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Biomass for Swiss Energy Future
Swiss Competence Center for Energy Research

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Biomass to liquid fuels

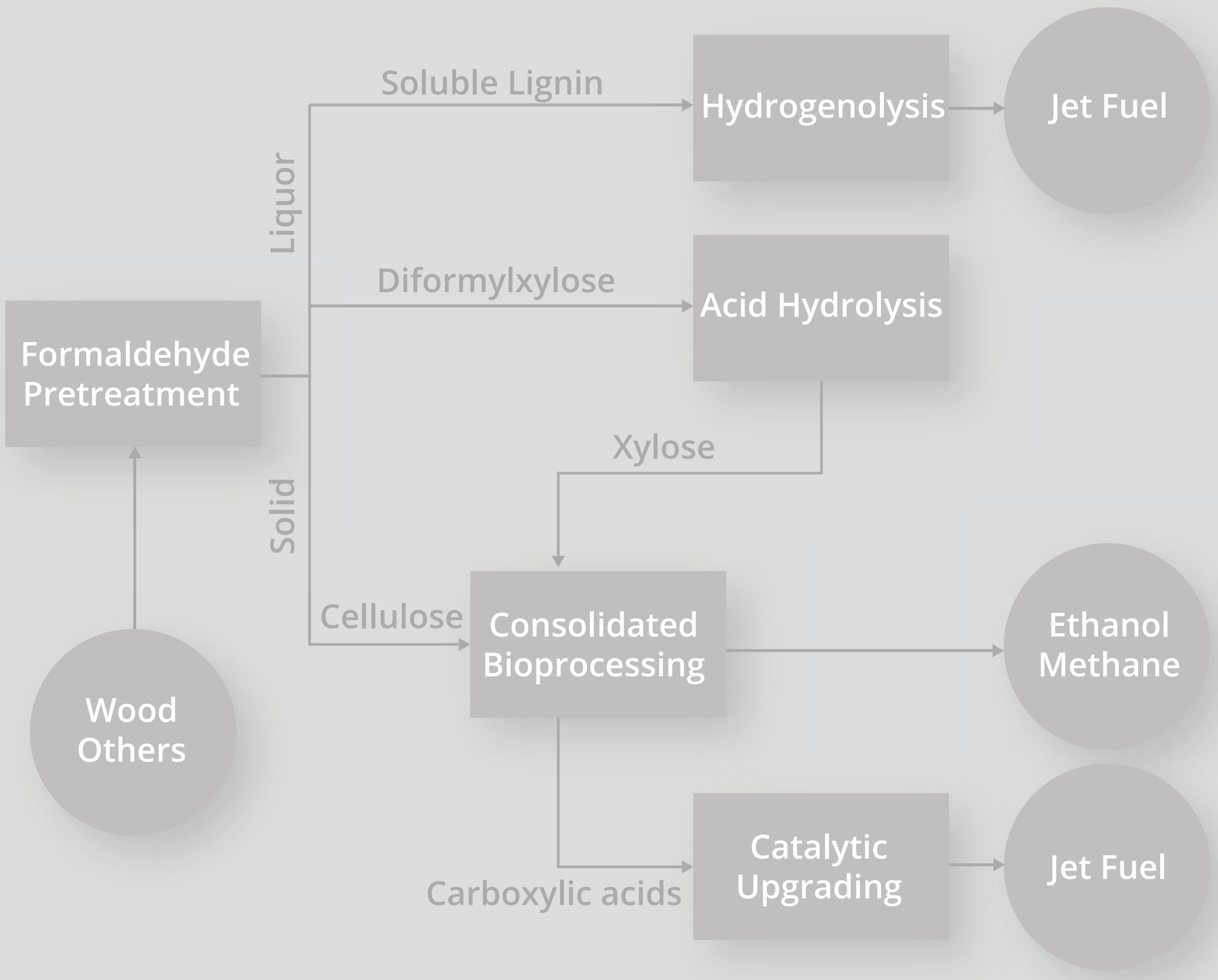
Novel method for efficient liquid fuels production

Combining new technologies for efficient fuel production

Aviation, heavy-duty machinery, long-haul transportation and marine applications will continue to depend on liquid fuels. These sectors can be decarbonized with renewable fuels derived from biomass. Sustainable production of these fuels requires interdisciplinary efforts from chemistry, microbiology and biochemistry. Ecological and social demands have to be considered all along the process chain.

