BtL: Bio-fuel of the future

Promotion of two plants based on different production concepts

With regard to the growing scarcity of petrol resources and climate protection problems, alternative fuels are a topic which is also being given intensive attention by the federal government. In its fuel strategy, it identified four alternatives which show the greatest potential for the reduction of fossil fuel consumption. One of them is BtL fuels. Two possible production variants for BtL generation are described in this contribution.

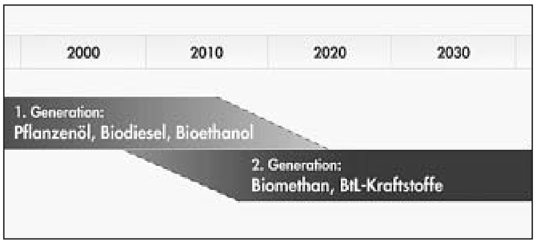

Fig. 1: Generations of bio-fuel

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It is not yet available at any petrol station, but BtL (biomass-to-liquid) fuel offers large quantity potential and good technical properties. Theoretically, any organic biomass can be used for its production. Due to its ability to adapt to different engine designs, the combustion of BtL fuels causes relatively few emissions. In addition, it can be used as an additive or as pure fuel in existing vehicles without the necessity to change engine design.

However, BtL fuel is not only interesting for the consumers, but it also contains potential for the raw material producers, i.e. domestic agriculture and forestry.

What are BtL fuels?

BtL (biomass-to-liquid) fuels are synthetic fuels out of biomass. They belong to the biofuels of the second generation, which are not yet on the market. Due to their positive characteristics, they are likely to supersede the bio-fuels of the first generation, such as pure vegetable oil, bio-diesel, and bio-ethanol, in the years to come (*Fig. 1*).

How are BtL fuels produced?

The largest part of the organic compounds contained in biomass are very complex. In order to reach the goal of conversion into relatively "simple" hydrocarbons, such as those in petrol or diesel, different technical processes are conceivable. BtL production uses a simple, though very efficient technique: At high temperatures and, if necessary, under pressure, the complex molecules of the biomass are split into their components. Like in a time lapse, this provides the same result as the formation of fossil fuels, which took millions of years. Then, the individual components are used for the production of synthesis gas, a mixture of CO and H_2. Those elements which are not necessary for hydrocarbon re-synthesis, such as nitrogen or sulphur, form their own compounds, which can be separated from the synthesis gas. Among the available methods of synthesis are Fischer-Tropsch (FT) and methanol-to-synfuels (MTS) synthesis.

Figure 2 shows a simplified diagram of BtL production: The biomass is put into a gasification reactor and converted into synthesis gas using heat, pressure, and a gasification additive, such as oxygen. This synthesis gas mainly consists of hydrogen, carbon monoxide, and carbon dioxide. After the gas has been cleaned and prepared for synthesis, CO and H_2 are synthesized into hydrocarbons, which can be processed to BtL fuels. Depending on the technique, this fuel has the properties of diesel or petrol and can be used in the existing vehicle fleet without any adaptations.

The use of biomass for the production of synthetic fuels is new. However, synthetic fuels based on carbon (coal-to-liquid, CtL) have already been produced for a long time. In Germany, production at the industrial scale began in 1927. The Fischer-Tropsch synthesis technique, which is used today, also comes from Germany, where it was developed at the Kaiser-Wilhelm Institute for Carbon Research in 1925.

Technical Properties

The common feature of all synthetic fuels is that their properties can be precisely determined and, hence, customized during production and subsequent processing. Therefore, they can be optimally adapted to modern engine concepts and allow for efficient, complete combustion while keeping exhaust gas emissions low.

BtL fuels also enable the currently applicable fuel standards DIN EN 228 for petrol and DIN EN 590 for diesel to be kept without any problems. Thus, today´s vehicle fleet along with the current distribution infrastructure for fuels can continue to be used without any alterations.

CO_2 reduction

In contrast to CtL fuels, BtL fuels promise large CO_2 reduction potential due to their vegetable raw material basis. Their combustion only releases the quantity of this greenhouse gas which was bound before by the plants during their growth. However, the energy consumption required for fuel production must be taken into account.

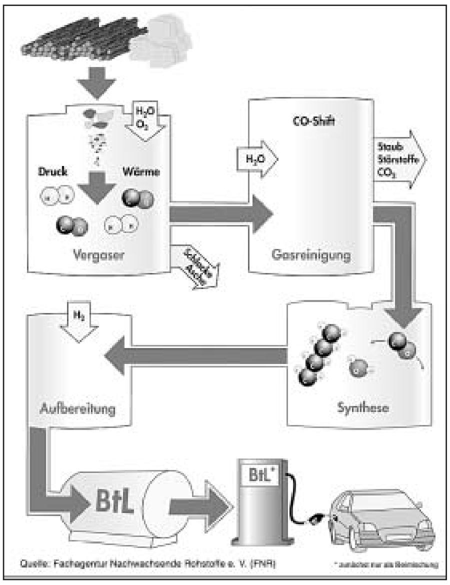

Fig. 2: BtL production process

Yields

A very wide range of plants can be used for production. It includes specially cultivated energy plants, fast growing or forest wood, as well as residues, such as straw and residual wood. It is also possible to use organic waste. In addition, entire plants can be utilized and not just individual components or plant parts. As a result, BtL fuels provide significantly larger yields per area unit than the bio-fuels of the first generation, for whose generation only the oil or the sugar are used. Experts estimate that the raw materials from one hectare of field area allow approximately 3,900 l of BtL fuel to be produced.

