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From plastic waste to petrochemical utilization by pilot-scale pyrolysis, fractionation and upgrading

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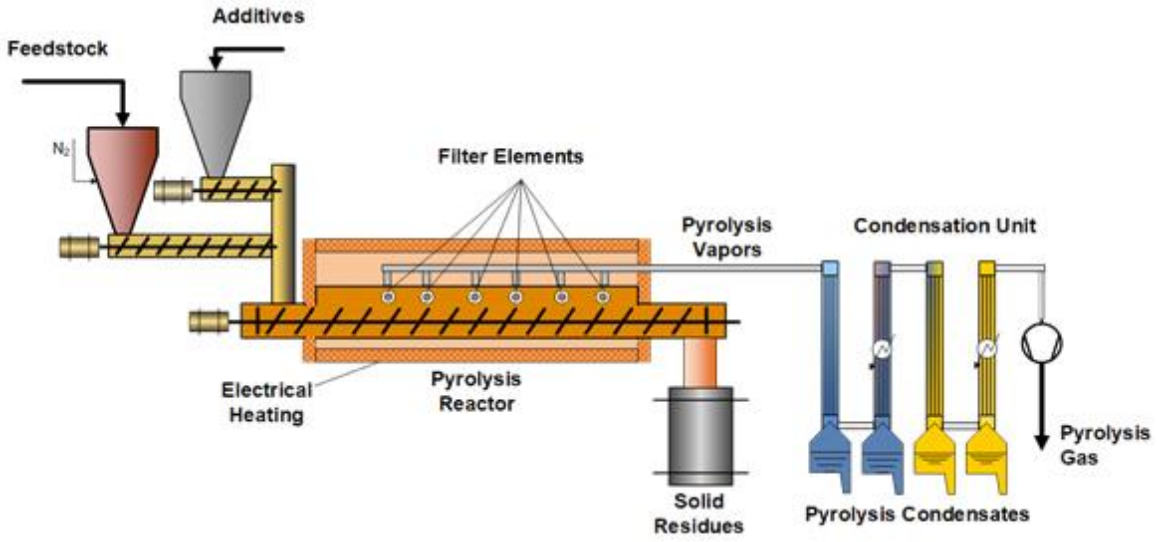
Plastic waste pyrolysis can convert heterogeneous and mechanically challenging waste streams into liquid hydrocarbon products with potential value for the petrochemical industry. However, crude plastic pyrolysis oils are usually not directly suitable as feedstocks for established chemical processes due to their broad boiling range, high chemical complexity, reactive unsaturated compounds and feedstock-specific impurities, including heteroatom-containing species. Targeted downstream processing is therefore required to move from pyrolysis oil production towards specification-oriented utilization.
In this work, plastic waste was converted in a pilot-scale screw reactor at the Institute for Technical Chemistry, KIT, generating representative pyrolysis oils for downstream evaluation [1].



Scheme of the pyrolysis reactor setup.

The oils were fractionated using a fully automatic vacuum distillation unit (PILODIST QuickDist 500 CC) to obtain boiling-range cuts relevant for petrochemical processing. Depending on feedstock composition and target application, these fractions can either serve as starting points for recovering aromatic base chemicals or as potential naphtha and gas oil streams for integration into steam cracking, fluid catalytic cracking or related refinery and petrochemical processes.
Detailed compositional analysis, including comprehensive two-dimensional gas chromatography, was used to describe the molecular structure of the pyrolysis oils and distillation fractions. The analytical and experimental data were then used as input for a model-based process evaluation. This evaluation considers different downstream strategies, including fractionation-driven enrichment of target compounds, recycling of heavy residue to the pyrolysis reactor for additional cracking, and hydrotreating concepts for improving feedstock quality.
The comparison addresses product yields, target compound enrichment, hydrogen and energy demand, heteroatom removal requirements and the suitability of the resulting fractions for petrochemical utilization. In

this way, the work links pilot-scale pyrolysis experiments with analytical oil characterization and process-oriented assessment to identify technically meaningful downstream pathways. The results demonstrate that the value of plastic pyrolysis oils depends not only on the pyrolysis step itself, but strongly on the subsequent fractionation and upgrading strategy selected for the intended petrochemical application.

References:

[1] Jonas Vogt, et al., (2025), Chemical recycling of refrigerator plastic waste by pyrolysis: Yields, product composition, and potential applications, Elsevier Ltd., Fuel, 135776, 400, https://doi.org/10.1016/j.fuel.2025.135776