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Pilot-Scale Fluidized Bed Gasification: How steam-to-biomass ratio affects syngas quality

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The transition from fossil fuels to renewable carbon sources requires diverse technological pathways. Gasification of biogenic residues offers a resilient route to convert feedstock energy and carbon into chemicals and fuels, less exposed to electricity market volatility than Power-to-X.
High-Temperature-Winkler® (HTW®) gasification is particularly promising, delivering high-quality syngas with minimal fuel pre-treatment. This study presents the first comprehensive evaluation of construction and demolition waste wood as feedstock for HTW® gasification.
Pilot-scale experiments were performed, in the 500 kW_{th} scale, at TU Darmstadt in an 11 m high, 400 mm Ø HTW® pilot plant featuring a bubbling fluidized bed in the conical lower section and a post-gasification zone above. Biomass pellets were fed into the bubbling bed where pyrolysis initiates the release of volatile compounds. Fluidization is achieved using steam, which also participate in endothermic gasification reactions with the fixed carbon. Oxygen and steam are injected at different reactor levels. The exothermic oxidation reactions with oxygen, supply the necessary heat for the endothermic steam gasification, producing valuable syngas components such as CO and H_2.
This pilot plant was used to conduct a comprehensive 100+ hours experimental campaign, focusing on the autothermal gasification of pelletized waste wood. During the campaign the steam to biomass ratio is varied systematically to identify conditions maximizing syngas yield and quality. This ratio significantly influences reactor temperature profiles, reaction kinetics, and product gas composition.
Performance indicators including syngas composition, yields and heavy hydrocarbon content, carbon conversion, and cold gas efficiency are evaluated. The bubbling bed temperature is found to have a major impact on pyrolysis behaviour and tar formation. In the post-gasification zone, additional oxygen injection raised temperatures up to 920 °C, promoting the decomposition of hydrocarbons and improving syngas quality. Lowering steam mass flow in the gasifier reactor increases the temperatures, CO concentration and the CO/H_2 ratio in the syngas, while H_2 remains stable. Methane and ethylene levels slightly decrease, enhancing syngas quality.
This study is conducted within the EU-funded project Bio-MeGaFuel and provides valuable experimental data for the development of scale up of HTW® technology with waste wood.