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Towards Sustainable Ethene: Techno-Environmental Assessment of a Modified Fischer-Tropsch Pathway from CO_2 and H_2

M. Hebenbrock,[1] V. Hagen,[2] T. E. Müller[1,*]
[1] Carbon Sources and Conversion, Ruhr-Universität Bochum
[2] Rubokat GmbH, Bochum

Abstract

Ethene is an important base chemical of the petrochemical industry, yet its conventional production *via* steam cracking is highly carbon intensive.

To provide a sustainable alternative, the SynGas2Ethene project explored an alternative route based on a modified Fischer-Tropsch synthesis (mFTS) based on renewable syngas generated from CO_2 and green hydrogen. The pathway aims to establish a more sustainable and circular value chain for light alkenes. In this subproject, the carbon footprint of mFTS-based ethene production was benchmarked against state-of-the-art technologies.

Data were obtained from mini-plant experiments using Ru- and Ru/Fe-based catalysts in a laboratory scale tubular reactor, exploring a range of process conditions. The focus was on quantifying conversion, product selectivities, and apparent activation energies across relevant temperature and pressure windows. A mechanistically guided kinetic model was implemented in Aspen Plus and validated against experimental data. Deviations between model and experiment were below 6% in high-yield regimes. under low-yield conditions, segmented regression and non-linear fitting methods markedly improved model accuracy.

To assess environmental performance, a cradle-to-gate life cycle assessment (LCA) was carried out. Under current technological conditions, assuming industrial grid electricity and conventionally sourced CO_2, the Global Warming Potential (GWP) of the mFTS-based ethene production was estimated at +1.2 kg CO_2-eq. per kg ethene. In a future scenario relying on renewable electricity and closed-loop CO_2 recycling, the GWP shifts to –7.4 kg CO_2-eq./kg ethene in an idealized cradle-to-gate estimation. This substantial difference underscores the importance of energy source defossilization and carbon circularity.

The results highlight the potential of mFTS to support a transition to carbon-negative alkene production, provided that infrastructure for renewable inputs is in place.