KEROGREEN: FOR GREEN KEROSENE

Photo: KIT / Pfeifer

Main achievements

- Individual elements have been demonstrated at lab-scale
- Individual elements have been integrated in a container sized system

Key figures

Plasma Reactor (step 4)

- Up to 0.7 kg CO/h production rate
- Typical energy cost: 0.12 kWh/kg CO

CO purification (step 6)

- Up to 98% purity (on single step)
- Up to 95% CO yield

Fischer-Tropsch and Hydrocracking modules (steps 8 and 10)

- In-line recycling (and cleaning) of residual wax
- Wax conversion > 50%
- Required isomer content of > 30% for kerosene obtained

Challenges

- Upscaling of the oxygen separator (step 5) from lab scale to system level is work in progress
- To produce 0.1 kg/h kerosene with a fully integrated system

What's next?

- We would love to get into contact with investors, policymakers, companies and airports
- Do you take green kerosene with us to the next level?

What can the EU, countries, or companies do?

The next steps to achieve a profitable product depend on several factors. It helps if the EU and countries or companies globally, provide funding or loans to enable the next steps. More important however, will be regulation to make e-kerosene cost competitive.

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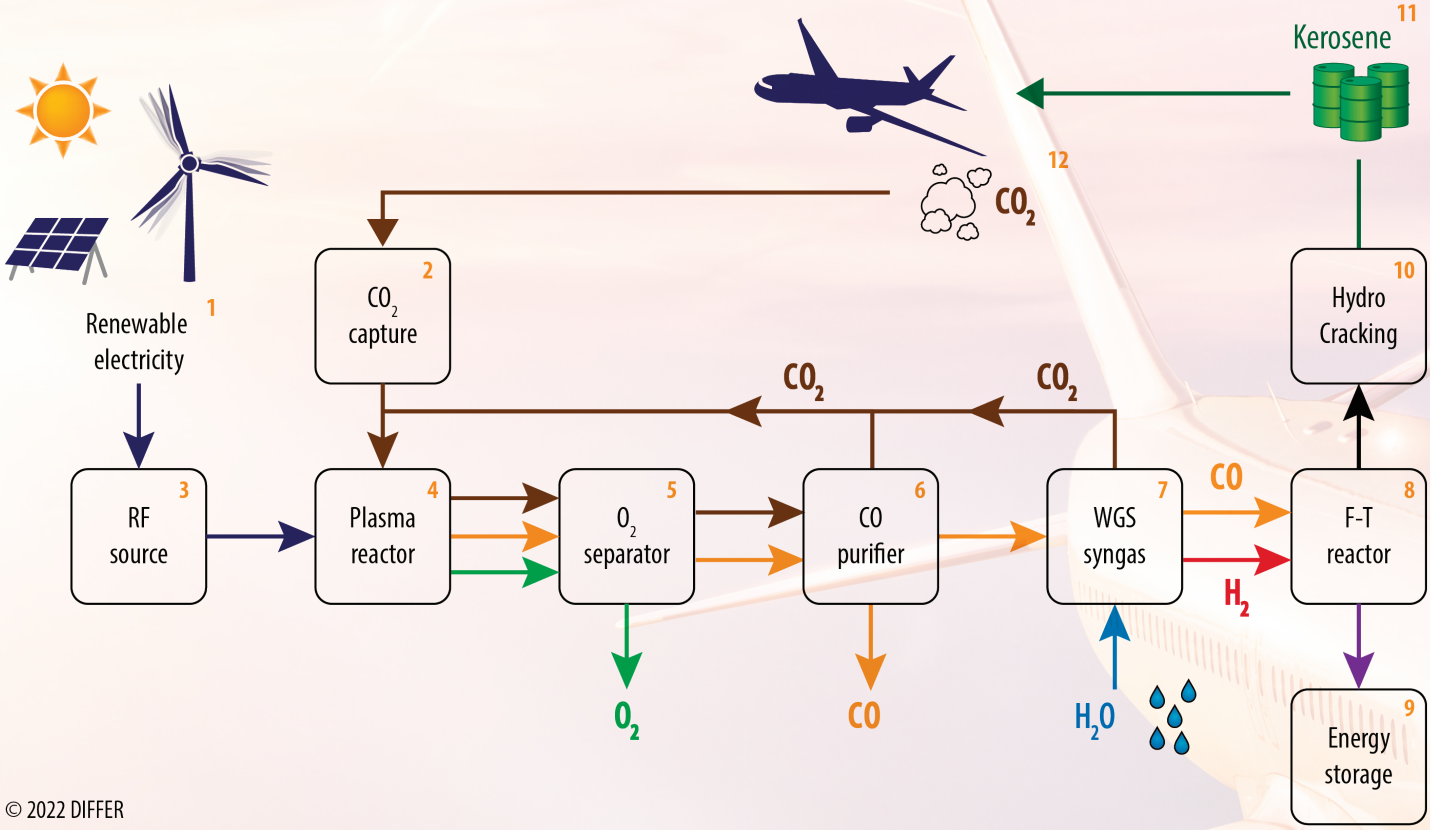
KEROGREEN

Making green kerosene out of CO_2, water, and renewable electricity

We integrated the individual, separate processes and installed it into a shipping container!
Will you fly with us to the next level of technology readiness?

