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KEROGREEN

PROJECT INFORMATION

The KEROGREEN project runs from **1 April 2018 to 31 March 2022**. The main milestones are:

Year 1: definition of the O_2 gas separator, the CO purifier and the Water Gas Shift (WGS), Fischer-Tropsch (F-T) and Hydrocracking (HC) units.

Year 2: subsystems validated including the plasma oxygen separator, CO purifier, WGS, F-T and HC sub systems.

Year 3: integration of sub-systems, notably the oxygen separator and plasmolysis reactor and the WGS, F-T en HC units.

Year 4: integration of the entire system at KIT with a critical review for system readiness planned at M42, concluded by integrated system tests.

The project runs in synergy with nationally funded projects, whilst the European Energy Research Association (EERA) links to the European Joint Programme on Energy Storage. The project is carried out by the following partners:

DIFFER is responsible for development of the microwave plasma reactor to split CO_2, plasma modelling and perovskite plasma membrane interaction experiments and modelling and tests of the integrated CO_2 plasmolysis - O_2 seperator assembly.

VITO develops the Oxygen separator with tests and characterisation of a lab scale single membrane and of a full scale multi membrane assembly for integration with the plasmolysis reactor at DIFFER.

Cerpotech develops advanced ceramic powders for catalytic Oxygen separation membranes, including characterisation of morphology, particle size and purity.

HYGEAR engineers and builds the Oxygen separator for integration with the plasmolysis reactor and develops the CO purification unit for integration with the Oxygen gas separation unit.

KIT-IMVT develops the Water Gas Shift and the Hydrocracking units and is responsible for process simulation and the data base. It will provide the site installation of the fully integrated KEROGREEN system.

KIT-ITAS carries out sustainability analysis.

INERATEC develops the Fischer-Tropsch synthesis unit and carries out the system engineering and system integration into a container sized module. INERATEC is winner of the German Entrepreneur Award 2018 Category Sart-Up, and the Cleantech Open Global Ideas Challenge 2018.

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Production of renewable aircraft grade kerosene from water and air. Development of a scalable, innovative reactor, powered by renewable electricity, to split CO_2, electrochemically separate oxygen, form syngas (H_2, CO_2) and synthesise kerosene by the Fischer-Tropsch process.

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

The grand challenge lies in achieving sustainable aviation by the year 2050

INNOVATION

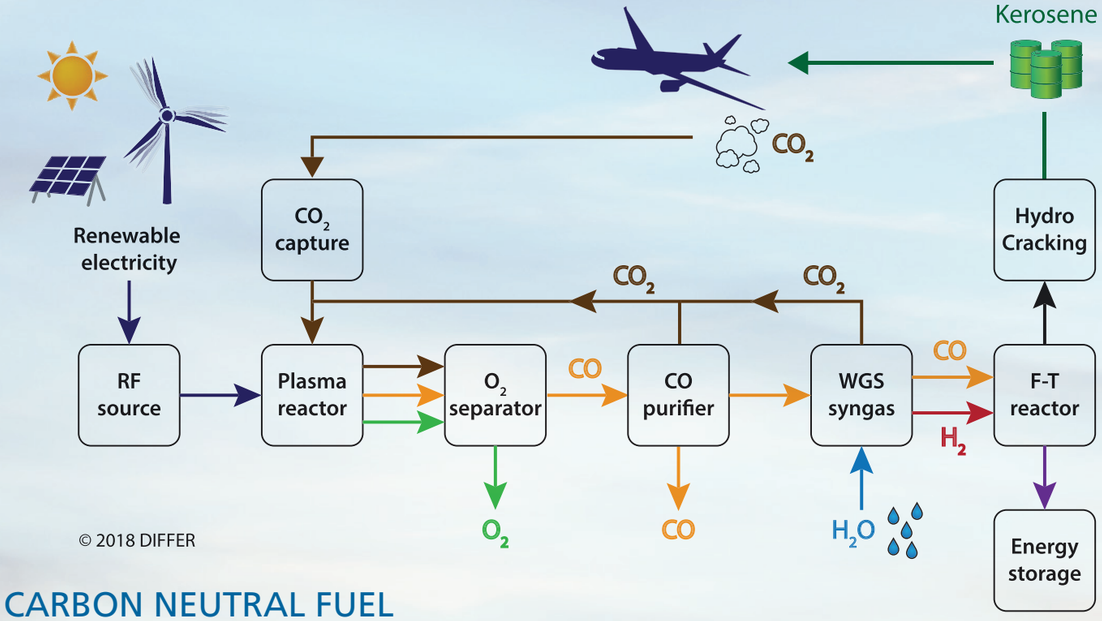
KEROGREEN offers an innovative conversion route to sustainable aviation fuel synthesized from water and air powered by renewable electricity. The conversion is based on plasma driven dissociation of air captured CO_2, solid oxide membrane separation of oxygen and Fischer-Tropsch (F-T) synthesis of kerosene. Synergy between plasma activated species and novel perovskite electrodes of the oxygen separator raise CO productivity and energy efficiency.

Innovation also comes in with the experimental validation of the process chain as a whole, with challenges in system integration of dissimilar technologies into one compact assembly by a multi-disciplinary team. Innovative heat integration raises overall energy efficiency. System integration into a container sized plant is set to produce 0.1 kg/hr kerosene. The technology is modular, scalable and relies on inexpensive existing infrastructure for storage, transport and distribution.

