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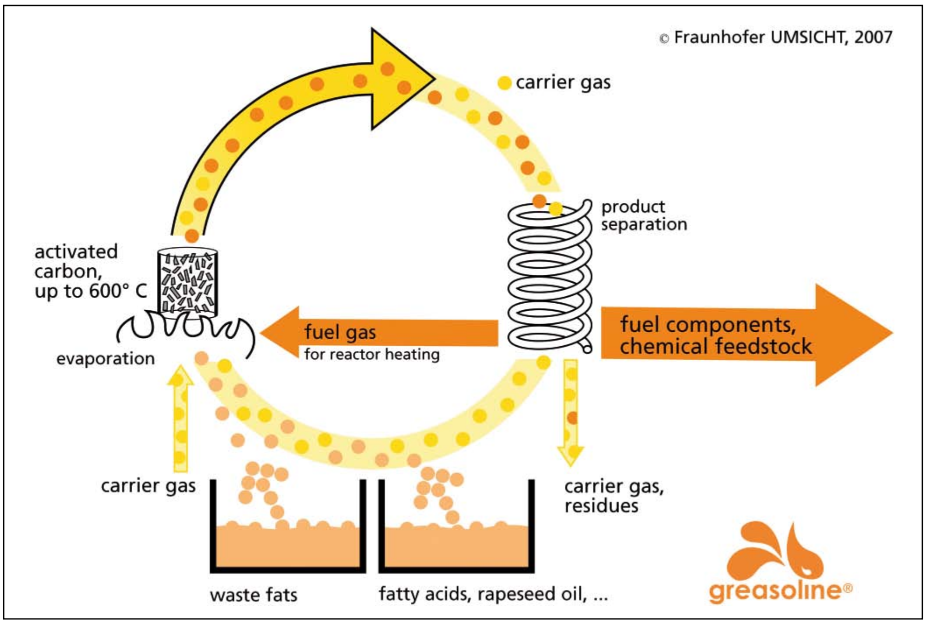
Boost Biorefineries

Future Concepts for Efficient Energy Production

Innovative Strategies – In times of high and continually rising energy demand and decreasing oil resources a supply of alternative resources is gaining in importance. Besides the increasing number of bioethanol and biodiesel plants, the development of biorefineries – that follow the concept of petroleum chemistry – to produce various products by highly efficient utilization of raw materials including waste and heat, has to be pushed.

According to the current state of knowledge, the term biorefinery means equipment and processes that convert biomass into fuels and chemicals and may produce electricity. This definition, given by the U.S. Department of Energy describes production systems from acre to products. These include energy, fuels, high value products for food or feed and chemicals for construction materials, cosmetics or medical applications. In addition, biorefineries are often discussed as processing plants for the biotechnological conversion of biomasses. In this view they are integrated production systems of the white biotechnology. Here the basic chemicals for the materials industry, that are traditionally obtained by steam cracking fossil oil, should be more and more replaced by products which are based on carbohydrates, vegetable fats/oils, lignin and proteins.

The most manufactured biofuel product worldwide is bioethanol with over 50 million m³ in 2007, and the major portions are produced in the U.S. (49 %) and Brazil (42 %). According to the European biodiesel board there are 241 existing biodiesel plants within the EU27 with an estimated maximum capacity of altogether 16 million t/a. In contrast to these established process routes, 2nd generation refineries that use the organic waste fraction from agriculture and ligno-cellulose are still rare. Existing production sites for biogas, biodiesel and bioethanol offer essential preconditions to be reformed to multi-product refineries. Although they have not been fully developed yet, they have the potential for the production of fuels and chemicals beside the food production using waste and non-food plants.



Catalytic conversion of waste fat and oils to biogenous diesel and gasoline – greasoline process