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement 763909

THE CIRCLE OF KEROGREEN FROM CO_2, WATER AND RENEWABLE ELECTRICITY TO GREEN KEROSENE IN 12 STEPS



Step 1: The 12 steps to produce kerosene cost a lot of energy. To produce green kerosene, the energy source has to be renewable. Good sources are solar energy and wind energy.

Step 2: CO_2 feedstock is to be (re-)captured from ambient air for the fuel cycle to become CO_2 neutral.

Step 3: The energy from step 1 drives a so called RF source, a kind of microwave-oven.

Step 4: A plasma reactor uses the microwave radiation and splits CO_2 in CO and O_2. This so called plasmolysis has been proven at small scale by DIFFER.

Step 5: To remove the oxygen (O_2) VITO and CERPOTECH produced oxygen permeable membranes. DIFFER demonstrated that oxygen is removed from the mixture. CO and CO_2 go to the next step.

Step 6: In the CO purifier, made by HyGear, undesired gases are removed to supply clean CO for the next step.

Step 7: The integrated water-gas shift and CO_2-removal is built by KIT. CO and H_2 go to step 8.

Step 8: The Fischer-Tropsch synthesis by INERATEC is a collection of chemical reactions that converts a mixture of carbon monoxide and hydrogen into liquid hydrocarbons, mainly alkenes to serve as a basis for clean diesel or kerosene, amongst others.

Step 9: An excess fraction, for example molecules that do not fit the kerosene specification, could be stored for later use as CO_2 storage.

Step 10: The molecules which have passed the hydrocracking step (by KIT) and fit to the kerosene blend, a mixture of carbon molecules with 8 to 14 carbonatoms, are sent to final upgrading for aviation.

Step 11: Kerosene can be stored in barrels and tanks.

Step 12: The aircraft is fueled by the synthesized kerosene propelling its jet engines, whilst emitting CO_2. This CO_2 is recaptured and re-used to feed the KEROGREEN synthesis system. The circle is closed.

FREQUENTLY ASKED QUESTIONS

Why green kerosene?
Green kerosene is a carbon-neutral fuel. It provides long-term, large-scale energy storage. This is important if you want to bridge periods in which the sun does not shine or there is no wind. Furthermore, green kerosene is a high-energy-density fuel. It enables long-range transport and mobility. And, last but not least: it does not increase the atmospheric CO_2 concentration.

Why not make electric planes or use hydrogen?
In 2016, when the KEROGREEN project started, sustainable aviation hardly figured in public debate. To date, green kerosene looks like the only solution for sustainable aviation. Not-yet-existing planes on hydrogen need enormous fuel tanks. Potential electric planes carry heavy batteries. A great benefit of green kerosene is that it uses existing infrastructure. The planes, the airports, and the fuel terminals: they do not need to be modified.

How much kerosene do we need?
The demand for kerosene is overwhelming. As of today, the world uses approximately 1 million tons of kerosene per day or 5 million barrels of kerosene per day. If you were to put those barrels in a square, you would have about a kilometre by a kilometre of barrels of kerosene. Each day. Usually, the demand is calculated in millions of tons per year. The demand for kerosene is nearly 300 million tons per year. The prospect of replacing kerosene with sustainable fuels is daunting.

How much produces the KEROGREEN project?
First, this project was not about producing enormous amounts of green kerosene. The project aimed to connect existing technologies and bring them to a higher level of technology readiness. Having said that, KEROGREEN produces 0,1 kg of kerosene per hour. If you would extrapolate that to a year, that would amount to 876 kg of kerosene, which rounds up to 1 ton of the 300 million tons needed. So, we are clearly not there yet.

How about the technology readiness levels?
The project objective was to reach technology readiness level 4. That means technology is validated in the lab. All elements, except the oxygen separator, reached this desired level of 4 or higher. In addition to that, the integration in one container actually corresponds to level 5: technology validated in a relevant environment.

What's next?
Unlike any other Synthetic Aviation Fuel (SAF) approach, KEROGREEN uniquely departs from air-captured CO_2, and is therefore worth pursuing. The picture below shows the impressive machinery presently installed on-site at KIT-IMVT, ready for further system development. This includes upscaling the oxygen separator and testing and characterization of the fully integrated system. After that, energy efficiency is to be improved by a system engineering approach. Followed by upscaling for demonstration in an industrial relevant environment.

Photo: KIT /Amadeus Bramsiepe
KEROGREEN container with the integrated system