Innovative size reduction of KEROGREEN equipment yields a compact container-sized kerosene production plant. Close-coupled to an offshore wind turbine or a remote solar power array, this offers the prospect for decentralised, onsite production of high energy density Carbon Neutral Liquid Fuel, with no need for an expensive upgrade of the electricity grid.

By dynamically converting surplus renewable electricity in Carbon Neutral Liquid Fuel, vast energy storage capacity opens up to the electricity system, providing flexibility and allowing increased penetration of renewable electricity in sectors of the economy hitherto impervious to electrification.

This Power-to-Fuel (P2F) technology is generic as it couples the electricity system to the excisting oil, gas and chemical infrastructure with the powerful potential to reduce overall CO_2 emission, strengthen EU energy security and create a sustainable transportation Sector.



CARBON NEUTRAL FUEL

CO_2 is a valuable commodity, life on Earth depends on it. Rather than wasting it to the atmosphere, or burying it underground, it better be recycled and put to good use.

Renewable electricity derived from sun and wind has made big strides over the past decade, their contribution to the electricity supply now exceeding noise level. However, overcoming the mismatch between renewable electricity supply and demand is the challenge that still lies ahead.

It requires a solution for long term (seasonal, inter-annual), large scale (hundreds of TWh) energy storage of the renewable electricity generated.

Carbon Neutral Fuel kills two birds with one stone: it provides long term, large scale energy storage to match intermittent renewable energy supply and it provides high energy density fuel to enable long range transport and mobility with no increase in atmospheric CO_2 concentration.

MARKET

Technology Readiness Level is raised from TRL 3 to 4. Projected costs at this stage are estimated at +50% of fossil kerosene. Market entrance will be facilitated by Carbon Tax, the Emission Trading System (ETS) and the International Civil Aviation Organisation (ICAO) regulation. The intermediate CO product is a valuable gas by itself. On-site production offers inherent safety. Technologies employed pose no risk to society and avoid the Fuel vs Food vs Flora trilemma.

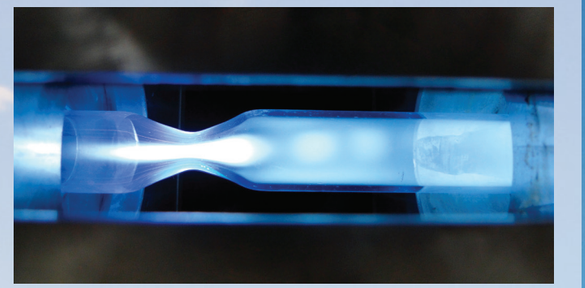
IMPACT

The UNFCCC agreement and EU directives aim to curb CO_2 emissions by 80% to 95% below 1990 levels by 2050. The EU target for transportation has been lowered to 60% CO_2 emission reduction by 2050. Aviation has seen a further relaxation of the EU target to 40% sustainable fuel by 2050. A similar target has been endorsed by the UN organisation ICAO to reduce CO_2 emissions to 50% below 2005 levels by 2050.

The reduced climate and energy targets for transportation illustrate the fundamental difficulty to produce alternative sustainable fuels, aviation fuel being a case in point. Aviation at present accounts for 2 to 3% of global CO_2 emissions. Kerosene consumption is set to grow by between 2.5% and 3.5% each year, hence will be more than doubled by the year 2050. This number accounts for efficiency improvements.

ICAO requests states for policy actions and investment to accelerate development, deployment and use of clean and renewable energy sources for aviation, including the use of sustainable alternative fuels. ICAO realises that these targets are unlikely to be met by incremental fuel efficiency improvement. Indeed, these targets require the development of radically new sustainable alternative fuel technologies.

Batteries and Hydrogen are free of carbon emission during operation, however, suffer from low power density compared with hydrocarbon fuel, which limits their range. Hence, long haul passenger flight powered by hydrogen or by batteries is unlikely to become feasible by 2050. Current EU policy, is directed towards biofuels. However, with a staggering 5 million barrels of kerosene needed per day for jet fuel alone, a solution based solely on biofuels will be faced with the Fuel vs. Food vs. Flora trilemma. Indeed, current biofuel technology does not meet sustainability and availability requirements set by projected 2050 global fuel demand.



DIFFER / CO_2 plasmolysis reactor

Carbon Neutral Fuels offer a third way to curb CO_2 emissions. Synthesised from H_2O and air captured CO_2 powered by renewable electricity, Carbon Neutral Fuels yield net-zero CO_2 emission to the atmosphere. Being Fischer-Tropsch synthesised, the fuel is ASTM certified as jet grade fuel at 50% blending ratio.

Carbon Neutral Fuels, being derived from indigenous sources, offer energy security and reduce dependency and cost of imported fossil fuels. Benefiting from high energy density contained in the chemical bonds of hydrocarbons, fuel can be stored for an extended period of time, transported and distributed to customers by existing, inexpensive infrastructures, with no need for a costly expansion of the electricity grid.

By avoiding CO_2 of fossil origin the climate objective of fossil CO_2 emission reduction is met. Because the sustainable kerosene emits no soot (no aromatics) and no sulphur, it also meets future aviation air pollution standards.

INERATEC / Hauser kerosene plant