Production concepts

For the realization of BtL production at an industrial scale, different process routes have been proposed. Based on the current status of development, it cannot yet be foreseen which one is ultimately going to establish itself or if several techniques are going to be used parallel. For this reason, the Federal Ministry of Consumer Protection, Food, and Agriculture is promoting two projects which pursue different process routes.

In a first step, only some of the individual process stages are going to be built at the two locations Freiberg and Karlsruhe. Below, however, the entire concept will be explained. For comparison, the basic steps of BtL production will be described first:

- raw material processing
- thermo-chemical gasification (production of synthesis gas)
- gas cleaning and –preparation
- the synthesis step
- product processing.

The methanol-to-synfuels technique

At the Technical University / Mining Academy Freiberg, a demonstration plant is being projected where the synthesis gas is first converted into methanol. This substance, which is rich in energy and able to be transported and stored, serves as an intermediate product. Actual fuel synthesis can then be carried out in a subsequent, centralized step using methanol-to-synfuel (MtS) technology. In the MtS technique, methanol can be converted into petrol or diesel fuels, as desired. Methanol production as an intermediate step allows biomass gasification and actual fuel production to be spatially decoupled from each other. Thus, biomass can be gasified in decentralized plants which have smaller outputs. Since biomass has a large volume and is less rich in energy as compared with fossil energy carriers, this approach promises logistic advantages. Methanol, which is considerably richer in energy, is then converted into fuels at central refinery locations, where the necessary infrastructure already exists.

Accordingly, only the construction of the first four process stages up to methanol synthesis is currently being planned in Freiberg. The following plant parts will be realized later at a location which is still unknown or will be integrated into an existing refinery location.

The technique applied in Freiberg also differs from others with regard to synthesis gas production and the synthesis step. For gasification, an improved autothermic fludized bed gasifier of the Winkler type is intended to be used, whose output can later be increased up to 100 to 500 MW_{th} in large industrial plants. This gasifier can process different fuels, such as diverse biomass, coal, and other materials containing carbon. It works safely at a pressure of ≥ 20 bar and promises an availability of at least 80%.

During subsequent MtS synthesis, methanol reacts to long-chain hydrocarbons with dimethylether and olefins on catalysers as intermediate products. By means of hydrogenation, these hydrocarbons are converted into diesel and petrol.

In Freiberg, mainly energy plants and straw are intended to be used as raw materials. The biomass comes from the Freiberg region.

The engineering process is currently underway and is planned to be completed by the end of 2006. The construction of the demonstration plant is planned for 2007.

This plant will be able to begin large-scale, profitable operation without any other intermediate steps.

Bioliq techniques

The pilot line for BtL fuels of the Research Centre Karlsruhe will also be realized and promoted in several successive steps. In the first step, bio-slurry production, during which biomass (in this case mainly straw) is converted into slurry rich in energy, is going to be realized. This slurry is a mixture of bio-coke and pyrolysis liquid, which is able to be pumped and transported and allows the transport requirements of large-volume vegetable raw materials to be reduced. Conversion by means of quick pyrolysis takes place in a mixed double-screw reactor at 500 °C. The energy density of the slurry is approximately 10 times higher than that of straw and can thus be compared with petroleum.

If this technique, which was given the name “Bioliq” by the Research Centre Karlsruhe, proves itself, not only biomass gasification (as planned in Freiberg), but also biomass processing could be carried out in decentralized plants. For this purpose, initial plans for pyrolysis units providing outputs of 40 to 50 MW have been made, which could process 50,000 t of biomass per year from a radius of 25 km around the plant. For comparison: The projected BtL plants, which are fed with uncompressed biomass, are expected to need 1 million t of raw materials per year. This means that the biomass would have to come from a significantly larger area around the plant.

The processing of the slurry follows a concept which is comparable with other BtL routes: The slurry is gasified, and the synthesis gas is used to produce methanol, which is converted into fuels through MtS synthesis. This processing will probably be carried out in Freiberg or at a refinery location where the methanol from the Freiberg plant is also converted into fuel.

The construction of the biomass processing plant in Karlsruhe began in November 2005. Commissioning is planned for 2006. The initial investment, a total of € 5.6 million, is partially funded by the Agency for Renewable Raw Materials, which granted an amount of more than € 2 million.