Biorefinery concepts are close to implementation

Coal, crude oil, what’s next? The preparations for switching from crude oil to other resources for the production of fuels and petrochemical products are underway. Crude oil (and also gas) reserves are in irrevocable decline. Pessimists believe that peak oil production has already been reached and optimists believe that this peak will be reached in 2020. Crude oil is not only our most important source of energy production, but it is also an important resource for the chemical industry. The transport sector is the biggest consumer of oil, while the chemical industry requires around seven per cent of total oil reserves.

This is not just a passing oil crisis, the changing climate means that industry is now under pressure to find new ways to produce fuels and materials that are CO2 neutral at the same time as conserving resources. Although petrochemical production methods can be replaced by coal and gas refinery techniques, this does nothing to solve the climate problem. Recent developments have shown that the use of alternative resources is necessarily limited because the production of biofuels and other products must not be allowed to put food production in jeopardy.

Biomass as carbon source

Experts do not envisage one perfect alternative for oil. The switch from crude oil to alternative ways of producing fuel and energy requires many different technologies. One solution might be the use of biomass, i.e. organic carbon that is continuously produced by photosynthesis in plants, for the production of chemicals, plastics and fuels.

However, this solution requires new processes of sustainable material supply to be put in place. Research in chemistry, biology, biotechnology, physics and process engineering need to be carried out in a more interdisciplinary way. Moreover, if biotechnology is to play a key role in these processes in the future, something all key chemical companies believe will be the case, sufficiently large quantities of high-quality and sustainable raw materials and a specific infrastructure are required. In addition, optimised, innovative technical enzymes, microbial metabolic processes that are adapted to the production of such materials are required, as well as larger space-time yields and efficient purification processes. And the list of necessary research and development activities goes on and on.

One of several concepts, but not the only one, is biorefineries. These biotechnological biomass conversion processes and equipment that are used to produce fuels, power and chemicals are likely to revolutionise today’s petroleum refinery processes, according to a recent comment by a chemical industry representative. He also said that these factories of the future cannot be used solely for the production of high-quality value-added fine chemicals, but must also be used to produce basic...
No biorefineries have yet been constructed. However, there are plans to develop a model refinery based on a petrochemical refinery at the on the site of the Leuna chemical factory. A refinery of this kind would, it is believed, help to close the gap between laboratory and industrial application.

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chemicals to combat rising oil prices.

Concept with an industrial-political dimension

As with petrochemical refineries, biorefinery processes involve a complex system of facilities and processes in which (terrestrial and marine) biomass is used as efficiently as possible to produce energy and materials, convert biomass into a broad range of product groups and process it into final industrial products. Biorefineries are more than just a purely technological concept, they also have an economic and industrial-political dimension. Biorefinery processes are likely to become an integral part of an economy based on the use of renewable resources, which would be able to generate basic (chemical) and refined products, bioenergy (biogas/methane) and biofuels. However, the industrial implementation of biorefinery processes is still in its infancy.

The implementation of biorefinery processes will take several decades

Just as the petrochemical industry required several decades to reach technological maturity, it will also take many years before the technologies used to convert biogenic raw materials are transformed into technologies for the industrial production of intermediary and final products. As with petrochemical processes, it is envisaged that the complex biomass will be separated into major substance groups from which industrially sustainable product lines will then be developed. The current idea is to produce more complex intermediary products from basic substances, which in turn
will be transformed into a broad range of secondary and final products.

In terms of producing high enough quantities of central basic chemicals for realistic use, currently available conversion technologies are only suitable for the production of chemicals such as synthesis gas (CO/H2), olefins, acetylene and aromatic compounds from crude oil. Synthesis gas can be produced from all carbon-containing compounds. Industry has technologies at its disposal that can, for example, convert mixtures of carbon monoxide and hydrogen into liquid hydrocarbons (Fischer-Tropsch process) or carry out the methanol-to-olefins (MTO) process which converts natural gas into olefins and the methanol-to-propylene (MTP®, Lurgi AG) process, which turns methanol into propylene.

Renewable resources make it possible to exploit known natural synthesis processes.

Differences in the first purification step

Biomass has a carbon, hydrogen, oxygen and nitrogen ratio that is totally different from that of oil.

Around 75 per cent of biomass consists of carbohydrates (cellulose, polyoses, starch and sugars), 20 per cent of lignin, which researchers have for many years found to be a hard nut to crack, fats and proteins (five per cent). In addition, it also consists of vitamins, pigments, flavours and odorous substances.

The processing of biomass focuses predominantly on mechanical compression, grinding and fractionation, biotechnological conversion using enzymes and microorganisms or gentle chemical
In terms of using renewable resources for the recovery of material, research and development activities focus mainly on the decomposition and depolymerisation of cellulose and lignin and the conversion and degradation of biogenic raw materials. The transformation of biogenic raw materials requires water-stable catalysts to be developed, and reaction and material separation to be integrated into the processes.

The availability and logistics of biogenic raw materials has only been focused on to a limited extent by researchers and developers. Such materials will need to be imported into Germany from other countries. Another problem that has so far received scant attention is the fact that biomass requires a lot of water and experts believe that water will be one of the most limited resources in the future.

Four types of refinery

At present, four types of biorefineries are being developed, each adapted to the particular raw materials used. LCF (lignocellulose feedstock) refineries use lignocellulose, wood, straw, grasses or municipal waste containing cellulose, all of these being the most important types of biomass in terms of quantities available.

Corn biorefineries use all the parts (stems, leaves and fruit) of starch plants. Green biorefineries mechanically fractionate primary raw material (green biomass) such as green grass, clover, lucerne and unripe corn. A handful of pilot refineries are currently being constructed in Germany and Austria.

Two-platform biorefineries involve the enzymatic or chemical conversion of plant-derived
carbohydrates into sugars, which are subsequently processed using biotechnological or chemical methods. Moreover, the biomass or the lignin can be thermochemically degraded into low hydrocarbons, methane, carbon monoxide and hydrogen (Syngas platform). As with coal chemistry, this synthesis gas serves as the basis for producing chemical feedstock (lactic acid, 1,3 propanediol, furan dicarboxylic acid, 1,18-octadecan dicarboxylic acid, n-butanol, succinic acid or sorbitol) or higher hydrocarbons.

Research consortia to advance development in Europe

Biorefinery processes are no longer just a topic restricted to conferences. Research-based pilot plants have been planned and constructed in Germany and the EU. For example, the "chemical-biotechnological process centre" project of the German federal and state governments has been established in Leuna, and is being coordinated by the Fraunhofer Society. This is a model refinery involving seven different process units. Other, mainly research-based biorefinery activities in Europe are known as 'Biocore', 'EuroBioRef' (a large cooperative project involving 28 partners from 14 countries), 'Sustoil' or 'Bioref-Integ'.

Germany links fuel and chemistry production

In Germany, research is mainly focused on linking chemical production with the production of second-generation biofuels. In future, it seems likely that fewer raw materials will be used for the production of biofuel (which is a ten times larger market) in favour of using them for the production of basic chemicals (200 mio. t/year).

In addition to focusing on feasibility and transferring the processes to larger scales, it is also necessary to evaluate these processes in ecological terms. The integrated use of biogenic raw materials in factories cannot just be called sustainable because these processes involve renewable raw materials. In addition to using regenerative resources, it is also necessary to analyse substance streams and develop ecobalances.

Literature/Sources:


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