Concepts for Processing Non-food Biomass

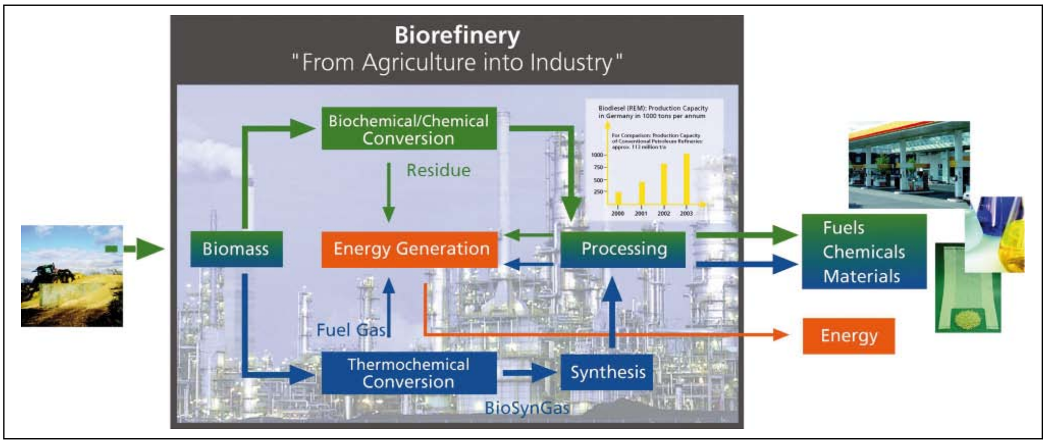
In most cases, dry ligno-cellulose materials are currently reserved to thermo-chemical conversion, because the additives (enzymes) and techniques for the hydrolysis of cellulose to obtain starch or sugar are still in their infancy. Thermo-chemical processes include the production of bio-crude oil by pyrolysis or hydrothermal treatment or gasification to produce synthesis gas. As subsequent steps, conventional processes like Fischer-Tropsch synthesis or other catalytic routes are under development, lead to biofuels and basic chemicals like methane, methanol and ethanol.

The first commercial production site for processing biomass to liquid will soon be put into operation in Freiberg, Germany (capacity: 65,000 t/a biomass) by Choren Industries (see CHEManager Europe 10/2008, p. 29). It produces synthetic gasoline from ligno-cellulose biomass by gasification and Fischer-Tropsch synthesis. A second, much larger plant that will consume approximately one million t/a of biomass for 200,000 t/a of product is being planned. A similar technology called bioliq is under development at the research centre in Karlsruhe, Germany (Forschungszentrum Karlsruhe). There, the first treatment step, the pyrolysis of biomass, can be done in decentralized plants. The pyrolysis oil can be stored and transported to a large scale gasification and Fischer-Tropsch site.

A new technology to produce ethanol from cellulose feedstock is being developed by 21 partners throughout Europe and Israel in the project NILE (New Improvements for Ligno-cellulosic Ethanol) within the 6th EU framework program.

Black liquor, a waste product of the pulp and paper industry has proven an ideal raw material for the conversion to biodiesel (DME, dimethylether). In the so called Chemrec process, developed in Sweden, the conversion is integrated into a pulp/paper mill.

Processing wet biomass like grass, clover and green cereal plants, delivers biogas as main the product. Additionally, the liquid fraction obtained by pressing is processed to gain lactic acid, proteins and soluble sugars. From the press



Concept of an integrated biorefinery

cake homogenous fibers to be used as fillers or for fiber boards are obtained. This concept of the green biorefinery has been developed and realized in Austria and Germany.

