

A-137

Enhancing Waste Gasification-based Methanol Production by Renewable Energy Integration – Hydrogen vs. Plasma

A. Helf¹, F. Keller¹, M. Gräbner^{1,2,3}

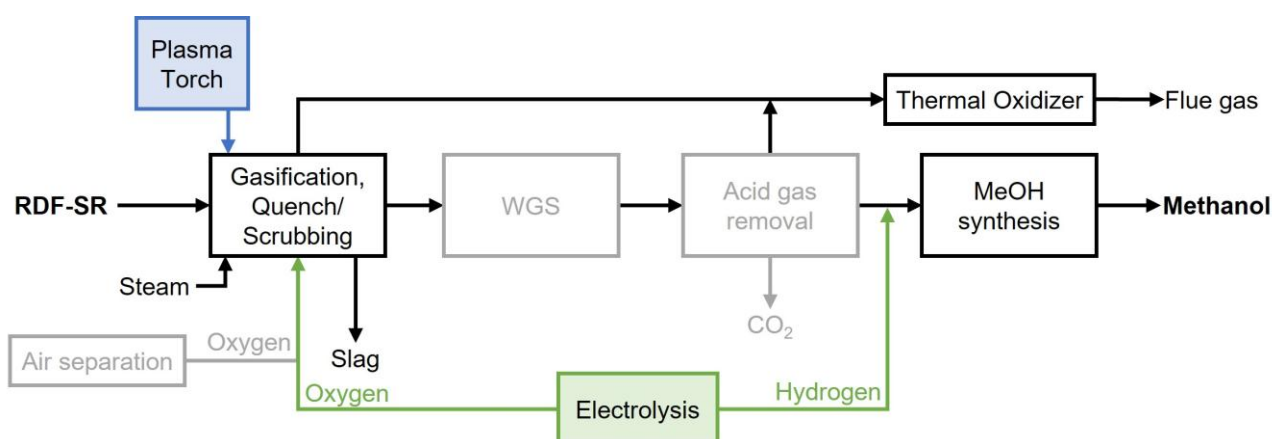
¹TU Bergakademie Freiberg, IEC, Freiberg, Germany, ²Fraunhofer IKTS, Energie- und Verfahrenstechnik - Kohlenstoff-Kreislauf-Technologien, Freiberg, Germany, ³Zentrums für effiziente Hochtemperatur-Stoffwandlung (ZeHS), Freiberg, Germany

Gasification-based chemical recycling offers a route for valorizing mixed and contaminated plastic waste streams that are unsuitable for mechanical recycling, but conventional process chains suffer from substantial carbon losses through intrinsic CO₂ formation during gasification and downstream syngas conditioning. This work addresses the research question of how direct and indirect electrification can improve carbon recovery and economic performance in waste-to-methanol process chains.

The objective is to compare non-electrified oxygen-blown gasification with electrified alternatives using plasma-assisted gasification, electrolytic H₂ integration, and combined plasma/H₂ configurations. Five process chains are assessed for a representative refused-derived fuel sorting residue stream, with methanol selected as the target platform chemical. The study combines thermodynamic process modeling in Aspen Plus with techno-economic assessment. Heat and material balances are generated for gasification, syngas treatment, water-gas shift, acid gas removal, methanol synthesis, electrolysis, and auxiliary systems. The cases are evaluated using carbon recovery rate, product energy yield, CAPEX, OPEX, levelized cost of methanol production (LCOP) and net present value (NPV). Sensitivity analyses and Monte Carlo simulations are used to assess the influence of electricity cost, CO₂ cost, plant availability, technology efficiency, financing assumptions, and investment uncertainty.

The results show that electrification can substantially increase carbon recovery from approximately 52% in the non-electrified reference case to about 82% for plasma-assisted gasification or limited H₂ integration, and to nearly full recovery for configurations with sufficient H₂ input. Plasma-assisted gasification provides the most favorable techno-economic performance among the electrified options, achieving the highest NPV and the lowest LCOP of the electrified cases, at approximately 635 €/t MeOH. H₂-only configurations achieve high carbon recovery but are economically constrained by electrolysis CAPEX and electricity demand.

The study concludes that plasma integration is a promising pathway for low-emission waste management and recycled-carbon methanol production, provided that low-cost, low-emission electricity is available. Further, technology-specific aspects including feedstock applicability and process reliability as well as the applicability of plasma-based energy integration for the production of renewable fuels in the RED legislation are discussed.



Process scheme for gasification-based methanol production with plasma and hydrogen-based energy integration