Bio-Jet Fuel — Challenges and Solutions

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Continuous growth of air traffic and its corresponding increase in CO_2 emissions can be offset by high-quality bio-jet fuels which meet all kerosene-related parameters. Some technologies are already certified and on the market. Greasoline is an innovative new technology which uses bio-based non-food resources and residues. It therefore broadens the raw material basis for bio-jet fuels and can supplement existing technologies.

Aviation Industry Growth and related CO_2-footprint

Aviation is amongst all transport sectors growing very strongly: annual growth rates are projected at approximately 4.5% per year throughout the next decades. The majority of this growth is expected to be linked to Southeast Asia. Technological progress in the aviation industry — mainly more energy-efficient planes — might reduce the fuel consumption a bit. Without further changes in the fuel sector, aviation-related CO_2 emissions would anyhow increase by 3% per year. The aviation industry expects to be reliant on liquid fuels for the next 30 to 50 years, since no alternatives for (bio)fuels — e.g. like batteries for cars — exist for airplanes.

This would put even more pressure on the CO_2-footprint of aviation: already today, 12% of transport CO_2-emissions and 3% of the whole man-made CO_2-emissions are due to aviation. European airlines consumed 53 million tons kerosene in 2010, the whole world even 200 million tons.

Challenges for Aviation Companies

Governmental bodies are discussing joint targets and implementing several regulative actions in this context. The European Union decided via its Renewables Energy Directive to use 10% renewable energies in the transport sector by 2020, and is targeting 2 million tons of 'sustainable' kerosene by 2020. Details can be found in the technical paper, *A Performing Biofuels Supply Chain for EU Avi*ation, of DG ENER 2011.

Aviation companies agreed on a voluntary self-commitment that they will only grow in a climate-neutral way from 2020 onwards. They are however confronted by several challenges. Their cost pressure is tremendous, and fuel costs are continuously increasing: more than 30% of operating costs in aviation are due to fuel. Established biofuels for land transport like bioethanol and biodiesel cannot be used in airplanes due to their fuel properties — air transport requires biofuels which are chemically identical with fossil kerosene.

State-of-the-art Processes for Bio-jet Fuel

State-of-the-art for producing non-fossil oil-based alternative fuels is summarized in an IATA report. Basically two routes are accepted by *American Society for Testing and Materials (ASTM)*:

First, there is the so-called Fischer-Tropsch (FT) process. In particular coal-to-liquid, gas-to-liquid and biomass-to-liquid products are addressed. Technology-wise, it implies gasification of feedstock to syngas with ash as a by-product. Syngas is converted further to a mixture of fuels containing naphtha, olefins, kerosene, diesel und waxes, which are treated in several steps by so-called hydro-processing and isomerization to yield fuels including jet fuel. Since those processing steps require very large units, typically more than 50% of fuel costs are due to investment costs.

Second, there are so-called hydrogenated vegetable oils, sometimes also called hydro-processed renewable jet (HRJ). Processing steps comprise, besides distillation, the steps hydro-treating, hydro-cracking and isomerization. Raw materials include non-food and recycled fats and oils. Here, more than 50% of fuel costs are due to raw materials. The hydro-treating step requires much hydrogen which currently can only be obtained from fossil sources. The technology is much more developed than the FT-technology for renewable raw materials. To preserve the activity of the hydro-treating catalyst, only feedstock displaying food-quality parameters can be used. Palm oil and tallow fat are the preferred raw materials due to their high degree of saturation requiring the lowest amount of hydrogen.

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Technologies not yet considered by *ASTM* but lining up for testing:

- Hydro-processed 'Synthetic Paraffinic Kerosene' derived from fermented alcohols. Initially focused on iso-butanol, but other variations will be considered too (*Alcohol-to-jet, e.g. Lanzatech/ Swedish Biofuels*)
- Synthetic biology, i.e. genetically engineered micro-organisms converting sugar to pure hydrocarbons, resulting in farnesene and other similar terpenes (*Sugar-to-jet, e.g. Amyris Biotechnologies, Gevo and Cobalt*)
- 'Synthesized Kerosene Aromatics' implying alkylated benzenes, a fuel component important for elastomeric seals and fuel lubricity (*e.g. UOP and KIOR*)
- Pyrolysis of cellulosic biomass to synthetic crude products (plus hydro-processing)
- Co-mingling petroleum and biomass in refinery hydro-processing. This is supported by refineries to optimize efficiencies, but is currently not allowed.

Greasoline Technology as a New Approach

In contrast to these approaches, Greasoline® technology is starting from bio-based fats and oils like HRJ. Greasoline however is based on a gaseous phase reaction technology and therefore can transform raw materials of significantly lower quality, because residual water and inorganic residues are separated in the evaporation step (Figure 1). The catalyst for the gaseous phase reaction also is highly tolerant to impurities. As a result, bio-based residues and side-products can be utilized instead of feedstock in the food-quality range.

Primary products are hydrocarbon chains identical with fossil diesel and kerosene fuels. Most of the diesel components can be transformed into the kerosene boiling range *via* isomerization. In addition to this the technology also produces bio-based alkylated benzenes which are crucial for jet fuel properties, especially as expanding agents in seals as well as for lubrication. These products cannot be obtained by hydro treating processes and therefore HRJ fuel has to be blended with fossil jet fuel.

The basic technology does not need external hydrogen, because the formation of coke as a by-product on the catalyst automatically closes the carbon-hydrogen-balance within the system. A subsequent hydrogenation step with little hydrogen consumption is optional to guarantee all product quality parameters. The catalyst itself is regenerated after the biofuel reaction in an industrially established process. The process is currently performed in a pilot plant at Oberhausen; plans for a demonstration plant are being elaborated together with partners mainly in the oil industry.

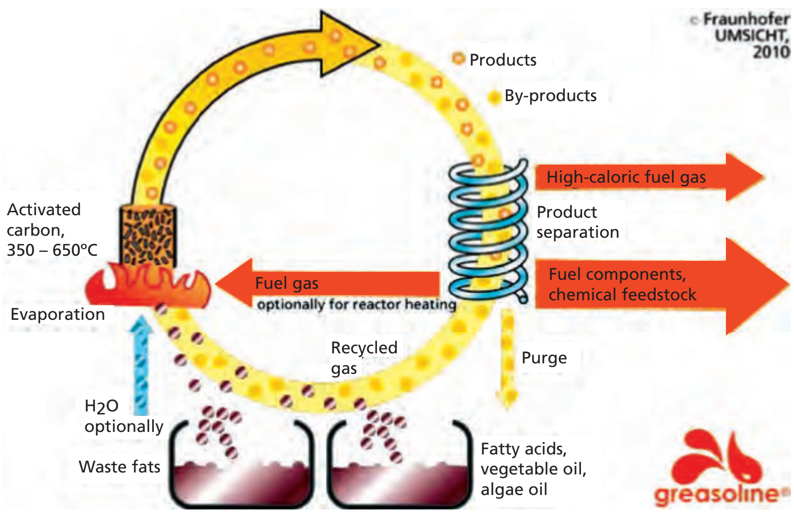

Figure 1. Greasoline process scheme — main fuel products: bio-jet fuel, bio-based alkylated benzenes and bio-based diesel.

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