**European Biofuels**
TECHNOLOGY PLATFORM

**Biofuel Fact Sheet**

# Bioenergy value chain 6: sugar to hydrocarbons

## Feedstock

Sugars can be fermented into alcohols. Sugars are obtained from sugar crops, starch crops and lignocellulose.

### Sugar crops

Among sugar crops, the most extended are sugarcane and sugar beet, and to a lesser extent, sweet sorghum. The sugar is extracted via milling (sugarcane, sweet sorghum) or via heat extraction and vaporisation (sugar beet).

### Starch crops

Starch crops are mainly maize, wheat, other cereals and potatoes. Starch is a polysaccharide and needs to be hydrolized into monosaccharides (sugars) for fermentation. For this saccharification the techniques commonly applied is enzymatic hydrolysis, generally associated to ”jet cooking”.

In the enzymatic hydrolysis, the starch crops are crushed and mashed; then enzymes (e.g. amylases) are added to the mash which dissolve the starch into sugar.

### Lignocellulosics

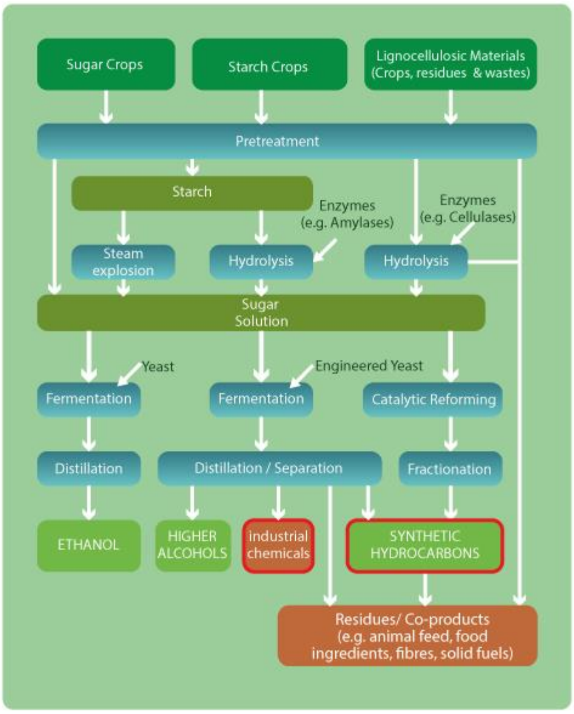
Lignocellulose is the structural material of biomass. It consists of cellulose (mainly C6 sugar polymers like the sugar extracted from sugar and starch crops), hemicellulose (mainly C5 sugar polymers) and lignin (aromatic alcohol-polymers). The term lignocellulosics includes agricultural and wood residues, wood from forestry, short rotation coppices (SRC), and lignocellulosic energy crops, such as energy grasses and reeds.

A pretreatment is generally first applied on the raw material before saccharification to separate the different above elements. The most common one is the steam explosion associated or not with an acid catalyst.

Once the cellulose and the hemi-cellulose are separated from the lignin, saccharification of these polysaccharides can take place, generally speaking through enzymatic hydrolysis (use of cellulases and hemi cellulases).

The C6 sugars can be fermented by common yeasts while C5 sugars need specific microorganisms to get fermented. Lignin is for now usually separated and dried to be used as a fuel for the process or for power generation.

Figure 1: Biochemical value chains



## Intermediate products

Furanics
Blended with diesel and gasoline

Farnesene
Feedstock for renewable diesel

## End products

Bio-gasoline

Renewable diesel

Bio-kerosene (jet fuel)

Bio crude oil

Isobutanol
Blended with gasoline and diesel

## By-products

Lignin
Often combusted to produce process heat; also serves as feedstock for a variety of chemical products.

## Farnesene via microbial fermentation

Engineered yeasts can be used to ferment sugar into a class of compounds called isoprenoids which includes pharmaceuticals, nutraceuticals, flavors and fragrances, industrial chemicals and chemical intermediates, as well as fuels. One of these isoprenoids is a 15-carbon hydrocarbon, beta-farnesene.

Beta-farnesenes can be chemically derivatized into a variety of products, including diesel, a surfactant used in soaps and shampoos, a cream used in lotions, a number of lubricants, or a variety of other useful chemicals. This process is applied by Amyris.

## Catalytic Reforming

Soluble carbohydrate streams can consist of a wide range of molecules such as C5/C6 sugars, polysaccharides, organic acids, furfurals and other degradation products generated from the deconstruction of biomass. These can be processed through aqueous phase reforming (APR). The aqueous phase reforming step utilizes heterogeneous catalysts at moderate temperatures and pressures to reduce the oxygen content of the carbohydrate feedstock. Some of the reactions in the APR step include: (1) reforming to generate hydrogen; (2) dehydrogenation of alcohols/hydrogenation of carbonyls; (3) deoxygenation reactions; (4) hydrogenolysis; and (5) cyclization. Hydrogen is produced in-situ from the carbohydrate feedstock.

The product from the APR step is a mixture of chemical intermediates including alcohols, ketones, acids, furans, paraffins and other oxygenated hydrocarbons. Once these intermediate compounds are formed they can undergo further catalytic processing to generate a cost-effective mixture of nonoxygenated hydrocarbons.

The chemical intermediates from the APR step can be reacted over a zeolite catalyst (ZSM-5) to produce a high-octane gasoline blendstock that has a high aromatic content similar to a petroleum-derived reformate stream.

The chemical intermediates from the APR step can also be converted into distillate range hydrocarbon components through a condensation step followed by conventional hydrotreating.

## Example projects on sugar-to-hydrcarbons production

### Pilot

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| **Avantium** | Dutch company producing furanic building blocks via catalytic dehydration followed by an oxidation process;<br>operational since 2011 |
| **Gevo** | US-company producing isobutanol via biocatalysis/ fermentation;<br>operational since 2012 |
| **Neste/ DONG Energy** | Finnish/ Danish joint venture to develop sugar-to-oil technology; pilot phase completed in 2014 |

### Demo

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|---|---|
| **Virent** | US-facility producing renewable diesel from sugar via the patented Aqueous Phase Reforming (APR);<br>operational since 2009 |

### First-of-its-kind commercial

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|---|---|
| **Amyris** | US-company producing farnesene from sugars facilities in Brazil;<br>first started in 2009 |

## Further information

Read up-to-date information about the biochemical conversion technology on www.biofuelstp.eu.