

Bioenergy value chain 1: biomass to liquid



Feedstock

For gasification, any lignocellulosic material is suitable as feedstock. The term lignocellulosic covers a range of plant molecules/biomass containing cellulose, with varying amounts of lignin, chain length, and degrees of polymerization. This includes wood from forestry, short rotation coppice (SRC), and lignocellulosic energy crops, such as energy grasses and reeds. Biomass from dedicated felling of forestry wood is also lignocellulosic but is not considered sustainable.

Gasification

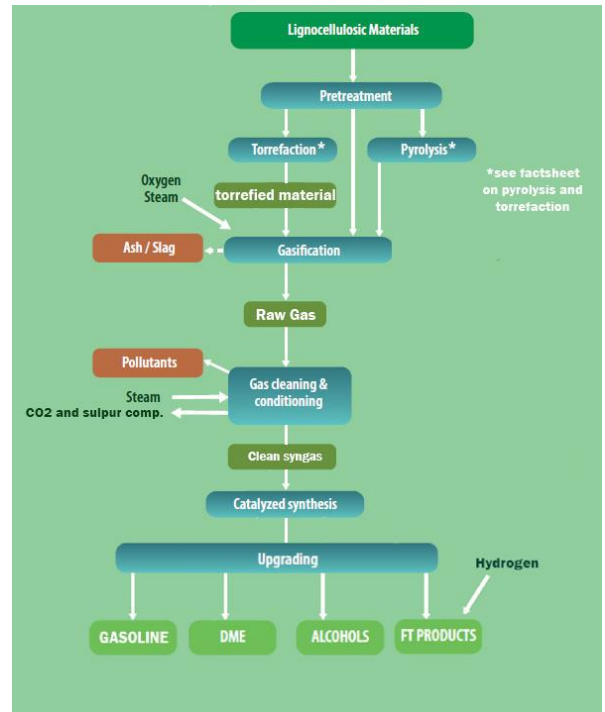
Gasification is a thermochemical process at 800-1300°C run at under-stoichiometric conditions (typically $\lambda = 0.2-0.5$). Under these conditions the biomass is fragmented into raw gas consisting of rather simple molecules such as: hydrogen, carbon monoxide, carbon dioxide, water, methane, etc. Solid by-products are: char, ashes and impurities. The gaseous molecules are then chemically re-synthesized to biofuels.

After size reduction of the raw material, it is moved into the gasifier. Typical gasification agents are: oxygen and water/steam. The choice of the gasification agent depends on the desired raw gas composition. The combustible part of the raw gas consists of hydrogen (H₂), carbon monoxide (CO), methane (CH₄) and short chain hydrocarbons; the non-combustible components are inert gases. A higher process temperature or using steam as gasification agent leads to increased H₂ content. High pressure, on the other hand, decreases the H₂ and CO.

Entrained-flow gasifiers operate at high temperatures (1000-1300 °C) and are therefore suitable when a low methane content is preferred. Bubbling and circulating bed gasifiers in contrast are operated at lower temperatures (800-1000 °C).

The process heat can either come from an autothermal partial combustion of the processed material in the gasification stage or allothermally via heat exchangers or heat transferring medium. In the latter case the heat may be generated by the combustion of the processed material (i.e., combustion and gasification are physically separated) or from external sources.

Figure 1: biomass-to-liquid value chain



End products

Biomethanol

Can be blended to gasoline; purely used in race cars

BioDME

Stored in the liquid state under relatively low pressure of 0.5 MPa

Biogasoline

Renewable diesel

Biokerosene (jet fuel)

In contrast to bioethanol or biodiesel (FAME), biogasoline, renewable diesel and biokerosene have the same combustion properties as their fossil based equivalents, gasoline, diesel or kerosene. They can thus be used without adaption or blend-limits in conventional engines.

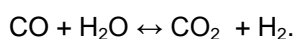
By-products

Naphta, e.g. from FT synthesis

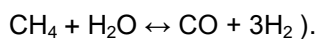
Impurities of the raw gas depend on the gasification condition and used biomass and can cause corrosion, erosion, deposits and poisoning of catalysts. It is therefore necessary to clean the raw gas. Depending on technology impurities such as dust, ashes, bed material, tars and alkali compounds are removed through various cleaning steps. Components having mainly poisonous effects are sulphur compounds, nitrogen and chloride. The sulphur compounds can be withdrawn by commercially available processes; to get rid of nitrogen and chloride wet washing is required.

The cleaned raw gas will then be upgraded to clean synthesis gas (syngas).

An optimal H₂/CO ratio of about 1 – 2 is obtained by the Water-gas-shift reaction:



The gas reforming reaction converts short-chain organic molecules to CO and H₂ (for example



CO₂ removal can be performed by physical or chemical methods. Other absorption methods are based on pressure or temperature variations.

Product formation

Fischer-Tropsch-Liquids

In the Fischer-Tropsch (FT) process, the clean syngas is transformed into alkanes using mostly iron and cobalt as catalysts. The Low Temperature Fischer-Tropsch (LTFT) technology (200 – 220°C and less 20 bar) provides outputs for diesel production. The raw product, though, cannot be directly used as fuel, it needs to be upgraded via distillation to split it into fractions; via hydration and isomerization of the C₅ – C₆ fraction and reforming of the C₇ – C₁₀ fraction in order to increase the octane number for gasoline use; and via cracking by application of hydrogen under high pressure in order to convert long-chain fractions into gasoline and diesel fraction.

Methanol and dimethyl ether (DME)

The syngas is converted into DME via a two-step synthesis, first to methanol in the presence of catalyst (usually copper-based), and then by

Example projects on biomass-to-liquid production

Pilot

BioDME producing DME; formerly operated by Chemrec and LTU (Sweden); now idle

Bioliq producing biogasoline; run by Karlsruhe Institute of Technology (Germany); operational since 2014

Güssing FT producing renewable diesel on gasifier side stream; run by Vienna University of Technology and BIOENERGY 2020+ (Austria); operational since 2005

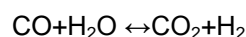
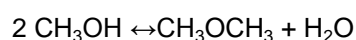
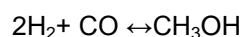
BioTfuel will produce biokerosene; run by a French industrial consortium; planned operation 2020

Demo

None in Europe

Edmonton Waste-to-Biofuels project producing ethanol and methanol; run by Enerkem (Canada); operational since 2014

The following reactions occur:



Alternatively, DME can be produced through direct synthesis using a dual-catalyst system which permits both methanol synthesis and dehydration in the same process unit, with no intermediate methanol separation.

Further information

Read up-to-date information about the thermo-chemical conversion technology at www.biofuelstp.eu.