The liquid fuel efforts within the SCCER BIOSWEET are focused on three main steps: pretreatment of biomass, bioprocessing and catalytic upgrading. The main task is to decrease the number of stages in each of the processes while increasing their efficiency. Less stages means reduced costs and easier adaptation to decentralized conditions like in Switzerland. The biomass pretreatment technologies that we have developed allow us to efficiently produce lignin monomers from cellulosic material with some of the highest reported yields in the literature. The remaining polysaccharides are converted in one stage within a combined bioprocessing reactor to carboxylic acids. This highly efficient biological funneling, produces a narrow distribution of product with a simple chemical structure that can be subsequently catalytically upgraded in a single step to liquid fuels.

Material flow of the new SCCER BIOSWEET biofuel production processes



Formaldehyde Pretreatment

Biomass pretreatment can play a significant role in the profitability of bio-refineries by enabling the extraction and upgrading of the major plant components. Even though lignin content in biomass is 15-30% by mass and up to 40% by energy and has the chemical structure which is closest to jet fuel within the plant, existing processes are mainly focusing on separation of polysaccharides, while the remaining lignin is used for heat production in furnaces.

A recently developed Formaldehyde (FA) pretreatment method enables us to perform a fractionation in a way that all the main components of biomass including cellulose, hemicellulose and lignin can be separated and used for further upgrading to higher value-added chemicals. This achievement could allow us to build more practical and economically feasible bio-refineries. The resulting soluble lignin can already be turned into jet fuel components at the lab scale.

Technology Readiness and Roadmap 2020

We have demonstrated this process in the lab. Further research is focused on optimization and configuring the process for integration in existing bio-refineries. By the end of 2016, a method will be developed for soluble lignin upgrading under mild condition in flow reactor and we will test continuous processing for several days. In 2017, further studies will start on cellulose upgrading to adjust the pretreatment and consolidated bio-processing to become compatible with conventional bio-refineries. The complete production process shall be patented in 2019.

Suitable feedstock

> Wood
> Straw and Corn Stover
> Mixed grasses
> Solid digestate from biogas plants

Consolidated Bioprocessing

Conventional biochemical production of fuels is an elaborate process. The process comprises three main operations: pretreatment, enzymatic hydrolysis and fermentation. It is complemented with additional solid/liquid separation, washing and detoxification steps.

In order to simplify the production and make it more cost effective we developed a highly integrated process. A microbial consortium consisting of a cellulolytic enzyme producer and a product fermenter allows for the direct conversion of pretreated biomass to the target product. The microorganisms grow in the biomass slurry from pretreatment as a two-layered biofilm on an oxygen permeable membrane. The aerobic fungal cellulolytic enzyme producer forms the first layer directly on the membrane. The anaerobic fermentative microorganisms grow on top of this first layer. Growth of the microorganisms benefits from their immobilization in the biofilm, which prevents wash out, and from the pretreatment, which protects against toxic environments.

Suitable feedstock

Consolidated bioprocessing can follow on Formaldehyde pretreatment or on other preparation steps like steam pretreatment.

Technology Readiness and Roadmap 2020

We successfully produced ethanol and lactic acid from pure cellulose and from pretreated beech wood on laboratory scale. C5- and C6-sugars were fermented simultaneously with yields up to 80% and product concentrations up to 50g/L. In 2016/17, we are working on the expansion of the output spectrum towards carboxylic acids as fuel precursors and towards higher alcohols. 2018 – 2020 a pilot scale ethanol production shall be commissioned together with industrial partners.

Marketable Product

> Ethanol
> Carboxylic acids (lactic, acetic, propionic)
> Methane

Catalytic Upgrading

Catalytic processing of diluted carboxylic acids streams is challenging because of their acidity and high water content which can deactivate the catalyst. Moreover, the products that result from current technologies tend to have a low energy content, which decreases their value as a fuel. However, by selectively choosing the upgrading catalyst, these issues can be addressed.

We have developed a process for the single stage condensation of carboxylic acids to a high value liquid fuel stream that can be used as a jet fuel. This stream has less than 1 wt% oxygen and spontaneously separates from water. Carboxylic acids are converted via multiple condensation reactions to alkanes of a suitable fuel range (C8-C16). These hydrocarbons are simultaneously (in situ) deoxygenated leading to a product with a high energy density. No irreversible deactivation of the catalyst was noticed using neat and diluted carboxylic acids streams. The resulting biphasic mixture of water and hydrocarbons can be easily separated.

Technology Readiness and Roadmap 2020

This process was demonstrated in the laboratory with model substrates. By mid-2016 reaction pathways and catalyst stability tests will be finished. By the end of 2016, continuous laboratory-scale experiments with biomass-derived feeds will be performed. In early 2017, we will test the effects of different modified streams obtained from consolidated bioprocessing. Depending on the results higher throughput reactor will be constructed to test production at a pre-pilot scale.

Marketable Product

> Jet fuel
> α-olefins

Lignin (left) and polysaccharide (right) derived jet fuel produced in our laboratory.

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