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Single-step syngas-to-distillates (S2D) process based on biomass-derived syngas – A techno-economic analysis

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HIGHLIGHTS

- ▶ Single-step syngas-to-distillate (S2D) synthesis approach is developed in lab scale.
- ▶ A systematic model combining biomass gasification and this single-step S2D is developed.
- ▶ Performance and cost are estimated for three cases with different assumptions.
- ▶ Key factors affecting the distillate production cost are identified.

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ABSTRACT

This study compared biomass gasification based syngas-to-distillate (S2D) systems using techno-economic analysis (TEA). Three cases, state of technology (SOT), goal, and conventional, were compared in terms of performance and cost. The SOT case represented the best available experimental results for a process starting with syngas using a single-step dual-catalyst reactor for distillate generation. The conventional case mirrored a conventional two-step S2D process consisting of separate syngas-to-methanol and methanol-to-gasoline (MTG) processes. The goal case assumed the same performance as the conventional, but with a single-step S2D technology. TEA results revealed that the SOT was more expensive than the conventional and goal cases. The SOT case suffers from low one-pass yield and high selectivity to light hydrocarbons, both of which drive up production cost. Sensitivity analysis indicated that light hydrocarbon yield and single pass conversion efficiency were the key factors driving the high cost for the SOT case.

1. Introduction

With increasing oil prices and depletion of global fossil fuel reserves, exploiting renewable sources for liquid transportation fuel is critical for reducing our dependence on fossil fuels and meeting increased energy demand. Biomass is an important domestic resource that has the potential to make a significant impact on domestic fuel supplies. Liquid fuels produced from biomass have been shown to have similar properties as those derived from crude oil, such as biodiesel generated from biomass gasification and Fischer–Tropsch (F–T) process (Kreutz et al., 2008). As a result, no substantial change to the current transportation fuel infrastructure is required to integrate biofuels into the fuel supply system, but production cost remains an issue.

Biomass can be converted to liquid fuels and chemicals via both thermochemical or biological approaches. For thermochemical approaches, biomass gasification or direct liquefaction are normally used to convert biomass to synthesis gas ("syngas") or bio-oil, respectively. Compared to liquid oil from liquefaction processes, syngas produced from biomass gasification has more flexibility for producing various products via synthesis and upgrading, such as hydrogen, methanol, mixed alcohols, gasoline, diesel, or electricity (Mueller-Langer et al., 2007; Phillips, 2007; Tijmensen et al., 2002; McIlveen-Wright et al., 2011). Biomass gasification technologies have been well developed and demonstrated, such as two biomass gasification based combined heat and power (CHP) production demonstration plants (scales of 2 MWe and 500 kWe) in Güssing and Wr. Neustadt, Austria, respectively (Bolhàr-Nordenkampf and Hofbauer, 2004).

In this study, biomass gasification based syngas-to-distillate (S2D) technology is investigated. In gasification, biomass is converted to syngas consisting of hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), and tars, which can be cleaned, and adjusted for liquid fuel production. A conventional S2D technology involves syngas conversion to methanol at 50–100 atm and

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