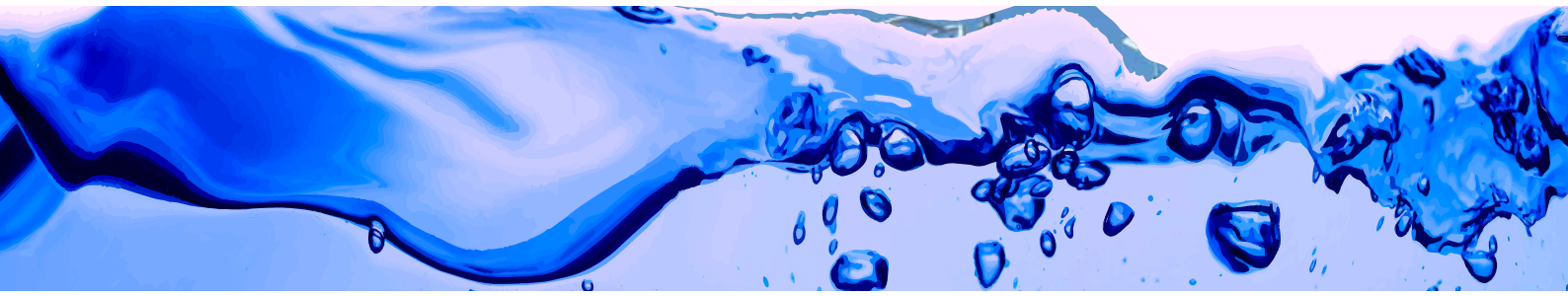

CLIMATE-NEUTRAL FUELS AND BASIC CHEMICALS

When it comes to limiting global warming climate-friendly energy sources play a key role. Although electric drives become more and more important in the automotive sector their role will remain a minor one when heavy-duty traffic, vessels and planes are concerned.

New "Power-to-Liquids" (PtL) technologies for the production of liquid fuels by use of renewable power are going to make an important contribution to the decarbonization of the transport sector. The existing infrastructure and vehicle fleets can continue to be used to the greatest possible extent.

The flexibility of these new technologies opens up a broader range of products from hydrogen through to basic chemicals – called "Power-to-X" (PtX). PtX facilitates a smart linking of renewable power, transport, heat and chemistry thus making the required magnitude of decarbonization possible to reach the climate targets.

TECHNICAL FEATURES

The production of climate-neutral fuels comprises of several process steps. Initially hydrogen (H_2) is produced with renewable power by way of electrolysis. The carbon still needed is obtained as carbon dioxide (CO_2) from industrial sources or the ambient air by CO_2 absorption (DAC, Direct Air Capture) and in a next process step (RWGS, Reverse Water Gas Shift) converted with H_2 into synthesis gas (H_2/CO). By selecting suitable process conditions the synthesis gas is set to a H_2/CO ratio of 2:1 whereupon the Fischer-Tropsch synthesis follows to produce synthesis hydrocarbons (e-crude).

By selecting suitable catalysts and reaction conditions the chain length of hydrocarbons can be varied so that preferably hydrocarbons can be obtained for fuels but also waxes. The e-crude is processed further by way of hydrocracking and isomerization to obtain fuels (e-fuel) or is used as a basic chemical (e-chemicals) (Fig. 1 and 2).

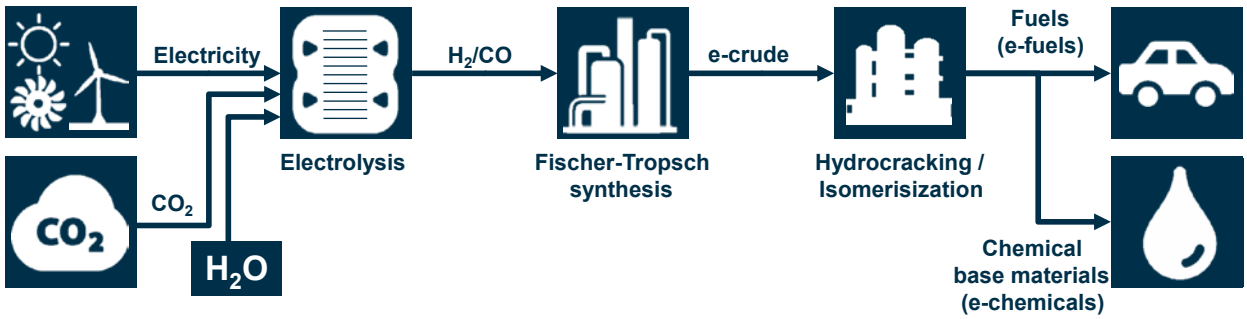

Fig. 1: Power-to-Liquids technology

With our PtX technology partners we rely on competence and experience of:

- Climeworks – Direct Air Capture (DAC)
- Sunfire – Electrolysis on the basis of SOEC (Solid Oxide Electrolysis Cell) and RWGS

The SOEC electrolysis of H_2O is currently being further developed to co-electrolysis of H_2 and CO_2 and is going to replace (from 2020 expectedly) the two-stage synthesis gas production by one process step thus saving costs of investment and operation.

Fig. 2: Pilot plant at Sunfire

FEEDSTOCK

- Renewable power from hydroelectric power, wind power and solar power stations, for example
- Water
- Carbon dioxide from industrial sources or ambient air

PRODUCTS AND YIELDS

The products are free from sulfur and aromatic compounds and almost 100 % climate-neutral when using carbon dioxide from ambient air.

- Fuels (gasoline, diesel, kerosene)
- Waxes
- Hydrocarbons for the chemical industry

The carbon yield related to the carbon dioxide used is over 93 %. About 60 % of the renewable power are available in a converted form as liquid hydrocarbons.

Besides the use in a manner analogous to conventional fuels power can be stored this way cost-efficiently and flexibly.

In addition to that other climate-neutral products can be made by alternative synthesis gas processes such as methanol synthesis. Methanol is used in fuels or for chemical purposes.

ECONOMIC EFFICIENCY

The energy and feedstock demand per litre of produced liquid hydrocarbon is:

Renewable power, kWh/l	15 - 20
Carbon dioxide, kg/l	2.7
Water, kg/l	1.0 – 1.5

BENEFITS FOR CUSTOMERS

As a technology and plant engineering contractor we serve as the integrator and combine new technologies of start-ups, such as Sunfire and Climeworks, with time-tested technologies and know-how in the areas of Fischer-Tropsch synthesis, hydrocracking and isomerization or methanol synthesis.

Our experience in the Fischer-Tropsch synthesis (Syntroleum, Choren/Shell), synthesis gas production and refinery processes puts us in the position to provide complete PtX solutions for our customers.

REFERENCES

Our PtX solutions are suitable for plant capacities of 500 l per day up to 30,000 l per day. Capacities are expected to rise to over 300,000 l per day.

PtL unit with a capacity of 10 million l per day, Norway (at the planning stage).

PtL demonstration unit at a German airport of 500 l per day (at the planning stage).

Development of PtL units of 500 l per day for autarkic supply of local airports with aviation fuels (at the planning stage).

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