bar reaction pressure. The hydrogen excess compared to the stoichiometric demand was 4.

The conversion of the intermediates increases to 100 % after the third HDO, while an overall BCP yield of 95,8 % was reached.

Conversions and Yield of bicyclic molecules during HDO runs



Discussion & outlook

The condensation of cyclopentanone and the subsequent hydrodeoxygenation of the jet fuel intermediates are a promising pathway to cyclic jet fuel components. Especially cyclic non-aromatic compounds are seen as key components for the performance of jet fuel. They are valuable blend components for biobased fuels. For example, the freezing point of BCP is -38 °C and therefore significantly lower than the freezing point of linear hydrocarbons.²

For the synthesis of bi and tricyclic hydrocarbons from cyclopentanone a two-step process has been developed in lab scale. The hydrodeoxygenation was operated stable but the condensation reaction shows a fast catalyst deactivation. The deactivation was addressed by intermediate regeneration. Nevertheless, more research is needed for a large-scale process design.

References

1. IATA, Annual Review 2023: p. 27-29
2. Muldoon, J.A.; Harvey B.G., ChemSusChem, 2020. 13(22): p. 5777-5807

