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Biomass to liquid: A prospective challenge to research and development in 21st century

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ABSTRACT

The biomass to liquid refineries need to build on the need for sustainable chemical products through modern and proven green chemical technologies such as bioprocessing including pyrolysis, Fisher Tropsch, and other catalytic processes. This review focuses on cost effective technologies and the processes to convert biomass into useful liquid biofuels and bioproducts. One of the most promising options to produce transportation fuels from biomass is the so-called biomass to-liquid (BTL) route, in which biomass is converted to syngas from which high-quality Fischer–Tropsch (FT) fuels are synthesized. Pretreatment of biomass is an important part of the BTL route, both to allow feeding of the biomass into the selected entrained-flow gasifier and to reduce transport costs by densification. A large-scale, central, overseas BTL synthesis plant would be the most attractive route for BTL production and it identifies biomass-to-liquid (BTL) fuels as the most promising way to accomplish the target. The evaluation of the future role of BTL is difficult due to complex and uncertain interdependencies between factors of influence. This study elaborates a life cycle assessment of using of BTL-fuels and the possible implementation of BTL-fuel production processes would potentially help to achieve this goal. The emissions of greenhouse gases due to transport services could be reduced by 28–69% with the BTL-processes using straw, forest wood or short-rotation wood as a biomass input. The reduction potential concerning non-renewable energy resources varies between 37% and 61%. BTL-fuel from forest wood is an interesting option to reduce the greenhouse gas emissions and environmental impacts. The LCA study shows that it is possible to produce BTL-fuels, which are competitive to fossil fuels from an environmental point of view. But, it also shows that for the use of agricultural biomass further improvements in the life cycle would be necessary in order to avoid higher environmental impacts than for fossil fuels. There is no general conclusion concerning the comparison of BTL-fuels with other renewable or fossil fuels due to the variety of different conversion concepts and possible biomass resources.

Contents

Abbreviations: BTL, biomass-to-liquid fuel including FT-fuel, methanol and DME produced from synthesis gas; BMTL, BTL (multi step) process; SNG, synthetic natural gas; CEF-D, centralized entrained flow gasification; CFB, circulating fluidized bed; CFB-D, centralized autothermal circulating fluidized bed gasification; MTS, methanol-to-synfuel; EUCAR, European Commission with the European Council for Automotive R&D; O&M, operation and maintenance; SD, sun diesel; FC, fuel cell; SI ICE, petrol engine; CI ICE, diesel engine; PEM, proton exchange membrane; H_2CO, formaldehyde; CH_3OH, methanol; MTBE, methyl-tertiary-butyl-ether; DMFC, direct methanol fuel cells; CH_3OCH_3, DME; H_2, hydrogen; CNG, compressed natural gas; CH, Switzerland; CTL, coal to liquid; DME, dimethylether; EI'99, Eco-indicator 99 (H, A); FT, Fischer–Tropsch (synthesis); GWP, global warming potential; GHG, greenhouse gases; GTL, gas-to-liquid; HHV, higher (upper) heating value; ISO, International Organization for Standardization; LCA, life cycle assessment; LCI, life cycle inventory analysis; LCIA, life cycle impact assessment; LHV, lower heating value; LPG, liquid petroleum gas; PM, particulate matter; Pt points, Eco-indicator 99 (H, A) or ecological scarcity 2006; RENEW, renewable fuels for advanced power trains; SNG, synthetic natural gas.

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1. Introduction

Biomass to liquid is a process by which, liquid biofuels produced from biomass. A generation with potential for the future: biomass-to-liquid fuels promise high returns and CO_2 neutrality as well as ideal prospects for large-scale production. Lignocellulose provides the basis for this fuel such as straw, wood, energy crops, agricultural waste – nearly all sorts of solid biomass in the world can be considered for the production of BTL biofuel. To produce BTL biofuel, biomass is converted into synthesis gas, which is subsequently processed into synthetic biofuels. Just as in the production of bioethanol from lignocellulose, the entire plant is used for BTL biofuels. This increases yields, while at the same time reducing the land that needs to be cultivated [1,2]. BTL fuels also have a very special property: their quality is even better than that of fossil fuels. They excel through significantly lower CO_2 emissions, zero emission of particulate matter, low NO_x emissions and an adjustable product quality (octane and cetane number). As a result they can be used pure or as a blend in vehicles without the engine having to be modified. Biomass to liquid (BTL) is one of the most promising processes available in the fuel sector. The greatest advantages of the resulting synthetic biofuel lie in the high biomass yield (up to 4000 l/ha), its high potential to reduce CO_2 emissions by over 90% and its high quality, which is not subject to any limitations of use in either today's engine or foreseeable next-generation engines. In its fuel strategy, the German government has therefore stated that BTL fuels have great potential for securing supply, mitigating climate change and providing added value in rural areas, and has decided to promote the development of this innovative fuel in a number of ways. German industry has earned itself a leading position in the global development of this technology. Biomass to liquid (BTL) or BMTL is a (multi step) process to produce liquid biofuels from biomass: the process uses the whole plant to improve the carbon dioxide balance and increase yield [3].

- The Fischer–Tropsch process is used to produce synfuels from gasified biomass. While biodiesel and bio-ethanol production so far only use parts of a plant i.e. oil, sugar, starch or cellulose, BTL production uses the whole plant which is gasified by gasification. The result is that for BTL, less land area is required per unit of energy produced compared with biodiesel or bioethanol.
- Flash pyrolysis – producing bio-oil, char and gas at temperatures between 350 and 550 °C and residence times <1 s (also called anhydrous pyrolysis).
- Catalytic depolymerization – using heat and catalysts to separate usable diesel fuel from hydrocarbon wastes.

The term BTL is applied to synthetic fuels made from biomass through a thermo chemical route. The objective is to produce fuel components that are similar to those of current fossil-derived petrol (gasoline) and diesel fuels and hence can be used in existing fuel distribution systems and with standard engines. They are also known as synfuels. Although the processes for production of BTL are well known and have been applied using fossil-feedstocks such as methane (GTL) or coal, commercial biofuels based on these technologies are not currently available in the market place [4]. However, BTL research & development in Europe is gathering momentum and the world's first commercial BTL plant is under construction in Frieberg Saxony, utilizing the Choren Carbo-V® Process.

2. Biomass-to-liquid (current process)

Currently, the major biomass-to-liquid production processes are gas-to-liquid conversion and pyrolysis. Both processes employ heat and chemical reactions to convert biomass into fuels, chemicals and power. The products of both processes are cleaner and more efficient than the solid biomass from which they were derived. Another benefit is that biomass-to-liquid processes can convert types of biomass such as wood and agricultural residues that are difficult to handle using other biofuel production processes.