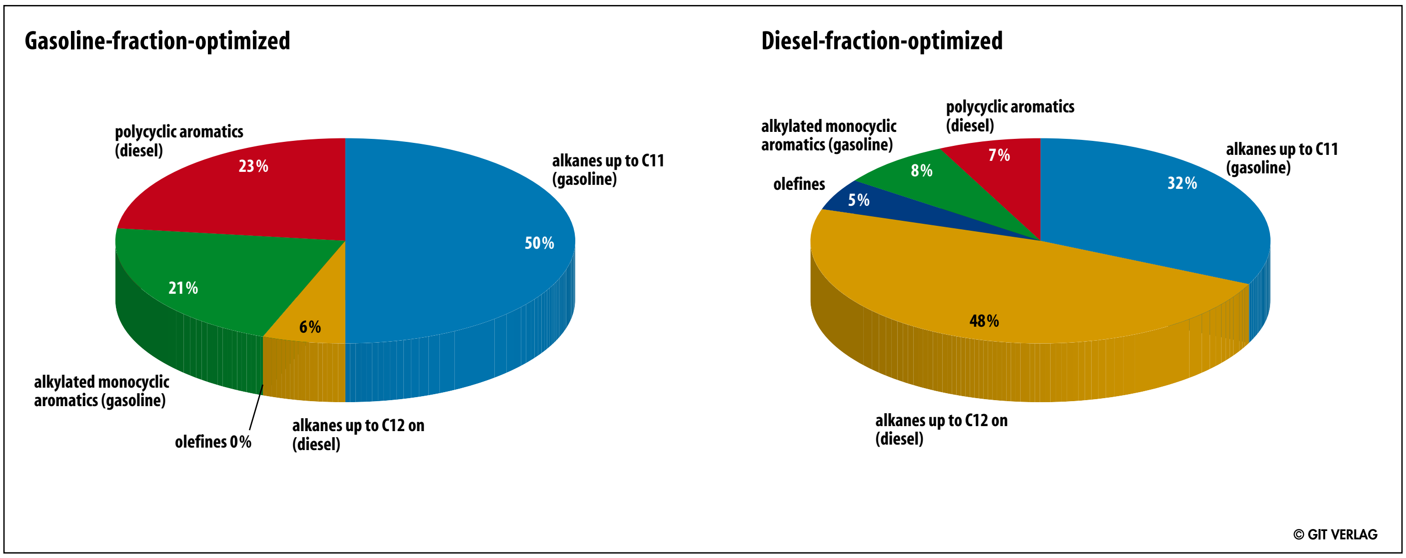
Boosting Ethanol and Biodiesel Plants

Some crucial developments to improve process routes based on biomass and to increase product portfolios have been made by the Fraunhofer Umsicht. There are three main pathways followed in several projects: one is to improve the efficiency of biodiesel plants by new catalysts, the second to produce biofuels from waste fats and oils and the third is concerned with the increased production routes that are offered by the fermentation of biomass to succinic acid as a platform chemical. They all should boost biobased production facilities to biorefineries which produce a spectrum of marketable products. For efficiency and for economic reasons, this will be a key factor for the success of future biobased production systems.

A new catalyst based on guanidine carbonate has shown to accelerate the transesterification reaction of vegetable oil and methanol to fatty acid methyl ester in a way that conversions of > 95 % can be reached with one process step in less than one hour. Contrary to conventional processes that use caustic and sodium or potassium salts of methanol as catalysts, the by-product glycerol is free of salts here. Alternatively, the utilization of nitrogen containing catalysts in the biodiesel process leads to considerable amounts of mono- and diglycerides as valuable by-products. Over and above the product groups fatty acid methyl ester (FAME) and mono- and diglycerides the pre-separation of vitamin E from vegetable oils may rise the gain of the whole production site.

The greasoline process implies the pyrolytic cracking of waste fats and vegetable oils with activated carbon as catalyst, which is inexpensive and easy to regenerate. In addition, the mass of converted feed related to the mass of spent catalyst is about twice as much as this value obtained with expensive zeolite catalysts. By varying the activated carbon catalyst, reaction temperature and contact time, the liquid product composition can be adjusted to typical fuel quality demands.

Succinic acid is known to be an important platform chemical for the production of various industrial and consumer products. Its established production process is based on the



Greasoline product compositions adjusted to typical fuel quality demands

C4-fraction of naphta, but it is also possible to obtain succinic acid by anaerobic fermentation of sugars. In a project funded by the government called “Example of the Process Chain Succinic Acid-Polyamide,” Fraunhofer Umsicht researches the process chain from renewable resources to new materials. Within this project screenings of different micro-organisms have been performed successfully and it became obvious that not only glucose but cheaper raw materials like cornstarch but also glycerol can be applied. The focus of interest is first set on the process chain biomass – C4-chemistry – high performance polymers. Some homo- and copolyesters of succinic acid are already produced industrially, but the process route with the final product PA 44 (Polyamide 44) has not been realized yet, although it is considered to be a promising route. To achieve this, basic research has to be done concerning efficient downstream processing. Additionally, one has to consider that contrary to the petroleum based succinic acid production the fermentation process delivers mainly succinate. So conversion routes based on the oxidized form must be optimized.

“Future production systems based on biomass are considered to be economically successful if they are able to produce different products for different markets.”

Outlook

Future production systems based on biomass are considered to be economically successful if they are able to produce different products for different markets. Furthermore it is beneficial if the complete biomass is used, if all materials are utilized in closed cycles and if the competition to food production can be avoided. However, the production of energy should be reserved to waste materials, while high value biomass like sugar, oil or starch containing raw materials may serve for the production of high value chemicals. Incidentally these principles are followed in the so called two platform refinery. This is an integrated system with one process chain based on sugar/starch containing biomass and the second one based on ligno-cellulose feedstocks. While the first one is intended to deliver high value chemicals by biochemical/chemical conversion, the second one is proposed to produce biofuels by thermochemical conversion. Residues and volatile hydrocarbons are to be used for energy production. Of course, considering the diversity of possible raw materials, of local conditions and market demands it becomes obvious, that there cannot be the one single biorefinery.

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